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ENVIRONMENTAL ENGINEERING AND RENEWABLE ENERGY

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PREFACE

This book contains the papers presented at the First International Conference on *Environmental Engineering and Renewable Energy* held in Ulaanbaatar, Mongolia in September 1998. The main aim of the conference was to give an opportunity to scientists, experts and researchers from different fields to convene to discuss environmental and energy problems and to be informed about the state-of-art.

Today environmental protection is increasingly becoming a matter of a great concern all over the world since the tendency towards the sustainable development is growing. The main concept of the sustainable development is to fulfill the demand of today's generation ensuring the needs for the next generations. Hence, sustainable development requires sound use and a management of the environmental, research and development in technologies with low environmental impact and a promotion of the use of renewable sources.

Renewable energies are the only environmentally benign sources of energy and available at any site and any time of the year. Moreover, the utilization of renewable sources of energy can contribute part to the increasing energy demand and advance the improvement of life standards in rural areas, where it is difficult to establish a permanent connection with central electricity systems. Application and adoption of emerging renewable energy technologies in rural and remote areas cannot be successful without transfer of knowledge, information and know-how.

Environmental engineering involves research and application of technologies to minimize the undesirable impact on the environment. In recent years there has been a growing interest in environmental engineering problems to focus on theoretical and experimental studies on atmospheric pollution, water management and treatment, waste treatment, disposal and management.

An important issue of this joint conference will certainly contribute a progress in scientific and technical fields of environmental engineering and renewable energy, to represent a valid basis for future research collaboration. A particular consideration is for the contributions, which are printed in this Proceedings, from experts in different fields and from different countries. The contributions are grouped into the sections: Sustainable Development and Environmental Protection, Renewable Energy, Air Pollution Control, Water Management, Water and Wastewater Treatment, and Solid and Hazardous Waste Management.

Editors are grateful to authors of the papers and to participants of the conference for their cooperation and support. Moreover, our special thanks to all the members of the Scientific Committee and the Organizing Committee for their help and cooperative work, which were essential for the organization of the conference.
Finally, we are grateful to the University of Rome "Tor Vergata", Mongolian Technical University, and other institutions for their encouragement and patronage to the conference.

The Editors
July 1998

TOR VERGATA

The most important aim of University is to promote the scientific research and to encourage the collaboration among scientists and with the society at large, in order to make faster the application of new technologies. The university core duty is to stimulate the scientists, experts and technologists towards the exploitation of technological application by research and knowledge transfer.

In this line as the Rector of the University "Tor Vergata" of Rome, I am happy that the cooperation between our university and the Mongolian Technical University, which started two years ago, brought about the organization of this interesting meeting, involving scientists and experts from many countries of the world.

This meeting gives an opportunity to people from different fields and countries to gather together and to discuss environmental problems. It is more significant nowadays since the environmental problem is becoming one of the greatest issues all around the world, both in industrialized and developing countries.

I hope that this meeting will be the starting point for many new collaborations in the near future.

Alessandro FINAZZI AGRO'

The Rector of the
University of Rome "Tor Vergata"

MTU

It is a great honor for me to welcome you at "our" Conference in Mongolia. The cooperation of the MTU and the University of Rome "Tor Vergata" did not start by chance. Both Universities have made a great effort to encourage the cooperation between professors. This Flagship event of the mutual cooperation of both universities is a product of the active involvement of specialists from two countries.

The debate will aim to disclose the current state-of-art and to project the trends for new developments in environmentally clean technology and renewable energy, which will surpass the threshold of the 21th century and lead the society in the future technology.

Sustainable development implies conserving the natural environment while improving living standards for its human inhabitants. However, over the last few decades, Mongolian government aimed to undergo rapid modernization. The industrialization brought to the untouched lands of Chinggis Khan in 20th century was a milestone in the history of the Mongols. Along with the growth of the national economy, the infrastructure, one of its integral part has extensively developed, including health care, education. Simultaneously, the by-products of economic development, particularly pollution and urbanization, threaten the integrity of the environment and the stability of social and cultural institutions. Today, in transition to the market economy, we must have a vision for sustainable development for the 21th century. This includes ideas like appropriate technologies, business catalysis and alternative technologies.

We hope that this Conference would contribute to the formulation of the science and technology policy for the next millenium.

Dendevin BADARCH

The Rector of the
Mongolian Technical University

Solar Energy is a peaceful form of energy in its nature and common wealth to all the planet population. Mongolia is one of few countries the Government officially supported the decision to provide power for almost all nomadic families using Renewable Energy Sources. These nomads provide the main sector of the national Economy with their livestock production. The first step is to provide them with domestic electricity supply for lighting, radio, TV set of nomadic families and rural administrator centers by Renewable Energy.

Mongolia attributes great importance to environmental protection and collaborates with other countries in the field of Energy and Environmental planning for sustainable rural development.

I hope that the First International Conference on Environmental Engineering and Renewable Energy will help in decision of the above issues, the enhancement of the scientific research in the areas of renewable energy and education in this vital field of Mongolia.

Prof. B. Chadraa

The President of the
Mongolian Academy of Sciences

AN ATTEMPT FOR ENVIRONMENTALLY FRIENDLY UTILIZATION OF OIL-SHALE IN MONGOLIA

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Abstract

Oil-shales from 8 deposits in the central economic region of Mongolia were characterized and carried out pyrolysis experiments on the basis of oil-shale samples. The oil-shale of Kh-46-th ditch deposit was chosen as a best quality oil-shale with maxim yield of pitch (15 %) and determined a optimum condition of it's pyrolysis (heating temperature-550 ^{0}C and rate of heating -137,0 C/min.). The yield of liquid fractions with different boiling temperature interval and hard residue of pitch were obtained by using an air-distillation. These liquid products can be used as a gasoline, diesel, oil materials and binding materials (bitumen like hard residue), after isolation of organic bases, acids and phenolic compounds from each fraction.

1 Introduction

Mongolia is rich in oil-shale and it locates about 312 thousand sq. km. areas. Only 20 % of this area were investigated geologically and had done resource's evaluation.
Until nowadays there are not any suggestions and project for any kind of utilization for this great resources in Mongolia.
Therefore our purpose was to characterize and to investigate the possibility of utilization by pyrolysis. We have investigated samples of oil-shale from following deposits named: Ovdog khooloin gashuun /OHG/, Bayanerkhet /BE/, Chagtsaliin Khudag /CK/, Nariin gol /NG/, Ulaantolgoi /UT/, Khoot /Kh/, Zuun shavartin ovoo /ZSO/ and Beliin jas /BJ/

2 Experimental Procedure

The main technical specifications of oil-shale samples from above mentioned deposits were-determined by method described in [4]. Pyrolysis of oil-shale carried out in a laboratory retort at different temperature and rate of heating, /GOST 4168-66/.

The oil-shale pitch /liquid product/ was collected with bigger scale retort designed by us and was done an air-distillation in laboratory flask. There were obtained several liquid fractions with different boiling temperature intervals and bituminous hard residue.

3 Results and Discussion

Results of technical analysis for different oil-shale samples are given in table-1.

Table-1: *Technical Analysis of Oil-shale*

No	Samples	W^a, %	A^c, %	V^a, %	Organic matter	CO_2, %	S, %	Q, kcal/kg
1	OKG	3,97	71,0	22,23	28,6	1,64	0,44	2808,7
2	BJ	3,72	84,5	10,90	15,03	2,76	0,22	1176,6
3	ZSO	2,22	88,88	7,20	10,87	1,80	0,19	849,5
4	CH	3,58	83,27	14,39	16,10	0,84	0,45	1262,2
5	Kh-46-th ditch	5,88	61,12	33,18	36,59	10,06	0,19	5100,0
6	Kh-eedemt	5,52	62,46	28,67	35,46	11,27	0,45	4910,0
6	NG	5,45	75,75	12,70	22,80	4,03	1,56	1792,1
7	UT	3,96	84,00	5,94	15,35	1,35	0,08	1186,2
8	BE	2,81	87,44	10,98	13,50	1,29	0,31	1444,5

Results in table-1 show that all oil-shales have different quality concerning the organic matter, which is an important specification for us. For instance oil-shale of Kh, OKG and NG are with higher amount of organic matter, which are comparable with similar oil-shale in other countries. Also it is good that the sulfur contents lower in all samples. Concerning the resource's reserve they are also different each other and deposits BE and ZS0 are richer in resource, but they are with lower amount of organic matter. Also deposits NG and OKG have less resource than BE and ZS0, but the quality of oil-shale is better. Therefore it is necessary to investigate them in detail. The pyrolysis experiments were carried out with number of geological samples from each deposit and the results in table-2 are averaged value of each deposit.

Table-2: *Yields of Pyrolysis Productions of Oil-shale.*

No	Samples	Results of pyrolysis productions of oil-shale, %			
		Pitch	pyrolysis water	hard residue	gas and loss
1	OKG	9,63	5,01	78,80	6,30
2	BJ	2,50	0,78	95,26	2,66
3	ZSO	0,89	1,57	94,63	2,90
4	CH	2,49	4,02	90,81	2,68
5	Kh-46-th ditch	5,62	3,93	73,45	6,99
6	Kh- eedemt	3,28	3,82	75,72	7,17
6	NG	4,49	2,89	84,26	8,34
7	UT	1,28	0,78	95,26	2,66
8	BE	2,50	3,21	90,44	3,81

Concerning the yield of pitch /shale-oil/ samples from Kh-46-th ditch, Kh-eedemt and OKG are best than others.

On the basis of our experiment /Table 1 and 2/ oil-shale of Kh can be used technologically, OKG- energo- technologically and NG and BE- energetically.
We have chosen the best oil-shale from Kh-46-th ditch and carried out detailed experiment of pyrolysis with different temperature and rate of heating. The results of pyrolysis with different temperature /rate of heating was same-18°C /min. for all experiments/ are collected in table-3.

Table-3: *The Yield of Pyrolysis Products at Different Temperature*

No	Temperature of heating ^0C	Hard residue	Pitch, %	Pyrolysis water, %	Gas and loss
1	300	94.46	6.08	2.42	1.88
2	400	80.83	11.98	4.29	2.90
3	450	67.60	13.56	4.35	5.21
4	500	74.14	14.10	5.04	6.71
5	550	73.45	15.62	3.93	6.99
6	600	72.45	14.47	3.25	9.83
7	650	72.06	13.44	4.47	10.03

With the rising temperature yields of pitch increases and reaches maxim value at 550°C. In other word, the thermal decomposition of oil-shale was completed at 550°C and this temperature was chosen as a optimum temperature of pyrolysis.
Certainly yield of pitch was less at lower temperature, because the thermal decomposition was not enough. The yield of pitch depends also from rate of heating, mechanism of thermal decomposition, polymerization and carbonization reactions in the retort and exit condition of pyrolysis products and so on.
Next experiments of pyrolysis were carried out at selected /550^{0}C/ temperature with different rate of heating. Results of these experiments shown in Table-4.

Table-4: *Yields of Pyrolysis Products in Different Rate of Heating*

No	Rate of heating ^{0}Ï/min.	Hard residue	Pitch, %	Pyrolysis water, %	Gas and loss
1	7.24	75.18	8.42	1.09	18.92
2	9.48	75.38	11.38	2.11	11.13
3	16.6	74.26	13.87	4.27	7.59
4	25.1	73.93	12.96	4.47	8.64
5	45.8	76.20	13.07	5.15	5.58
6	91.6	73.45	17.27	3.28	6.00
7	137.5	73.69	18.54	1.43	6.34
8	253.8	77.13	12.98	2.03	7.86

The yield of pitch also increases with is rising the rate of heating. There was chosen the rate of heating -137,5°C/min., because the yield was highest in it. The yield of pitch is less in lower rate of heating, because decomposed products can react each other forming polymerized and carbonized production as a hard residue. Also in the condition of higher rate of heating increases the pressure in retort and pyrolysis products leave very fast the thermodestruction zone and maybe they did hot condensed completely.
We have collected pitch by using of bigger size retort in the optimum temperature and rate of heating.
The yield of 3 liquid fractions with different boiling temperature interval and hard residue of pitch by air distillation are given in table-5.

Table-5: *Air-distilled Fractions of Shale-oil*

No	Boiling temperature interval, ^0C	Yield of fractions, %	Note
1	20 – 180	14.09	light fraction
2	180 – 280	28.43	middle fraction
3	280-320	4.92	heavy fraction
4	320 <	36.87	hard residue
5	Loss	15.68	

Higher yield of fraction was obtained at 180-280^{0}C temperature interval. The hard residue is a bitumen like product with lower softening temperature.

These liquid products can be used as a gasoline, diesel and oil materials, after isolation of organic bases, acids and phenolic compounds from each fractions.

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BUILDING DESIGN: SUSTAINABILITY AND SOME ENERGETIC AND ECOLOGICAL ASPECTS

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Abstract

In the paper a general overview of the connections between architecture and the field of environmental care is presented. Sustainability is related with the system of human activities, thought as a holistic one: among these, architecture represents a holistic complex itself. Energy consumption reduction and pollutant emissions cut down are seen in the light of the maintenance of our health. Building plays an important role in the environmental impact of human acting, therefore it takes many responsibilities on its back. Building impacts on nature in several ways and some data about environmental burdens deriving from activities related to building are given, with a certain stress laid on the Italian state. An overview of the green building philosophy, pointing out the importance of renovation of existing building estate, and some basic aspects of green building design are presented; some examples illustrate the realization of bioarchitecture's principles. The acknowledgement by technical standards and rules has been dealt with through short account to give an idea that things are getting going.

1 Introduction

The concept of sustainable development is the point of arrival of a process, which probably began, with the oil crisis of the mid-1970s. Rising cost of fuel was the first alarm bell; since then we have acquired a deeper awareness of the finiteness of resources; for too long a time energy had been available in apparently unlimited amount and at reasonable costs, so that none had paid attention to consumption reduction. During the last two decades research has pointed out how the development of human activities has had a destructive impact on natural environment and new monitoring systems have further stressed these dangerous effects.
If we also consider the late attitude of mind, which tends to observe everything from the economic point of view, it will be easy to understand how we get to an idea of an economically and environmentally lower cost development. We don't need to illustrate present wastes and damages to the ecological balance so that it appears clearly how sustainable development is not fashion, and that sustainable stands for the possible maintenance of present standard of life as we are accustomed to.

Sustainable development is a way of thinking, it is an organic and comprehensive way of approaching the whole system of relationships between men and environment, with the aim to optimize and guide human activities growth within affordable-by-the-world boundaries. Someone could object that we have add only a label to our instruments and knowledge and really the urge of facing up troubles such as pollution, the finiteness of traditional energy sources and of raw materials is nothing new, nevertheless the importance of this strategy is just its global view of proper interventions. As fields of human activities involve each other (we have some needs which have an economic value, we need money, knowledge and technology to fulfil them...) isolated interventions would result in a failure, while only a common effort of economics, science and policy will probably success. Being a comprehensive philosophy it involves most disciplines from economics to psychology, and obviously architecture too: bioarchitecture is the application of sustainable thinking to architecture. Since architecture creates the places of human activities it is a very important media between these activities and the environment, furthermore it is surely the most evident instrument by the means of which we impact on nature so that architecture, which we mean to include also urbanistic and so on, has really a great role in planning our future existence in this world.

2 Low environmental impact architecture

2.1 Why we need bioarchitecture

Sustainable development principles characterize bioarchitecture as it proposes itself as an organic approach to well building. From many points of view good architecture is already a sustainable one: good designers should try anyway to optimize all architectural performances including those that we hold to be biocompatible. Most ancient buildings represent good architecture and many devices that are typical of bioarchitecture have been used since ancient times. During this century the ever-growing population has forced politicians, builders and designers to implement low quality buildings with a general falling off of standards. Nowadays we need again good architecture both at the single house level and at the larger scale of town or environmental planning: bioarchitecture is an attempt to realize good architecture.

Bioarchitecture has three principal aims: energy consumption reduction, low pollutant emission, health-care and well being of people (of users directly and indirectly of the population in general), with the awareness that only a global planning of all constructive phases can get to the quality levels required. Energy consumption cutting down was first needed because of high costs of fuel; nowadays we pay more attention to the role that energy production has in the environmental pollution. Because of the present state of the environment we are most interested in our health-care which is actually the final goal both of energy consumption reduction and of pollutant reduction.

Table 1: *Environmental Burdens of Buildings, U.S. Data*

Resource Use	%Of Total	Pollution Emission	% Of Total
Raw Materials	30	Atmospheric Emissions	40
Energy Use	42	Water Effluents	20
Water Use	25	Solid Waste	25
Land (in SMSAs)	12	Other Releases	13

Building plays a great role in the environmental impact; the following data, even if non-homogeneous or related to the Italian situation will be helpful to have an idea of that. Quarrying and carving materials deeply modifies morphology of the ground, jeopardizes water layers and damages the habitat, needs large amount of energy and produces equally large amount of earth and air pollutant, the production of building materials of each other kind

requests energy, then these material are carried to the yard, we must finally add building energy consumption. These amounts are difficulty quantified but we hold them to be relevant. According to the present constructive standards we can asses the energy for producing buildings (embodied energy) at 2000 KWh per m^2 of useful built area.
The civil sector (housing and tertiary) is responsible, in Italy as in Europe and U.S.A, for one third of final consumption of energy and in Italy of 30%-40% of CO_2 e CFC emissions.

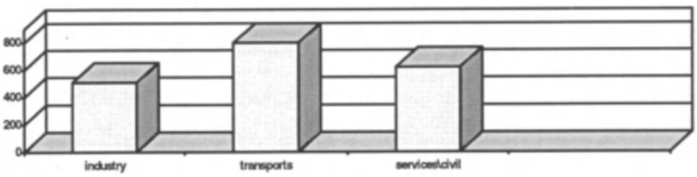

Figure 1: *CO_2 Emissions Per Sector of the European Union In 1995 (Millions of Tons of CO_2, source: European Commission 1997-Annual Energy Review)*

Energy of use is due for 2/3 to the heating, cooling, ventilation systems (HVAC) and for the remaining 1/3 to lighting. Unfortunately Italy distinguishes itself by energy consumption: 34.4 TOE (tons of oil equivalent) make Italy the leading European Country for energy consumption [1]. It is finally reasonable to consider also transports, which are responsible for a quarter of total energy consumption and are closely related to settlements planning: a certain savings could probably result from an intelligent design.

Table 2: *Average Consumption for Building in Europe (source: ENEA, Italy)*

	Austria	DnK	France	Ireland	Italy	Norway	Nld	Greece	Portugal	UK
Energy consumption for buildings (TOE)	1.83	1.92	1.75	2.02	1.45	2.13	1.82	0.72	0.54	1.90
Electricity consumption for building (KWh)	3940	4534	4895	4094	2953	17273	2929	2791	2250	4355
Energy consumption for building normalized to European standard climate		1.72	1.72		2.02	1.67				1.73

In the following pages we will show how and how much an intelligent design can improve buildings environmental performances. As a general introduction we can say that, at the present state in Italy the use of so called passive design techniques can get to 50% savings for HVAC and 30% for lighting in new buildings, while we can save up to 20% for refurbishing considering only HVAC. Other non-passive ways to approach green design can achieve further performances.

Table 3: *Energy Budget In Italy In 1994 (Million TOE, source: ENEA, Italy)*

	Solid	Gas	Oil	Energy	Total
Total End Use	6.6	32.3	61.7	19.9	120.5
Industry	5.2	1401	6.0	9.8	35.1
Transport		0.2	37.4	0.5	36.1
Buildings	1.2	17.2	6.8	9.2	34.4
Agriculture		0.1	2.7	0.4	3.2
Non-Energy Uses	0.2	0.7	6.4		7.3
Bunkerage			2.4		2.4

2.2 A green approach to design

A good philosophy of building should consider each architectural system as a holistic one and then try to optimize all life cycle of what is going to be built. Each constructive phase has its wastes to be cut down. Nowadays the building cycle is very complex and only a team of

architects and engineers can face the several aspects of an environmental-conscious design; some of these aspects will be dealt with afterwards.
Before thinking of what we are going to build, it would be better to pay attention to what we have already made. Some reflections on the matter should be done. We have already seen some damaging effects and some costs of building as itself (cf. 2.1), further we can say that about 30% of solid urban refuse is constituted by waste material coming from construction and demolition processes and that according to present assessments within thirty years quarry materials will be depleted, at present levels of consumption. Table 5 represents an Italian example of construction costs.
In the end we refer to the Italian state: in Italy there are 21 millions families and 25 millions residential units so that there is no actual need for new residences; on the other hand there is the fact that most of them present not-acceptable high consumption level. These are some reasons, which make the refurbishment of our building estate an important topic.
A useful strategy could be associating ordinary and extraordinary maintenance to interventions of environmental performance improvement. Degraded pollutant materials could be gradually substituted with other ecological ones, water-recycling systems could be integrated and so on. Thermal energy savings could be obtained introducing systems of intelligent building management, improving thermal insulation through the use of better materials or reducing thermal bridge and unwilled airflow. Passive systems are not easy to be implemented as they require transformations of architectural spaces which are often incompatible with the structures; nevertheless greenhouses, Trombe-wall, a careful study of glasses and windows as much as the use of brise soleil or vegetation for shadowing can help to optimize solar gains and environmental relations. Viceversa active devices to catch solar energy such as photovoltaic panels or eliothermal equipment are generally well integrated in the preexisting structure.

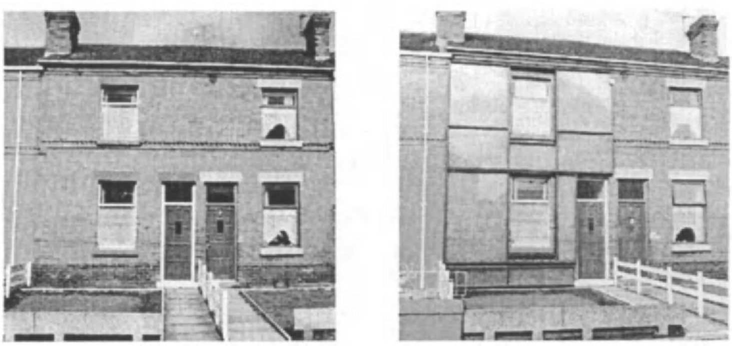

Figure 2: *Environmental Reclamation By Direct Solar Gain System in Haydock, UK*

Interventions of new building can get obviously higher environmental performances, trying to optimize all variables.
A good planning should begin with a monitoring of the site were the building would take place. There are some site's characters that would be desirable to know. Climate aspects of the region such as sun exposure, dominant winds, precipitation, humidity rate and average temperature are very important for a climate conscious architecture, yet microclimatic features are sometimes more important since microclimate of the site can differ from the general climate of the region in a certain way. Microclimate is partially influenced by biophysic aspects. For biophysic aspects we mean geological and topological features of the earth, superficial and deep water, vegetation. It is evident how the presence of water and vegetation and the kind of plants can influence microclimate. On the other hand it may be we are dealing with an anthropized contest, analogous consideration can be led on about the effect of this contest on microclimate: we should take into account high heat-store levels, shadowing or even the global effect of thermal equipment (in some New York's street

HVAC systems send out hot air causing temperature increase of about 5°-7°). We must pay attention to these aspects for a correct evaluation of the coming performances: thermal, luminous, acoustic and energetic in general. We should plan a site development as less environmental destructive as possible: small footprint, run-off control, preservation of water courses, natural vegetation and habitat; these are just some of the themes now debated.
New technologies are now gradually leading from the traditional "wet" " yard to the "dry" yard, which makes building division more similar to the industrial more advanced compartments. This change represents a step forward in the path toward a more ecological way to build as it allows optimizing constructive phases, reducing pollutant emissions and energy costs. Acting so we reduce water wastes, pollutant emissions due to the use of synthetic adhesives and to releases of water dissolved substances, many refusal due to the getting under the way would be eliminated, some pollutant processes can be better controlled if realized in factory, further industrial optimization leads to reducing energy and economic costs.
Choosing materials represents an important topic: a wide range of materials is now available and besides their structural capabilities it is time to pay attention to their ecological characteristics. Customers often request designers to use ecological materials, anyway many prejudices have to be put away. Among these prejudices the idea that only natural materials lead to ecological building or, on the other hand, that the use of materials deriving from chemical synthesis precludes that objective. An assessment on the environmental quality of a product requires several evaluations. Some materials derive from renewable sources and we must optimize their exploitation, others are related to biological cycles which have to be respected, it is necessary an evaluation of the potential environmental impact due to the exploitation of resources . We should know environmental costs in terms of energy necessary to producing or transforming them and in terms of production pollution, and costs related to the installation. We should choose as much as possible local materials to reduce transport costs. Important parameters are durability and the possibility of being recycled after use, the easiness of cleaning and maintenance in general. Selecting durable building materials that can be expected to perform well over an extended useful life will generally result in a better environmental choice than one that must be replaced twice or even ten times during the same period. This is evident from the approximately ten-fold greater relative additional resource extraction/consumption, manufacturing, transport, installation and disposal. A roof used in many European applications may last one to three hundred years, while in the United States typical roofs last ten to thirty years. Durable materials tend to have low emissions. Therefore, they tend to be better for indoor air quality (IAQ) then less durable ones. They may also require less frequent application of maintenance and surface renewal chemicals, and use of less harmful chemicals. The choose of materials is one of the most important factor to contribute to indoor air quality: surface characteristic, such as exposed area or easiness of cleaning, chemical composition and emissions, the possibility of becoming dust or pollutant or microbial sink are parameters related to indoor comfort.
During these early phases of planning it is used to pay attention to a careful examination of future real use of what will be built and to a careful examination of comfort criteria. At the present about one third of energy used for lighting is wasted, since areas where no activity is performed are lighted, or it is used too intense a light or it is not used natural lighting. We have to use comfort criteria as flexible as possible, that will result in satisfied users (the more users are satisfied the longer building's life cycle will be) and lower consumption. Buildings that assure constant values such: 21° temperature, 50% humidity and 500 lux lighting all day long, have high heating costs in winter, high cooling costs in summer and do not fit users' habitudes. We would prefer a range of temperature between 19° and 24°, humidity between 40% and 50% in winter and in summer respectively: that would stress less the HVAC system reducing costs. Natural lighting is the optimal lighting source as it presents a light-power ratio of 160 lm\watt, while best mercury vapour light only achieve 80 lm\watt. Natural lighting has

to be mostly preferred: while 300 lux are generally hold to be minimum lighting value, it has been demonstrated that users delay switching on of artificial lighting until 150 lux, in case of presence of two natural lighting source in the area.
For what concerns methods to be implemented while planning, orientation and disposition of rooms, according to climate and sun exposure, are basic. Among methods and technologies now used to fulfil sustainable buildings we can distinguish between passive systems and active systems. The former tries to implement buildings in which the optimization of energy relation with the environment is inherently due only to structure and to the articulation of architectural spaces, as to achieve a sort of automatism without continuos control. The latter provides for the use of devices able to modify energetic performances time by time according to variable parameters. Passive system for heat storage mainly uses solar gains in a direct or indirect way. Direct solar gain systems are greenhouses or windows which exploit greenhouse effect, or solar manifold which store heat by a means, water typically, then used for heat equipment. Indirect systems essentially exploit thermal mass of walls roofs and particular structure such as Trombe-wall or Costantini-bar.
Passive cooling system such as solar chimneys, wind scoop, wind tower or solar facade typically exploit thermal differential to create air circulation, forcing air to pass through cool zones (underground, basement, water courses, Nord exposed or shadowed zones). Yet these device are not as much efficient as passive heating systems.
Intelligent building management system have to be considered active systems. They constitute a network of monitors that time by time analyze present situation as it concerns lighting and inner climate, the actual state of use of rooms and so on, compare these parameters with the outside data and dispose on working of the various equipment. Within the number of active devices we can mention mechanical equipment for shadowing such as swinging brise soleil and thermotropic glasses. The former, whose working should managed by the building management system, act as filter of sun rays, some types exploit repeated reflections to allow comfortable lighting anyway. The latter too is a device which react in a different way according to the intensity of solar radiation. These glasses are able to pass from a transparent to an opaque state. Active systems include devices for producing energy, such as photovoltaic panels.

2.3 Examples

2.3.1 Youth dwelling at Windberg

Figure 3: *The Hostel at Windberg*

Thomas Herzog is an architect very interested in energy savings and his architecture is able to integrate specific devices in a good design. That is the case of a hostel at Windberg. The building is the dwelling for a hundred students of the adjacent monastery. A careful forecasting of future possible uses provided flexibility criteria and suggestions for energy savings. Bedrooms have been located in the southern zone of the building: that allows wonderful views and solar gains in a period of greater exposure. Actually bedrooms are used mainly at night with relatively low temperature. The southern facade acts for heat maintenance. One third of it is glassed while the remaining is constituted by a wide thickness wall painted in black. A transparent insulating layer made of thin tubes has been put on it. The system keeps heat at night while acts as greenhouse since early morning: in a case with an outside temperature of $-14°$ the surface was at 70°. Because of the thermal inertia of the wall the inner side get the higher temperature (about 18° in winter) at midnight. In summer the wide overhang of roof shades the facade further protected by a defence with swinging thin plate. Wide windows and diffusion systems provide natural lighting during the day.

2.3.2 An example of dry yard

The following buildings have been planned by Dubosc&Landowski, they have been realized in Saint-Martin d'Hères and represent an example of dry building site. Dubosc&Landowski's purpose is an overall quality of a building rather bioarchitecture: they have spent most of their architectural career trying to devise methods capable of turning conventional building in an industrial process.
That allows construction system to be managed with great precision resulting in an overall control and improvement of a building. In this occasion they have planned a couple of twin buildings, facing each other to create an internal courtyard. Steel has been used for structures and composite panels for curtains and dividing wall; the mass production resulted in a cut down of time and costs. Typically this system uses horizontal fixtures made of sheets of steel injected with a layer of concrete cast after the sheets have been set in place: slabs like these slow down and complicate assembly operations. In Saint Martin d'Hères Dubosc&Landowski have finally devised a completely dry slab known as P.C.I.S.

2.3.3 The Pavilion Plaza de America in Seville

This work really do not represent an intervention of new building, but the length of transformation is relevant. The project has been developed by a teem led by Jaime Lopez de Asiain. The Plaza de America Pavilion has been adapted and developed anew to fit the request of the faculty of Civil Engineering. Besides the architectural value studies and works have been focused on energy savings through natural lighting and passive cooling. Works have get a reduction from 3 millions frigories to 1.6 millions frigories per hour: about 15 millions pesetas savings. First of all new patio spaces have been opened in it, both for

Figure 4 : *The Pavilion Plaza de America in Seville*

departments and blocks of classrooms. Facades have been modified establishing windows modulation for the system of offices and classrooms to be implanted, with an opening percentage near to 90% to guarantee its relation with the exterior space, light, sun etc. Lighting should mostly fulfilled by solar lighting, though this type of illumination has two drawbacks: its directionality and its intensity. To avoid these drawbacks systems of light diffusion have been adopted. If the facades were to be maintained without shading devices (especially on the south and west) in winter, although natural lighting would be acceptable at a meter from the window (700 lux), four meters from the same window the lighting would be less than 120 lux and six meters away the lighting, of 60 lux, would be insufficient.

Figure 5 : *The Interiors of the Pavilion*

Only 10% of the considered spaces would have some guarantee of sufficient day lighting. However , it must be cited that all these spaces would not be totally habitable next to the glass because of the inevitable thermal problems. In summer the lighting values would rise disproportionate. One meter away from the window we would find a level of 5000 lux and six meters away 500 lux, creating overheating and glare. On the other hand the rooms with northern orientation, the illumination would be insufficient, similar to winter conditions. For what concerns passive cooling two aspects have been dealt with: solar protection and ventilation. It has been adopted the isophlet method (lines of temperature deriving from the integration of daily temperature in an annual matrix). Then it has been planned an adequate thermal insulation. Dominant winds have been studied: in summer west-south winds predominate, especially west winds during the night; in both west and east facades 50% of the glazing is operable to achieve cross ventilation. During the night temperature are less then 25°, so that night ventilation achieve a sufficient cooling. Ventilation has been induced by

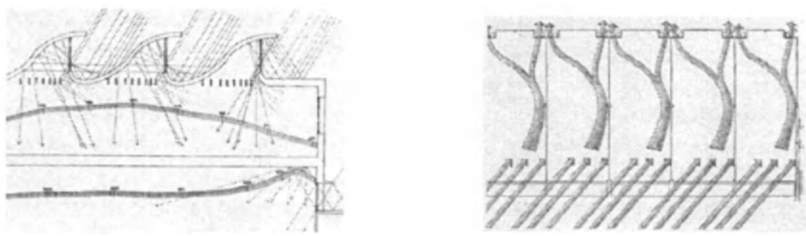

Figure 6: *Isophlets and Day-Lighting (Left); Ventilation with South-Eastern Winds (Right)*

temperature differences; in order that the system function correctly, a difference in eight greater than 8 meter has been realized in some area: a sort of solar chimney.

2.3.4 Sverre Fehn's work near Norkopping

There are no doubts about Sverre Fehn's architecture quality (he won Pritzker Prize in 1997): though nature is relevant in his architecture we cant define him a bioarchitect, nevertheless we would mention this project because of some aspects of its. That is a housing prototype built on the wooded hills of south-eastern Swedish coasts near Norkopping. That would have been the first unit of a larger never built complex, for tourist and sport purposes. Apart from the foundations the house has been built by Sverre Fehn's students within eight weeks during a didactic summer campus. Building has revealed to be a mere dry assembly of components and semimanufactured products deriving mostly from local rough materials. On a platform made of concrete a wood structure, made of pinewood beams, has been installed and then in-filled by big blocks made of clay and straw mixed and sun-dried. Walls have been finished by natural plaster colored in the mass. Besides of the very good insulating capacity of blocks like that, insulating layers have been placed on the roof, natural fiber, cork, bark have been used for the purpose

3 Standards

We have reminded several times within this paper, the importance of a comprehensive strategy of planning interventions. An overall system of standards would be the suitable instruments for a green management of building-related acting. We can no more allow, as it happened till now, that some decisions or choices are left to the only sensibility of clients or to the uncertain competence of designers; while it would be desirable that certain operative method or procedure related to building are codified, spread and sometimes imposed both to the society and professionals, as it happens in many other technical fields (structural calculus for example). A proper system of standards would perform a double role: on one hand it would act as a useful guideline for designers, on the other it would perform an action of awakening of purchasers. It would not be possible a recognition of rules concerning environmental performances in all Countries, we will restrict the treatment of the subject to the activities of normative Institutes (ISO, CEN, UNI...) and to the European condition.

The theme of environmental care has been received by ISO through the standards of the series 14000. ISO's 14000 standards. These standards have the aim: to give a practice guide for the creation or the improvement of an environmental management system; to give instruments for the evaluation of single aspects of the management system; to give reliable means for spreading news about environmental aspects of the products and services. The strategy of 14000 standards is similar to that already adopted for 9000 series; 14000 series provides instruments for planning environmental care at each level of firm's hierarchy and for each phase of producing process: defining an environmental care policy, planning phase, fulfilment phase, control phase.

In the sphere of European Community we must notice EEC regulations 1836/93 known as EMAS regulations. Being a regulation and not a rule it has been fully received by all Countries of EEC, it is a volunteer not imposed instruments. It allows firms which wants to commit themselves to improve their environmental performances to reach a sort of environmental certification, providing guidelines for their improvement and some minimum quality levels to attain. Firms will receive as a counterpart facilities for being admitted to competitions and for what concerns bureaucracy, besides the support given by local government consisting in information campaigns, stages of teaching and so on. Quality levels to attain are essentially those required by ISO 14000 standards, received by CEN as EN ISO 14000 with some differences treated by the "bridging document" (CEN CR 1269).

In Europe a certain sensitiveness has been demonstrated by France and in a major way by Anglo-Saxon sphere. Some firms or Institutes needing a new head office building have required to designers to implement some green directives: that is the case of Greenpeace's head office, or of those owned by Montagne Jeunesse (a firm producing cosmetics interested in showing a face as much as possible ecological as means of advertising) in Wales, as much as Eland House the London site of Department of Environment; evidently these are all cases in which the owner was interested in showing an ecological facade.

England has mostly showed its interest about the topic. In 1991 the Department of Environment issued the "Environmental Action Guide", that is a guide facing up a very wide range of building topics. The guide includes the "Advisory Notes" that provides a bibliography and references to Institutes which deal with environmental care, and examine closely single issues such as: exploitation of water sources, earth management, lighting and so on. Of late we must notice the "Environmental code of practice" issued by the Building services research and information association (BSRIA) involving both professionals and purchasers. The Environmental code uses as a starting point the linear sequence of building phases schemed by the Royal Institute of British Architects (RIBA) in the "RIBA plan of

Work", analyzing each phase with the aim to optimize the exploitation of resources since the planning moment. The viewpoint is based on the concept of total life cost that is to say an assessment on the environmental costs of all life cycle of buildings, provided so the code has added to the RIBA plan "N" and "M" phases which deal with demolition and recycling method with the aim to conclude the life cycle.
The Department of Environment for the construction Heland House has imposed some Green Criteria that abolished 16 families of materials and suggested the BREEAM (Building Research Establishment Environmental Assessment Management) as an instrument for evaluating planning choices. BREEAM is an instrument for giving a score to environmental performances of buildings created by Building Research Establishment collaborating with Ecd Partnership. In the end we refer to the manual created by the Environmental Services Department of The London Borroughs Of Islington and "Organizational Aspects Of Energy Management" by BRECSU. An important activity has been performed in creating guidelines for a green building in the sphere of competitions "Zephir" on the design of multifunctional buildings (office\housing) and "Living in the City" on refurbishment energetically conscious, and "Working in the City" organized by the European Commission Directorate General XII for Science, Research and Development and Directorate for Energy (DG XVII). In that occasion designers were provided of guidelines to follow in the implementation of plans and of software for evaluating performances (LT by ERG).

4 Conclusions

The aim of this paper was to show the wide field of bioarchitecture. We would have provided a quick roundup on the theme, addressing interested ones to the specific literary essays for a closer examination of each single aspect. The aim was to demonstrate that we dispose of knowledge and technologies to achieve a great progress on the field of environment care. Unfortunately some obstacles still persist to the realization of it. The lack of sensitiveness of politics on the theme is demonstrated by the late and incomplete ruling activity.
Professionals, even if sometimes posses knowledge for planning a sustainable building, have been educated to other aspects of architectural practice: perhaps Universities and research Institutes should stress more on this topic and diffuse their knowledge.
In the end we would point out how the debate is led mostly by western or developed in general Countries, while developing Countries suffer from a severe lag. The topic reveals its importance if we think that developed Countries that already use in a relative way green technologies, are not expected to increase consistently their consumption, while developing Countries, whose forecasts on consumption increase are worrying, still use highly resource-depletive method both in the building field and in the others.

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DESIGN BUILDINGS WITH THE CLIMATE: LEARNING FROM THE PAST

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Abstract

Before the 1900's, the climatic aspects always influenced design choices in the architecture practice, both from the formal and from the building standpoint. The exterior shape of the building, so as the typological solution, the constitution of the building components and the building details, was influenced depending on the geographical position and on the building different purposes.
In modern architecture, after the 1900's and in the contemporary one, the climate has not an important role any more, following the introduction of building system components. Nowadays, the inner climatic behaviour of the building has been re-evaluated in the design process, together with the need of use of renewable resources; alternative energy suppliers and the energy saving solutions are pursued to get a sustainable building.
Within this framework it is important to study the traditional vernacular architecture, based on the good climatic behaviour of the buildings, and on the use of natural and local materials. From the study of this particular architecture we can get some suggestions both methodological and practical, to operate the reuse of wood in buildings according with a climate respectful design process.

1 Introduction

In the next future, it will need to pay more attention to the spread use of the not renewable resources preferring the renewable one, even if they are more expensive and imply difficult productive cycles.
First of all, we must try to use high recyclable materials at great length, so that the environment will not be overloaded with waste which are always difficult to be removed.
Another way to safeguard the environmental healthiness for what concerns not only the problem of the waste but even the possibility of decreasing the impoverishment of the resources, is the use of renewable resources with a strong natural and biological value.
It is a current opinion that it is impossible to give a new "virginity of nature" to the environment, most of all where men have influenced and changed it to their own advantage.

However we can stop the environmental damaging making a wide-spread use of renewable resources and paying more attention to their management. In this way, we can probably start a new way of operating, causing a more and more limited level of damage.
In the past time, not natural materials were often preferred for buildings. The new technologies and the new materials that were introduced, caused a waste of resources and an uncorrected use of materials. In fact building elements were often oversized both for their performances and use, or were not employed for the need they had been produced for. A clear example is that the energetic problem was completely undervalued during the years of the "international style", when they thought to get the igrothermal balance in the inner spaces only through the use of the oil, just because new materials, such as steel and glass, where not able to assure it.
If we want to follow policies taking into account the problem of the environmental safeguard, our future choices will have to take into account the climatic aspects and underline the dependence of architecture from the climate for a good buildings design.

2 Design Buildings with the Climate

Before the 1900's the climatic aspects always influenced design choices in the architecture practice, both from the formal and from the building standpoint, playing a very important role in the regional characterization of the building itself. In particular, they have influenced the choices regarding both the whole building and its single parts, both the building components and the design of the building details.
Climate has changed the exterior shape of buildings with the same purposes influencing their formal setting up; just think to the difference between a building with a plane or with a pitched roof. Not only the shape, but even the number of windows on the facade is related to the local climatic aspects: facades with few windows on the sunny coasts of the Mediterranean sea, opened facade to allow the ventilation of inner spaces in equatorial regions or to let the light enter inside the North-European buildings where people are usually forced to live in the darkness for many months. Even the inner distribution of spaces is deeply influenced by the climate: buildings with an inner court where people can restore themselves during the day with the fresh air of the night, compact houses sometimes with no windows at all to protect themselves from the cold climate of the alpine regions; dug houses into the earth or into the mountains to have little inner variation of temperature compared with the higher outer one. Besides giving shape, transparency and body to the buildings, climate gives even colour and generates the visual aspect of the built environment in different ways. Just compare the dazzling, white and monotone landscape of Santorini with the coloured ones of Scandinavian countries.
The climate aspects have deeply influenced the building design not only for what concerns shape, dimension and height of inner spaces, but even their orientation and their inner distribution. In particular climatic conditions, different shapes for the same functions have been drawn, or the same functions have been transferred to the open space: for instance to sleep in the open spaces, or on the flat roof, to relieve from the hot climate.
The climate has always influenced the building components: in their inner constitution, because of the particular material or because of the use of stratified materials, and in the design of the building details working with the principle either of strength, or of strength and tightness or of tightness alone.

3 Building and Installations

In modern architecture, after the 1900's and in the contemporary one, the climate has not an important role any more, following the introduction of building system components. In fact, using appropriate inner installations we cannot care of the closed relationship between the inhabitants needs and the building solution for inner comfort. System components let us design buildings with comfortable solutions once impossible in determined contests. The climatic aspects are now solved only with the introduction of appropriate installations, while the designer can take great care over other aspect independent from the thermal comfort. Now the main problem is both the right relationship between the system components and the building, and their position inside it, so that the built system and the installations could complete each other in a right way.

So there are two different solutions to this problem: the hidden one and the one in sight. They represent two different ways of thinking and considering the building itself. With the former one, the building is seen as a group of "pure volumes under the light", and system components are hidden in skylight passages, niches, false beams, and many other solutions that do not contrast with the ideal shape. With the latter one, system components have a very important part in the building, and it seems that they are like decorative elements with a specific essential function. From the extreme purism of the hidden installations to their emphasis, where the system components are able to qualify and to characterize the building itself.

On one side, the presence of installations has been able to simplify the design process for what concerns the inner climate problems: in the past time, for example, designers had to face the problem of orientation, of shape and the difficulty in the constitution of the building and of its components. On the other side, now the design process is seen as a complex action that cannot be divided into the functional, built and installations study; it is a global work, made by an equip of professionists with different competencies, but knowing that the design itself is a whole, just one thing.

4 The Importance of Climatic Aspects in the Building Design

Nowadays, the inner climatic behaviour of the building has been re-evaluated in the design process, together with the need of use of renewable resources and alternative energy suppliers as the sun. But we need to make a careful study of how to use new materials. By this way we could save energy for what concerns the climatic aspects during the building of the houses as well as for their following management.

So, we must take into consideration both renewable resources, energy saving and climatic aspects during the design process.

Within this framework it is important to study the tradition to understand the importance of the climatic aspects so that we can solve climatic problems using renewable, and so natural, materials such as wood, cork, sheep wool and so on. Only recovering the past knowledge we can have the background to propose new solutions in the design process.

Nowadays, with traditional techniques and materials we cannot build houses of more than 5 floors, but we can widely use the new solutions for residential and social buildings with few floors.

We can also find some meaningful examples and learn some new methods by the traditional vernacular architecture. In it, we can find the knowledge made on field during the past centuries, handed down to us by voice. It is characterized by a strong natural content that we can see not only in a particular shape or in a particular use of materials, but even in the appropriate use of alternative energy sources, such as: the position on the field comparing with wind, sun, altitude, and so on.

From this kind of architecture we can also understand how to take again into the right consideration the climatic aspects and the use of natural materials during the design process. But we must pay attention to a correct use of these teachings. Of course we must not try to use and propose them again as they were in the past; we must use natural traditional materials with new techniques, setting a new knowledge learning from the past, because those lessons can help us still nowadays to solve the problems involved with climatic aspects.

5 Climate and Traditional Wooden Architecture

Wooden buildings have always been constructed in two different ways: the log system and the frame one. Depending on the geographical position and on the belonging to different social areas one was preferred to the other. The choice was due both to the wealth of the surrounding forests and, most of all, to the builder sensibility, to the different purposes and to the climate.
The frame system is the one that is more suitable to the use of wood. Most of the times they have built frame buildings with a closing mantle outside, just because of the lightness of the elements, their bending and tearing capability, the easiness to joint them together. However, they began to use the logs as building components for walls, to protect themselves from the bad external climatic conditions and to increase the walls resistance. So they could build houses with stronger elements using a simpler process and getting a good inner comfort.
Starting from the medieval age, builders have widely used the log and the frame systems, and they have improved them according to the new handtools. In particular, the log system has been deeply transformed. First they used to put one log over the other, the so called *block-bau* system, then they began to joint pieces together realizing a frame building and closing walls in a second time, the so called *platform frame* system first, the panel system in a second time.
The *block-bau* system developed during the late medieval age in the alpine regions, in the centre and eastern part of Europe, in Scandinavia, in the northern part of Russia and in Siberia. In some regions they used it for rural buildings, while in other regions they were able to refine the techniques and to use it to build churches, sighting towers, bridges, mills, fortifications and even fortified towns.
This building system was able to guarantee air, water and thermal insulation through a simple but efficient joint, done using some particular technique on the logs: fitting them together one over the other, putting earth, musk or hay between them, or jointing them with pitch and hemp.
The log system was used even to build barns and storehouses. In this case, in the *block-bau* system the choice of the logs and the building details are not so important, because the main specification is to have more air through the walls to dry hay or other things held inside.
Both for living and for store buildings, they faced the problem of outside atmospheric conditions with waterproof roofs or using a not porous roof done with the trees bark (birch or European aspen) or with a continuous covering made of wooden planks or tiles. They were able to assure the thermal insulation of the top of the buildings by using the floor below the roof as a barn.
During the latest years the *block-bau* system has been improved and builders have introduced a lot of variations for what concerns the building details. From a formal standpoint it has been always preferred the horizontal position of the logs. But sometimes for climatic reasons, buildings have been covered with horizontal or vertical planks to preserve logs from the atmospheric agents, most of all the rain. Most of the times, in fact, this system was applied in those regions nearest to the sea, where air is full with saltines or where there are the worst atmospherical conditions. In the following centuries, with this system they were able to increase the walls thermal and acoustic behaviour, even filling the space between the logs and the external planks with insulating elements.
In the pre-industrial age, frame systems with different characteristics had mostly been used, and they had peculiar features according both to the different areas in which they where built and to their different purposes.

The *grind*, the *stav* and the *frame* systems were widely spread over the Scandinavian area, while the *Saxon* and the *fackwerk* one were spread over England and Germany. In the alpine regions, because of the Central European influences of the stone culture, there were hybrid solutions between the frame and the log system.
The *grind* system, based on a very simple building method, spread over the southern Norwegian coasts most of all, and was used only for little secondary buildings (for example barns, sheds, warehousing, and so on). This system had no particular thermal features, just because it had not a residential use.
Even the *stav* system, used to build the typical wooden Norwegian churches, did not presented particular thermal features because the walls were done only with wooden planks of very little thickness. In this case, the system had a strict relationship both with the climate and with its own purposes; in fact, even if the walls were very thin and the climate was hard, there were no problems regarding the inner environmental comfort just because there were a lot of people standing there for a very short time. When there was the Reformation passing from the Catholic ceremony to the Protestant one, people had to stay inside the church for a longer time, so that the *block-bau* system was used to modify, to enlarge or to rebuild these buildings according to the new thermal insulation needs.
The *fackwerk* and *Saxon* systems, together with the general *frame* ones, have been widely used for the living architecture as well as for the social representative one. There are even examples of buildings made with natural or artificial stones mixed with these systems. Usually, wooden elements had only a static role, so that the thermal insulation was reached putting insulating materials between them. Sometimes it was assured using stone materials, or panels with insulating elements inside, or with block wood elements.

6 Climate and Wooden Architecture After the Industrial Revolution

The spread use of the steam-engine at the end of the XVIIIth century caused a deep changing even in the wooden buildings all over the world. In fact, there was the possibility to have a greater number of joists at minor costs, and this fact influenced the building systems themselves. Particularly in the Northern part of the United States, they began to build using thinner and closer elements through a better utilization of the material. This way of doing had been possible even for the introduction of the nail-machine, by which it was easier to make correct joints between the several parts of the structure. This was the aim of the *ballon-frame* system, introduced by G.W. snow in 1833, in which the joists constitute all the structure, from the walls to the roof and the floors. Regarding the thermal conditions, the *ballon-frame* system was different from *the block-bau*, because it needed an additional insulating coat to guarantee the inner comfort.
The *ballon-frame* was not a flexible system, because it was always linked to the double floor. So, the *platform-frame* system was introduced, by which the floor and the roof laid directly on the frame box. The several panels, of one floor each, were coated with planks with the function of wind-brace.
With the introduction of new productive systems, wooden panels made with the *platform-frame* system were pre-assembled in factory; in a second time, they were produced together with other coats, such as the thermal insulation and the plywood panelling, ready to be joint together to realize a whole building. In this case, it is important both the easiness of the assembling phase and the dimensional tolerance. So, during the design process designers had to pay attention to a correct definition both of the joint shape and of its dimension, together with a correct choice of the materials.
Nowadays, a lot of buildings are built with these systems, from the regions of Scandinavia to the ones of Northern and Southern America. But it is difficult to speak of wooden architecture. In fact, most of the times this buildings are used together with brick-block

masonry walls, and wooden elements are limited only to some parts of the structure. In the latest years, it is used to cover wooden buildings with masonry walls to protect them from outer aggressive agents, as fire for example, or just to confuse them with other buildings where there is not a strong wooden tradition (Spain, for example, or other Mediterranean coastal countries).

7 Differences Between Wooden and Masonry Structures

There are both economical and energetic costs in the building process. Starting from the production of the building components (from the first productive phase to realize raw materials, passing through the mould process to form elements with particular features for their future use, to end with their packing and transport to the building yard), to the final part of the process regarding the construction of the building itself, there are a lot of explicit and implicit costs which deeply influence the building process. Just think to the cost of the materials, of the equipment, of the workmanship, of the transport as well as to the use of not renewable resources that causes many problems to the environment with many repercussions both on the present and on the future generations.
In the last years it is used to build with renewable resources such as wood together with a clever design process, so that it is possible to reach good results at low costs, most of all for what concerns the comfort of inner spaces. So, we must pay more and more attention to the design process of the building parts (most of all walls, floors and roofs) for what concerns the igrothermal aspects; in fact, the most important parameters which deeply influence human behaviour during its life or its working period, are inner air temperature, walls temperature, relative humidity and air speed. These parameters have different values according to the materials or the building process with which the building parts we said before are realized.
Recently, some researchers have compared the behaviour of wooden frame buildings with the masonry ones. The latter ones are more expensive than the former ones for what concerns both the building phase and their future management, even if the two different building components have the same U-value. Some examples are collected in Table 1.
As one can see, insulating element is the one that deeply influence the behaviour of the building components regarding the U-value. Different types of insulating elements, as well as their thickness, can change the walls answer to outer impute for what concerns the thermal conduction. This is true most of all for wooden walls, where the thermal resistance deeply depends on the presence of a specific insulating elements, such as a mineral wool or polyurethane, because the frame box cannot assure sufficient insulating values for a correct inner thermal comfort. Instead, brick-block masonry walls do not need such elements, because the blocks themselves can assure a correct comfort; in fact, they are able to accumulate the thermal energy of the sun and to leave it when the inner temperature values go under the outer one.
But the most important thing is that wooden buildings have thicker walls than masonry ones, so that they can be built and put together to form the whole building in a short time; so, at the end the building process is cheaper both during the building phase and during the future life of the structure. In fact, to increase the U-value of a wooden building, you can easily change the insulating material or add another layer, while for masonry buildings you need to intervene with expensive works to fit the new standards, such as, for example, an external insulation element. By this way, a longer working out is requested, and only qualified firms can assure a correct final result, just because the relationship between the new elements and the existing ones, such as between the elements and the ground, is very complicated. Moreover, the shape and the volume of the building is often changed, and so the inner nature of the building itself is altered.
Of course, one building element is not better than another just because of its material. The

building is a complex structure whose several elements must be related in a right way to work well, and they must be built and designed depending on the users requirements and on many other conditions, first of all the climatic and morphological conditions.
Certainly, using wood to realize the main building frame, together with a clever choice of materials to assure a correct inner comfort, is the right way to save time, energy, building and management costs. Of course, by this way the design process is easier both for the new buildings and for their future refurbishment concerning changes to the inner distribution of spaces.

Table 1: *Comparison between Wooden and Masonry Structures*

Typology of Walls	Thickness [mm]	U-value [W/m^{2}K]
facing brick mm 102 clear cavity mm 50 mineral wool mm 90 wooden frame box	265	0.41
vertical tile hanging mineral wool mm 90 wooden frame box	215	0.44
facing brick mm 102 clear cavity mm 50 mineral wool mm 140 wooden frame box	316	0.29
vertical tile hanging mineral wool mm 140 wooden frame box	275	0.31
facing brick mm 102 polystyrene beads mm 75 inner aggregate block mm 100 (2000 kg/m^3)	292	0.43
facing brick mm 102 clear cavity mm 50 extruded polystyrene mm 50 inner aggregate block mm 100 (2000 kg/m^3)	317	0.43
facing brick mm 102 polystyrene beads mm 50 inner aggregate block mm 100 (2000 kg/m^3) inner polyurethane insulation mm 28	319	0.28
facing brick mm 102 clear cavity mm 50 extruded polystyrene mm 50 inner aggregate block mm 100 (2000 kg/m^3) inner polyurethane insulation mm 28	344	0.28

8 The Refurbishment of the Traditional Wooden Architecture and the Climatic Aspects

It is very difficult to refurbish the traditional wooden buildings in a right way. The bigger problem is that both the shape and the frame box of the building can be altered using unsuitable materials to solve the static and the comfort requirements. In fact, the risk is to save only the outside idea but not the inner building aim.

In many cases, while refurbishing wooden buildings, the whole structure is deeply changed to fit the new living standards concerning most of all both the igrothermal environmental conditions and the sanitary one. Sometimes, it is easy to fit the new regulations about thermal insulation or windows air tightness making a wrong use of waterproof materials as well as thermo-acoustic insulating elements; however, by this way we change the values of humidity and temperature that there had been for years before the introduction of the new materials. Sometimes the building suffers more when even its own purposes is changed because of the new different users requirements. Just think to the re-use of those buildings that had been built with a non residential purpose, so using rough techniques, low-quality wood and, most of all, designed without taking into account the inner igrothermal conditions. The building techniques were not casuals, but they depended on careful choices concerning the conditions to be satisfied. In fact, it is better to use rough-hew and bent logs to let the air in where there is the hay or where the animals live. Usually, for example, a barn is deeper changed than a residential building when it is refurbished with a different purpose from the one it has been built for. In fact, walls must be insulated using materials that first were not necessary to reach an appropriate inner temperature value. The building really suffers for this like a living being, because most of the times its exterior wooden part has only a symbolical function, just to remind what it was in the past time, while the real building is made of brick-block masonry built inside the older structure. Let's see, for example, those buildings where they added a thermal insulating coat (like mineral wool) inside the old wooden structure, together with an inner wall made of clay tiles.

So doing, even the new sub-system, both sanitary and electric, are introduced into old buildings in a wrong way. Most of the times, designers do not take into account that these structures had been born without installation of any type. The most problematic system is the heating one; in fact it usually has very large pipelines that are placed in the floor, so that sometimes the mortar thickness is bigger than the wooden one.

But it is for this reason that the cultural heritage of wooden architecture is decreasing more and more, most of all in particular geographical areas, like the mountain regions of Trentino-Alto Adige.

A possible solution to this drastic way of doing is to use new building techniques to refurbish buildings for residential purposes, so that the features of the building elements could be maintained as well as an appropriate inner environmental comfort. There are three different kind of solutions to this problem:

- a correct design of the inner environment, so that the previous inner typological aspects can be saved;
- a clever location of the installations, putting them near the new parts of the building so that they do not disturb the ancient one;
- a new conscious utilization of the bio-climatic aspect of the traditional architecture, used to improve the igrothermal environmental conditions; for example, the geographical position concerning the thermal radiation (i.e. the position of the sun during the daylight), the inclination of the ground, the presence of other surrounding buildings or of wind barriers or of rocks reflecting the sunlight, and so on.

9 Conclusions

In the latest years, the climatic aspects are recovering an important role in the building design process and they can suggest new solutions to the designers regarding both the inner distribution of spaces and the building functional aspects. Nowadays we are realizing how much we have deeply injured the environment, even in an irreversible way, through the use of not renewable and polluting raw materials. So we could began a new process using few energy resources, taking into account both the climatic aspects of the building design process and a correct use of natural materials. This could improve the environmental condition or, at least, could preserve the current situation without causing no more damage.

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ENVIRONMENTAL COMPATIBILITY OF CONTROLLED LANDFILLS IN RELATION TO THE VULNERABILITY OF THE AQUIFERS: A PROPOSED APPROACH

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Abstract

In the present article a methodology for the evaluation of the environmental compatibility of controlled landfills is suggested.
On the basis of an analysis of the vulnerability of the aquifers, carried out through a Point Count System Model (PCSM), of which a brief and careful observation has been provided here, a classification of the territory has been obtained and afterwards crossed with a classification of the specific danger of various landfills according to certain featuring parameters.
The final result is a map of the potential locations and hydrogeological limitation.
As an example this methodology has been applied to an area of the Basilicata (Southern Italy).

1 Introduction

Over the last few years we have witnessed a continuously increasing process of groundwater deterioration, specifically a qualitative deterioration, connected with various human activities and territory transformations.
Particularly dramatic is the circumstance that in almost all countries, even in the industrialised ones there are a great number of illegal and/or uncontrolled landfills or plants designed for municipal waste but filled in without any criteria with toxic and harmful waste, without any means of protection for the surrounding environment.
In Italy a recent survey of the Civil Protection [3] has singled out 4256 illegal landfills of R.S.U and toxic and noxious waste. In Basilicata, the situation is not less difficult, as highlighted in Regional Plan for Land Reform.
Even in the case of controlled landfills which are therefore equipped with proofing systems, the possibility of polluting the underground waters is not at all remote. In fact, it is possible that some kinds of leachete can attack synthetic line materials, damaging them in various ways.

Further deterioration of the syntetic line material, can be seen because of sloughs of the foundation ground, or a bad placement of the synthetic line material, etc...
As a consequence, the leachate is no longer restricted and can seep into the underground, polluting any eventual water tables underneath or nearby. In this case, a landfill, which should function for the control and redution of pollution, can become itself a dangerous focal point for the spreading of pollution and results in the qualitative deterioration of the underground waters.
From what has been said it can be deduced that the location of the landfills should not be chosen randomly or influenced only by morphological, economic and logistical factors, but should be the result of a precise survey that leads to a selection of the locations, and whose leading criterion should be the evaluation of the vulnerability of the aquifers to pollution, outlined in suitable thematic maps of various kinds, according to the methodology used and the available data. Such a criterion has remarkable and various practical spin-offs: it allows the foreseeing and controlling the consequences of a wide-spread or punctual pollution, the singling out of the areas which more than the others are likely to have installations or plants potentially dangerous (plans for the location of landfills or other plants for the waste disposal); it allows the planning of the networks for the environmental monitoring, which should control the impact on the territory of potentially dangerous activity.
Our study is included in the POP-FESR programme regarding the productive use of water resources and waste management, a programme financed by the Basilicata Region and the European Union.

2 Tools and Work Methodology

The suggested methodology is aimed at the singling out of the locations and types of landfills designed for reducing the risk of environmental contamination to a bare minimum.
The features of the vulnerability of the water tables and potential danger of the landfills are analysed here in parallel, in order to obtain an assessment of the possibility of locating waste disposal plants in areas with less vulnerability, that is to say, in areas with the same vulnerability, and defining the compatible plant typology.
The organisation of the suggested method will be structured as follow:

a) *Acquisition of the basic elements.* Acquisition and processing of data concerning: geological geomorphological features of the areas; the climatic features involved ; hydrogeological and hydrodynamic features of the aquifers; the hydrogeological regime and features of the main springs and water points in general, the chemical and physical features of the underground waters; the geometrical configuration of piezometry and related spatial and temporal variations; the marking-out of the present landfills (site, type of realisation, type of waste, type and production of leachate and the age of the landfill). Such elaborations will facilitate a precise definition of the hydrogeological features of the investigated areas, the areas of the feeding of the water tables, the assessment of the water potential of the aquifers, the direction and the speed of down flow of the underground waters. All this has great importance in the further assessment of the features of vulnerability of the investigated aquifers.

b) *Definition and selection of the criteria featuring the method of vulnerability evaluation*
On the basis of the results achieved in the previous phase, the parameters necessary for the evaluation of the intrinsic vulnerability will be defined, by means of a point count system model, capable of taking into consideration some parameters which by putting in together the features of the aquifer and the centre of danger (controlled landfill) influence the infiltration, percolation and diffusion of the polluting agent in the water table. The choice of the parameters to be used in the evaluation of the vulnerability will be influenced by such factors as: the type and hydrogeological and hydrodynamic features of the aquifer

under examination; the possession of depth data and information resulting from geognostic research and hydrogeological surveys on the geometrical configuration of the water tables, the hydraulic conductivity of the aquifer, the depth of ground water table (*soggiacenza*) etc.

c) *Evaluation of the elements of danger in a landfill.* To be evaluated are the plant solutions activated (in the existing landfills) or those planned (for new plants) for the different functional needs. The dimensional aspects analysed are: the type of waste, the management of the effluents, environmental monitoring and management of the after landfill closing.

d) *Evaluation of the integrated vulnerability of the examined areas.* By adding the vulnerability features to the indexes of the dangerousness of the landfills examined it will be possible to define the integrated vulnerability of the examined area and express a judgement on the suitability of the location and of the specific typology of the landfills in relation to the investigated site.

3 Analysis of the Vulnerability of the Aquifers

The intrinsic vulnerability may be defined *as the specific susceptibility of the aquifers systems, in their different component parts and the different hydrodynamic and geometrical situations, to absorb and spread, by limiting the effects, a fluid or hydro-vehicled polluting agent, in such a way as to cause an impact on the quality of the underground water, in time and space* [3, 4]. When to the intrinsic vulnerability is added the presence, position and typology (and therefore the dangerousness) of the existing and/or planned danger centres, the interaction between the vulnerability and the danger centres will be defined and the integrated vulnerability of the investigated territory obtained. The charts of integrate vulnerability consent the evaluation of the conditions of the potential risk the examined areas are subjected to .

From vulnerability comes the concept of Risk, which is a function of vulnerability, plus the importance of the polluting event and the value of the water resource.

The main factors and basic parameters which sustain the vulnerability of the aquifers to pollution are, according to Civita [3], reported in Table1 The methods of evaluation of vulnerability can be divided in three groups:

- Division for homogenous areas
- Parametrical methods
- Numerical methods

Evaluations of the vulnerability for homogenous areas are based on the knowledge of the hydro-geological features of the geological formation which characterise a territory, and from these the evaluation of vulnerability is derived by using techniques of chartographical overlapping. The most used parametrical methods include various calculation systems such as Matrix Systems (MS), Rating System (RS), Point Count System Model (PCSM).

The basic principle is always the same, after singling out and selecting the hydrogeological parameters that influence the vulnerability, a score is given to each parameter, which is then subdivided into value intervals and varies in relation to the importance of the role played by the single parameter incomparison with vulnerability.

As for surveys on the best location of plants which are potentially dangerous regarding the quality of underground waters, the systems mostly used are those with point count system model (PCSM). They take the Legrand System [6] as a starting point. The introduction of PCSM has been an important innovation for the study of vulnerability.

In detail, in the calculation, one or more weights are introduced for each parameter taken into consideration, which then amplifies its score to give the proper importance to the parameter considered for the evaluation of vulnerability.

Table 1: *Main Factors and Basic Parameters Which Condition the Vulnerability of the Aquifers [3]*

Main process	Basis Parameter
TIME OF TRAVEL	Depth to ground water table (soggiacenza), thickness, texture, porosity, permeability, soil specific retention, litology, grain size, fracturing index, kerst index, structure and vertical permeability of unsaturated zone, density, viscosity, pollutant water solubility, mean natural recharge
UNDERGROUND OUTFLOW	Aquifer hydrogeological features (porosity, permeability, structure, geometry, phreatic surface)
ATTENUATION CAPACITY OF POLLUTANT IMPACT	groundwater temperature, density, viscosity and water solubility of pollutant, depth to ground water table, mean natural recharge, topographic surface average slope and use, density of river system and relation with aquifer, thickness, texture, mineralogical composition, specific retention, physical and chemical characters and permeability of unsaturated soil.

In Italy, a PCSM calculation system has been developed taking into consideration 7 different hydrogeological parameters of the aquifer; the system is called SINTACS (Depth to ground water table (Soggiacenza) - Infiltration - depurator Effect of unsaturated ground - Type of soil - Features of the Aquifer - hydraulic Conductivity - topographic Surface average slope) [3]. This system provides the calculation of the index of vulnerability, in a 6 degree-scale (from very low to high vulnerability) which enables the distinction of the vulnerable areas, in the aquifer on similar levels.
A point count system method, taken from the SINTACS (but simplified and adapted to the investigated Lucanian complex hydrogeological situations examined), has been applied to the evaluation of the vulnerability of some carbonatic aquifers [4, 5].
The numerical methods are based on the evaluation of an intrinsic vulnerability index (Iv) based on analogical - mathematical expressions which can be either simple or complex.
The examined territory is divided in squared cells which form a mesh of irregular shape. For each single cell an index of vulnerability (Iv) has been calculated, which is obtained by adding the values of the single parameters (*Ppar*), conveniently weighted. The index of vulnerability has therefore been obtained through the following relation:

$$Iv = Ppar * weight$$

The total range of the vulnerability indexes (between maximum and minimum) has then been, divided into intervals, and to each of these a degree of vulnerability increasing from low to average, and high has been given.
From this division those particular points, which for geological (e.g. a doline) or hydrogeological characteristics (e.g. a spring) can put the water table into direct contact with the polluting source, are excluded.

4 Intrinsic Potential Danger of Landfills

Waste normally contains several organic and inorganic substances which, compared to the environment they are put into, are considered contaminating.
The environmental damage, potentially caused by a landfill, depends largely on the environmental sensitivity of the area of the plant and also on the presence of damageable objectives. This approach, on which the present criteria of environment impact evaluation is based, tends to put the type of plant into a lower profile and the related degree of dangerousness, tied up with management and building aspects.

The necessity for creating disposal plants and the general opposition to this from the people involved, on the one hand reduces of a great deal the areas of a possible location, on the other leads to the utilisation of containment systems of the impact quite often in an acritical way.
We risk building the, wrong plants in the wrong places, creating both economic and environmental damage as a result.
A closer analysis of the elements of potential danger of a single plant may consent a better evaluation of potential risks, and therefore, this could be a guide for technicians and administrators who have to make decisions regarding the realisation and location of the plant.

4.1 Evaluation Method

Suggested is a criterion of a disjointed analysis of different causes of potential dangerousness and quantitative evaluation of the risks according to the different technical solutions chosen both during the planning phase and the management phase.
Firstly, the structural and operational components of evaluation must be singled out:

Table 2 Risk Elements and Related Weights

Risk elements	**Weigh "W"**
Potentiality of the plant	5
Leachcate collection system	5
Type of refuse	3
Physical state of refuse	3
Typology of stabilization	2
Monitoring system	2
Disposal criteria	1
Final cover	1

To each of the above elements a weight related of the potentiality of the impact must be attributed, whereas for the single elements an reduction factor "R" of the magnitudo of the potential damage in relation to the specific used technical measures are defined.
In this way a principle is introduced according to which the plant in itself is not dangerous but the specifically used solutions can be a source of damage.
Consequently an evaluation of the dangerousness index "I_d"is obtained:

$$I_d = \Sigma\ Wi*Ri$$

which can be used together with the indexes of hydrogeological vulnerability of the territory for the preliminary locating of new plants or for the carrying out of land reclamation of sites involved in waste dumping.
Reported here are some brief notes of explanation concerning the choice of the risk elements.
Potentiality of the plant: the size of the plants is extremely variable both in terms of volumetry and the potentiality /capacity) of daily disposal.
In low-urbanized areas, landfills weighing of a few ton/d are realized compared to those plants more than 1000 t/d in the cities which still utilize this technology; the latter for their size and consequent difficulties in carrying out repair work in the eventuality of defaults.
Leachcate collection system: the risk of leachate losses is basically tied up with the possibility of breaking in the conteniment layers; the same event can be more or less serious according to the eventuality of having leachate stagnation at the bottom of the basins.

Conditions permitting, the possibility of keeping the basins permanently drained (with external sewage collection) greatly reduces strongly the quantity of dispersed materials on a par with the damage to conteniment structures.

Type of waste: this item aims at following the indications found in several technical sets of rules which establish degrees of dangerousness according to the nature and the origin of the waste and which make distinctions, for example, between inert, urban and dangerous waste.

Physical state of the waste: the consistency of the waste inserted in the landfill is extremely important as far as the danger of contamination in the ground is concerned.

Solid or solidified waste with inert matrixes will guarantee a minor release of polluting substances compared to muddy or polverulent materials.

Stabilization: the management of the plant can be done in such a way as to favour the aerobic stabilization (also as a pre-treatment) so that the reduction of biodegradable substances and the setting-up of an alcaline environment determines the formation of leachate of reduced dangerousness.

Monitoring and control systems: the infrastructure of the work consists in
providing the plant with systems of active protection (under geomembrane nets) and control systems (underground monitoring) so that there will be an increase in the total safety related to the possibility of alert and intervention in short time if there is a functioning default or an accidental event.

Disposal criteria: the different ways of refuse disposal in the basins, covering, compacting, leachate recirculation, can weigh most heavily on the dangerousness of the plant; especially the compacting and its effects on the mechanical stability of the accumulation, having an important role which leads to the choice of high compacting systems rather than the deposit of loose materials.

Final cover: even if the total closing-up of the landfills can jeopardise the stabilizing of the organic fractions, there is no doubt that by reducing the meteoric seepage to a minimum this will greatly limit the risk of leakage from the leachate.

Table 3. *Reduction Factor of the Weights of the Single Elements of Danger Stated in Table 2*

	1	R		R		R		R
Potentiality of the plant	2 < 10 ton/d	0.1	10-50 ton/d	0.2	50-500 ton/d	0.4	>500 ton/d	1
Leachcate collection system	Free drainage and external collection	0.1	Internal drainage and extraction with pump	0.3	Stotage and seasonal recycle	0.5	Not present	1
Type of refuse	3 Inert	0.1	Urban	0.5	Industrial – not dangerous	0.8	Dangerous	1
Physical state of refuse	Solidified with inert matrix	0.1	Solid	0.2	Sludgy W<70%	0.5	Sludgy W>70%	1
Typology of stabilization	Non biodegradable	0.1	Aerobic	0.3	Both (anaerobic and aerobic)	0.5	Anaerobic	1
Monitoring system	Monitoryng well + under geomembrane net	0.1	Under geomembrane net	0.3	Monitoryng well	0.5	Not present	1
Disposal criteria	Compacted with hidraulic press	0.1	Compacted with steel wheel compacto	0.2	Compacted with crawler	0.5	Eny compactatio n	1
Final cover	Compacted clay + soil	0.1	Only compacted clay	0.2	Only soil	0.5	Not present	1

4.2 Relationship Between the Vulnerability of the Site and the Potential Danger of the Landfill

The suggested criterion does not exclude the possibility of locating landfills in determined areas, apart from the peculiarities described at paragraph 3 but this result is derived from a cross analysis of the hydrogeological and plant aspects, after defining the index of dangerousness (I_d).
The tolerance threshold for high-sensitivity areas has been set at 3 allows the realization of plants for urban waste disposal of modest potentiality and high protection standards.
The following intervals of I_d < 6 and < 10 define the possibility of placing the landfill respectively in the areas considered to be of average or low permeability, whereas for I_d < 10 both plant and operational measures should be taken to lower the degree of potential danger.

Table 4: *Index of Dangerousness "I_d" Allowable for Areas of Different Vulnerability*

I_d	**Allocation area**
< 3	Any area
3 – 6	Medium vulnerability area
6- 10	Low vulnerability area
>10	Is necerrary to take measures to reduce intrinsic dangerousness

5 A Study Case: The Carbonatic Aquifer of Mount Volturino (Agri River Valley)

The main objectives of this study are the definition of the hydrogeological features of the underground water flow and the assessement of water potentiality and the intrinsic vulnerability in Mount Volturino (High Valley of Agri River). The outcropping rocks, mostly afferent to the Lagonegro Units, are (from base to top) : the Argillites and marls (Trias Medium); Limestone with cherts (Upper Trias); radiolarian cherts (Jurassic); shales with marls (Upper Jurassic - Cretaceous).
The structural shape of the area is conditioned by the complex anticline of Mount Volturino and Mount Lama, intensively and largely involved by important direct faults and some systems of fractures.
In Fig. 1 the hydrogeological framework of the examined aquifer is reported. It is formed mostly by Limestones with cherts, highly permeable due to fissures and by some Radiolarian cherts. It is bordered everywhere by a water-proof belt of Slates with marls. The aquifer is divided by some tectonic line in four separate sectors, characterized by the different directions of underground water flow and bordered on by underground watersheds (Fig, 1). On the boundaries of the four sectors, are located most of the springs that drain the conspicuous underground waters [5, 6] .
The hydrogeological study carried out was the necessary starting point for the evaluation of the intrinsic vulnerability of this *aquifer.* The latter has been evaluated, by considering those factors and/or parameters which (directly and/or indirectly) influence a possible inflow and diffusion of polluting substances, generally hydro-vehicled, in the underground aquifer.
Although the method used herein follows closely the guidelines of methods which have been largely applied to other areas in our country [3], it has been adjusted to the features of the territory being studied and the availability of the data. In fact a reliable approach for the definition of the thickness of saturated and unsaturated areas (except for those areas near spring) is difficout because of: 1)the morphological configuration, which is typically mountainous in the area, 2) the remarkable hydrogeological complexity of the Aquifer, 3) the lack of data and direct information, (coming from surveys and/or wells), 4) the complex flow path following the discontinuity net in the natural rockle. All this reduces greatly the number

of the available parameters for the evaluation the vulnerability. As a consequence, the parameters used in the evaluation where those available, such as lithology and the permeability features of the territory, the topographical surface average slope, fracturig index of the rock and effective rainfalls.

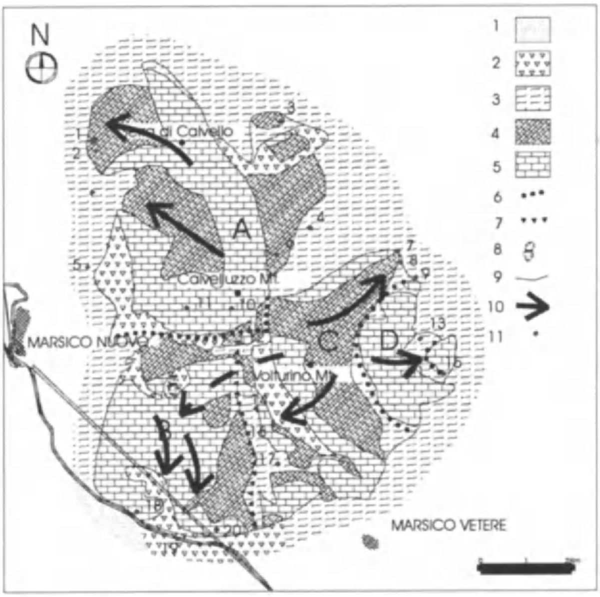

Figure 1: - *Hydrogeological Map of Mont Vulturino: 1)Alluvial deposits; 2) Debris; 3) Shales with marls; 4) Radiolarian cherts; 5) Limestones; 6) Underground displuvium; 7) Underground displuvium with ground water inter-exchange; 8) Doline; 9) Basin boundary; 10) Direction of underground water flow; 11) Spring*

The used parametrical system (PCSM), was based on the attribution of a score (Ppar), between 1 (low influence) and 10 (high influence) to each class (value interval) of the parameters involved. The score, obtained in this way, has been necessarly amplified by the product with a multiplying factor ("Weight") previously decided in order to guarantee the right evidence for the parameter considered in the evaluation of the vulnerability.
Table 5 reports the value intervals given to the factors and/or the parameters used in the evaluation of the Index of Vulnerability (Iv) in the case of the Mounts Volturino and Calvelluzzo are reported.
The examined territory has been divided in squared cells with a 500 m. side (25 ha) forming a grid of irregular shape. For each single cell an index of vulnerability (Iv) has been calculated, obtained by the addition of the values of the single parameters, suitably weigthed. The index of vulnerability is the result of the following relation:

$$Iv = Ppar * Weight$$

The total range of the indexes of vulnerability (between minimum and maximum) was subsequently divided, into intervals to which was given a degree of vulnerability increasing from low to high. The results have been reported on a map drawn to a scale 1 to 25,000, from which it is possible to deduce, sector by sector, the features of the intrinsic vulnerability of the aquifer this simplifies the selection and singling out of the different areas which, being more vulnerable and thus more exposed to pollution risk, have to be excluded as location of potential danger. In Fig, 2 there is an outline of the chart itself.

Table 5 - Scores and Weights Given to Different Parameters Used in the Evaluation of Vulnerability

LITOLOGY	SCORE	WEIGHT
Debris	10	8
Limestone	7	8
Radiolarian cherts	4	8
Slate and marls	1	8
FRACTURING INDEX ($\Sigma L/A$)		
$0 - 10*10^{-3}$	1	10
$10*10^{-3} - 18*10^{-3}$	4	10
$18*10^{-3} - 36*10^{-3}$	7	10
$> 36*10^{-3}$	10	10
TOPOGRAFIC SURFACE AVERAGE SLOPE		
0° - 5°	10	5
5° - 15°	7	5
15° - 30°	4	5
30° - 50°	1	5
EFFECTIVE RAINFALL		
< 500 mm/a	2	6
500 - 540 mm/a	4	6
540 - 580 mm/a	6	6
> 580 mm/a	7	6

The area examined includes part of the territory of Calvello, Marsico Nuovo, Marsico Vetere, Paterno. Each of them has used highly dangerous landfills for Urban Waste disposal. (particularly for the scarse level of containment of the leachate).

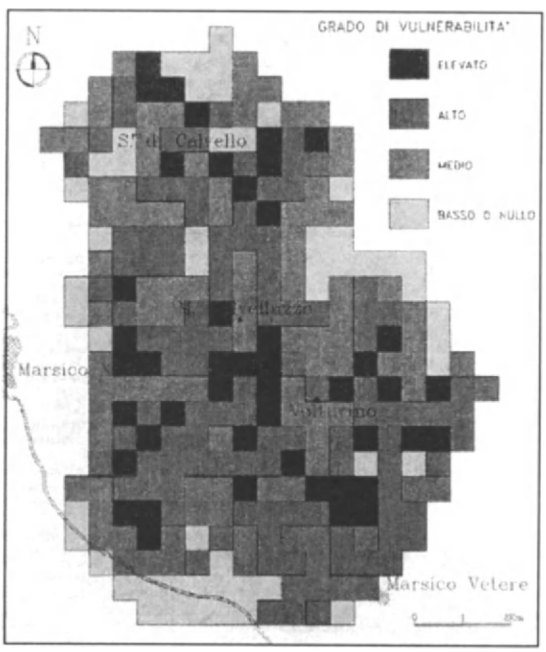

Figure 2 - *Outline of Vulnerability Features of the Examined Area [5, 6]*

The Regional Plan for Land Reform of landfills has assessed N°20 of contaminated sites in the area of study or nearby. All these sites have to be classified as of medium to high potential danger, because they lack the simplest containment measures. A further element of risk for the precious, rich underground water sources in this area lies in the research and extraction activity of hydrocarbons and the related plants for treating and stocking drilling waste.

6 Conclusions

The suggested criterion seems to be effective for a preliminary definition of the placing of controlled landfills and the planning of the land reform of the areas involved in waste disposal; it must be underlined that in this way the degree of potential danger and the type of plants are involved into an analysis of the plant costs and the environmental risks.
According to the classes of potential danger compatible with the various degrees of vulnerability it will result extremly advantageus, where possible, to set up plants in areas with low permeability and at the same time carrying out plant economy and environmental safeguards; in other words, the building of wrong plants in unsuitable places will be avoided.
A first application of this methodology, to which the data here reported refers, has been carried out in an area in Basilicata (Southern Italy) in the research program POP-FSR 1997/99, financed by the Basilicata Region and European Union.
The results of this survey are now being published.

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HIGH-SPEED RAILWAY: ENVIRONMENTAL EFFECTS ON NATURAL RESOURCES DURING THE CONSTRUCTION PHASE

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Abstract

The aim of the research is to focus on the hazard of air, water, nature and landscape pollution that is linked with the construction phase of a linear work such as the high-speed railway Florence-Bologna in Italy.
This paper analyses the Environmental Impact Assessment of the Fiat Engineering project, describes the technical characteristics of the project, the peculiarities of the territory crossed by the line, the effects of the project on environment and the measurements adopted to minimise the environmental impacts. Besides it pointed out how scientific and technological progress can be used to design in the respect of environment.
At the end the paper analyses the activities of the Environmental Observatory which checks the construction phase with particular regard to surface water, groundwater and noise pollution.

1 Introduction

The integration between environmental impact and transport is one of the main purposes in sustainable development. The traffic increasing is a strongly negative effect of urbanisation: reduction and regularisation of traffic will be basic to protect the environment.
The train is, without doubt, the transports mean more respectful of environment.
The UE commission for high-speed railway, in the Final Report (17 December 1990) compared the different means of transport. The results are resumed in Table 1.

Table 1: *Environmental Impacts of Transport Means*

	High-speed train	Car (motorway)	Aeroplane
Soil occupation	1	3	-
Energy consumption	1	2,2	2,5
Air pollution	1	7	3

2 Project

In Italy the High-speed Railway Project is part of the National Transport Plan, which is linked to the European Plan for High-speed Network.

In France, Germany and Spain the high- speed network is already at a satisfactory stage, and the Italian system has to be brought to European standards and integrated in a continental High-Speed network, in order to be connected with France on one side (Torino-Lione) and Germany on the other.

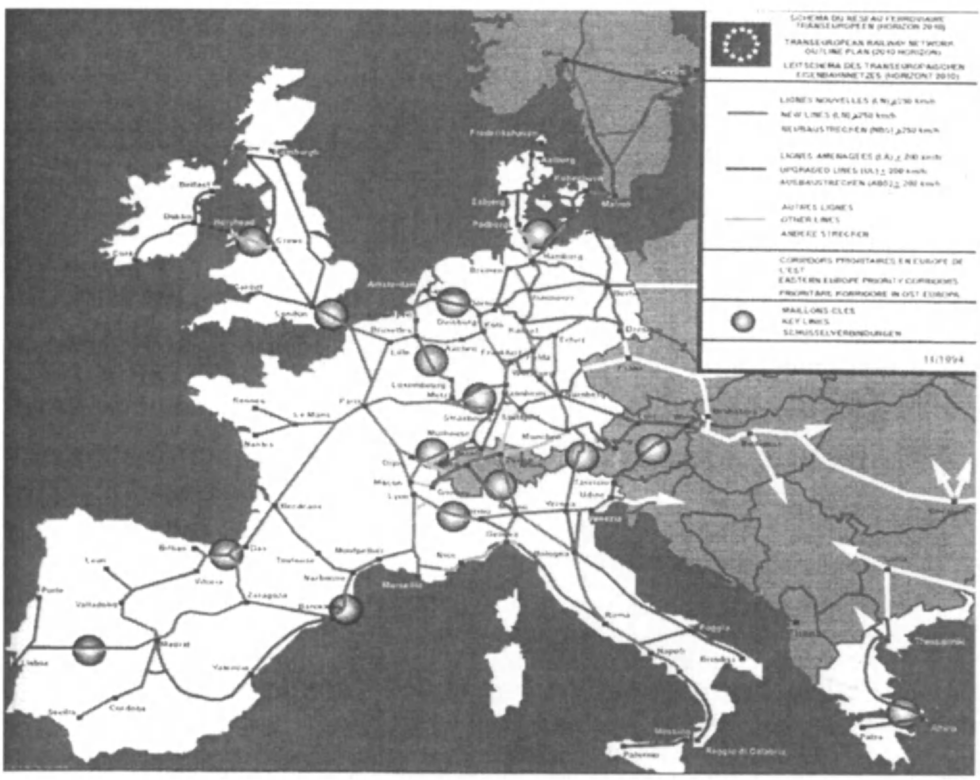

Figure 1: *European and Italian Railway Network*

This project redesigns the Italian railway system quadrupling the number of tracks on lines with new high-speed routes in East-West direction and North-South direction.

The National Transport Plan has the object of both improving the main axes North-South and East-West and moving to the railroad part of motorway traffic (people and goods).

The Bologna to Florence section constitutes the greatest design and construction commitment as far as Italy is concerned.

2.1 Project Characteristics

The design of High-speed railway line has very restricted conditions, such as a wide bending radius and a gradient not superior to 18% outside and 15% in tunnels.
The railway tunnels have been designed with small dimensions: a cross section to be excavated of approximately 135 sq.m.
The geology of the route is very varied. It includes flyshioid formations, clays and argillites as well as loose soils. In order to tackle such heterogeneous conditions, to respect the restriction and to maintain a small section, the most advanced technology has been employed. The approach is based on the analysis of controlled deformations in rocks and soils in an operational phase and in a monitoring phase which doesn't end with the completion of the works but continues during the entire life of the tunnel to constantly monitor safety during operation (Fiat Engineering Co. and Rocksoil Engineers co.).

Table 2: *Line's Technical Characteristics*

Max. speed	300 km/h
Commercial speed	170-190 km/h
Min. bending radius	5 540 m
Max gradient	18%
Natural tunnel section	82 m2
Artificial tunnel section	100 m2

Data from EIA, 1992

The technical restrictions prevent the railway from turning around physical or environmental obstacles. The solution found was to design the most of the line underground: we can say that the line is a unique long tunnel connecting Florence with Bologna. More than 80% of the railway, 73 kilometres of the 78-kilometre route across the Apennines, is underground coming out just across the main rivers, mostly on viaduct with a length of about 100-m.
The passengers travelling between Bologna and Florence will have the sensation of passing trough a single very long tunnel.
This solution permits to minimise the environmental impacts during the service phase.
The railway is characterised by four principal work typologies with different environmental impacts.

Table 3: *Line's Typological Characteristics*

Total length (m)	77895	100%
In tunnels (m)	67879	87,2%
In banks (m)	6487	8,3%
On viaducts (m)	3511	4,5%
N. tunnels	18	
N. bridges or viaducts	17	

Data from EIA, 1992

The final design is partially different from the design presented for the first EIA in 1992; it involves the construction of nine underground tunnels for a total length of 73 km. There are also 13 access "windows" (shatts) with a total length of 12 Km. These windows serve not only as intermediate adits on the longest tunnels (from 10 to 14 km) with the purpose of reducing construction times, but also as emergency exits in the event of accident when the tunnel is operational.
In order to ensure completion of the line within the 78 month provided for in the contract, 40 tunnel faces must be driven simultaneously; it means that all the construction sites must be operating at the same time.

The resulting mobilisation of means and manpower makes the project one of the largest currently in progress and one of the most heavy for environment.

Table 4: *The Evolution of Railways Routes for linking Florence to Bologna*

	PORRETTANA LINE - 1864	DIRETTISSIMA LINE - 1934	HIGH-SPEED LINE - 1996
Underground stretch	11%	30%	92%
On surface stretch	89%	70%	8%
Total length	132 km	97 km	78 km
Tunnels	15 km	29 km	72 km
Mountain pass	616 m a.s.l	328 m a.s.l	413 m a.s.l
Max ruling gradient	25%	12%	12%

Comparing the 1996 project with the old project of 1864 and the line in function at present, designed in 1934, we can see how this project represents a work of civil engineering of unique value and interest both for the technical and the environmental importance: it is an example of how design and construction philosophies evolve as a consequence of scientific and technological progress and of a growing awareness of the need to respect the environment.
Environmental impact identification brings together besides the analysis of project characteristics, the analysis of baseline environmental characteristics.

2.2 Environmental Characteristics

The new railroad will cross the central part of Italy from SW to NE passing through countries with quite different features: an anthropised territory, a natural one, than again an antrophised territory.
The line will start in the suburbs of Florence in a territory with urban features, after that it crosses a rural territory with a high historical value. In particular the area of Mugello is relevant both for the architecture of same important villas and for the agricultural landscape. Besides the most of the land is protected by archaeological restrictions.
The Apennine's part is mountainous. Few villages are settled in this part, the most of the territory is natural, there are parks, protected areas, ecological oasis and geological sites.
Before Bologna the territory is again anthropised, in this part the architectural value is lower, but the zone is densely inhabited.

3 Environmental Impact Assessment

Both the rural and the natural landscapes have a high environmental value and the project results very impacting.
The analyses for the EIA have been brought on following the Italian law (Premier's Decrees of 1988), the factors examined have been:

a) air
b) surface water and groundwater
c) soil and geology
d) flora and fauna
e) complex ecosystems
f) human health
g) noise and vibration
h) landscape
i) magnetic radiation

The analysis shows that the most important effects during the service phase will be the noise pollution, in particular at the mouth of tunnels.
During the construction phase, on the contrary, the effects on environment could be very negative if not controlled carefully.
For the excavation of long tunnels in a mountainous area is necessary to forecast the setting of several construction sites, approximately one at every mouth of tunnel and starting of bridge. Besides it is necessary to forecast the camps to guest the nearly three thousand workers.
In order to ensure completion of the line within the 78 month provided for in the contract, 40 tunnel faces must be driven simultaneously, each with his construction site.

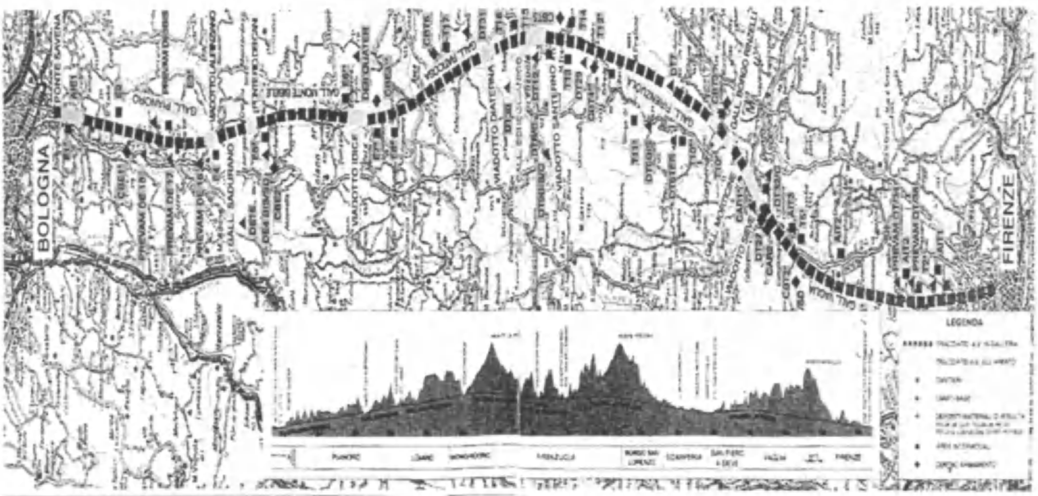

Figure 2: *The Territory Crossed by the Line.*

The construction sites have strong negative environmental impacts: air and water pollution; noise pollution; visual disturb.
Rows and curtains of trees and brushes, chosen from those typical of the zone, have been planted along the camp borders to minimise these impacts. The trees work as noise and visual barriers, and protect the nearby from the dust predicted in the sites.
The excavation of a 70-km long tunnel involves an enormous quantity of waste material.
The rocks excavated - most of them have bad technical characteristics being constituted mostly by argillites, marls and loose soils - can't be used for other works along the railways. The location in dumps of all this material constitutes a big environmental problem because involves:

a) land topography alteration;
b) landscape and visual impacts
c) water pollution
d) flora and fauna disturb
e) soil lost and increasing of trunk's traffic

Waste material can be used to landfill quarries, but the quarries are not easy to reach.
The transport of waste material by big trucks along small mountain roads is considered more impactful than to locate it somewhere near the construction site. The Department of Environment required for all dumps plans a restoring design. The aim was to reconstruct, for what is possible, the landscape existing ante operam.
The construction phase will last about 5 years and during these 5 years the territory will be interested by 31 construction sites, one every 2-3 Km, plus 27 dumps and 6 extractive sites.
It is clear that so many works along the line will be heavy for all the environmental factors: landscape, water, air and vegetation.

Table 5: *Construction Phase Data*

	Toscana district	Emilia-Romagna district	Total
N. construction sites	14	8	22
Total area (i.c.s.) mq	78 400	54 000	132 400
N. camps	6	3	9
Total area (b.c.s.) ha			125 000
N. guests			2499
N. dumps	17	10	27
Total area (d)	1 292 200	607 880	1 900 080
Total amount waste material (mc)	8 692 770	4 782 800	13 475 570
N. extractive sites	3	3	6
Total amount excavated material (mc)	3 688 500	2 066 000	5 754 500

Data from EIA, 1992

During the process of construction and service of the line, the construction phase is the most impacting. It was decided to make a complete SIA for each site necessary for the line construction. The study was carried on according to the classical scheme of matrices (project actions/environmental factors). The result was a complete environmental impact assessment for each site. The different situations have been compared according to environmental besides technical parameters.
The consequence was that the discussion around the location of construction sites and of dumps was long, difficult and deep. Several times, local and national authorities asked to change some locations in order to improve the general environmental situation.
In Table 5, we have summarised the different number and size of construction sites, camps and dumps decided since the production of EIA in 1992. When at the end the last solution was approved in 1995, the tracks of the line were shifted to the North in order to move some dumps from the too sensitive area of Mugello.

Table 6: *Changes Before the Final Approval*

	1992 EIA	1993 Transportation Conference	1995 EIA
N. construction sites	25	22	22
Total area (c.s.) ha	11,1	29,2	30
N. camps	9	9	10
Total area (b.c.) ha	12,3	12,5	20
N. dumps	24	25	26
Total amount waste material (millions of mc)	13	12,5	13,3

CONSTRUCTION SITES

	PROJECT ACTIONS / EFFECTS ON ENVIRONMENTAL FACTORS	Spring's flow changes	Ground water	G.w. quantity	Dray up springs	Permeability changes	Waterground pollution	Surface water pollution	Surface water flow change	Transport change	Streams dry up	Streams change	Geotechnical changes	Geomechanical changes	Underground pollution	Morphological changes	Sedimentation changes	End of natural reserve	Soil erosion	Landslides	Subsidence	Tectonic movements	Pedology changes	Soil pollution
CONSTRUCTION PHASE	Temporary land use																							
	Permanent land use																							
	Fences																							
	Drillings																							
	Tunnel																							
	Cuttings																							
	Excavation																							
	Demolishing																							
	River excavation																							
	Surface soil excavation																							
	Surface water diverting																							
	Surface water alteration																							
	Roads construction																							
	Facilities construction																							
	Temporary construction																							
	Supporting structures																							
	Drainage																							
	Impermeabilizing structures																							
	Banks																							
	Stabilisation structures																							
SERVICE PHASE	Special processing																							
	Heavy means movement																							
	Surface water intake																							
	Surface water discharge																							
	Electric power																							
	Open storage areas																							
	Waste disposal																							
	Work means in function																							
	Noise production																							
	Dust production																							
R.	Land restoration																							
	Vegetation restoration																							
	Environmental factors	WATER											SOIL AND GEOLOGY											

LEGEND

- Principal factor
- Conditioned factor
- Strong condition
- Improving factor

Figure 3: *Example of Matrix for the Construction Phase*

4 Environmental Observatory

The last act of the EIA is a Proceedimental Agreement among all the subjects involved in the project (Toscana and Emilia-Romagna Districts, Department of Transportation and Department of Environment, National Railroad Administration, FIAT Co.).
In the Proceedimental Agreement are specified all the directories to follow for working in the respect of environment.
The Environmental Observatory is a Technical Body whose job is the definition of the guidelines of the final project. During the construction Phase the Observatory must control the correct compliance with all the EIA directories.
Four environmentally sensitive factors have been pointed aut in Florence-Bologna line:
- surface water;
- groundwater;
- noise;
- Vegetation.

Monitoring of all these factors has to be carried on during all the construction phase and for the first period of the service phase.
Every construction site, camp, dumps and quarry must be planned and the plan must include a restoring plan for the area.

4.1 Monitoring

The monitoring process can be divided in four parts:
a) analysis and environment assessment ante operam;
b) monitoring;
c) assessment during the construction phase;
d) Assessment post operam.

At present, June 1998, the parts that are going on are f) and g), the monitoring of the weaker factors and the assessment of the construction phase, the factors monitored and the control points are:
- Surface water: in 45 surface streams section are collected chemical-fisical parameters and bacteriological parameters, gathered in synthetic indicators and in quality classes. The biological quality of water is analysed to find the IBE index);
- Underground water: Control points are put at 38 drills and 65 springs for flow measurements and water quality analysis. The data collected are correlated to piezometrical measurements and water flows in the tunnels;
- Air: Have been selected 10 areas for air quality control (6 near the most impactful construction sites, 4 for traffic pollution). The dusts are under particular control. Air pollution is measured with the help of lichen bio monitoring;
- Noise: there are 9 control sections along the rail line, 18 control sections near the construction sites and 9 control sections along the roads to monitor the traffic noise. Law parameters are used as reference indicators;
- Vibrations: 12 control points, the most finalised to the service phase;
- Vegetation: 22 control points, the points are located near the construction sites and on the surface tunnels, the disturb to vegetation is monitored trough field surveys and trough the analysis of infra-red rays pictures;
- Soil: erosion and soil movements are monitored. All the soils that must be reused for recovering plans, have been pedologically characterised;
- Electromagnetic radiation: it has been foreseen the possible radiation emission in same critical points. These emissions will be monitored during the service phase.

5 Conclusions

A big work like high-speed railways is always a very impacting one.
It is impossible to cross a country of high natural and historical value and densely inhabited, without disturb.
The problem is how to minimise the impact and how to be sure that the restrictions decided will be respected.
In the case of Florence -Bologna railway line it was decided:

a) designing the less impactful line putting the most of it underground. The solution adopted on the Bologna to Florence High Speed line was also an innovative design approach based on analysis of controlled deformation in rocks and soils which permits to run small tunnels;
b) minimising the noise pollution at the mouths of tunnels with the use of noise barriers;
c) considering attentively the construction phase and conditioning same choices to this phase;
d) planning a monitoring of weak environmental factors during the construction phase, and continuing the monitoring also in the first part of the service phase;
e) designing of recovering plans for all the sites used temporally (construction sites and camps) and for the dumps.

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IDENTIFICATION OF MICROBIAL INDIGENOUS SPECIES IN AN AROMATIC HYDROCARBONS CONTAMINATED SOIL

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Abstract

The recovery of a soil contaminated by aromatic hydrocarbons was studied in a lab-scale bioreactor. Native microorganisms capable of degrading the tested aromatic hydrocarbon mixtures were selected during two experimental runs in aerobic conditions. Both the disappearance times from the solid matrix and the removal kinetic constants were determined by HPLC (High Precision Liquid Chromatography) analysis.
The results showed that the biological removal process could be described by means of first order kinetics and that it depended on the pollutant molecular structure.

1 Introduction

In the last years, the need to recover contaminated sites has made necessary the development of biological techniques that make the destruction of pollutants such as aromatic and aliphatic hydrocarbon complex mixtures possible. These substances are very important because of their large-scale use in the production of resins, explosives, pharmaceutical products and dyes; moreover they are found in oil contaminated areas as well as in uncontaminated soils and sediments.
Biosynthetic activity allows for the assumption that the origins of these substances may be due to plants and microorganisms, so it is not surprising that hydrocarbon-oxidizing bacteria are widely distributed in nature.
As reported in the literature, numerous bacteria such as *Pseudomonas*, *Acinetobacter*, *Flavobacterium*, *Corynebacterium* and *Arthrobacter* are able to make use of aromatic and aliphatic hydrocarbons as carbon and energy sources. Nevertheless most of the studies on the biodegradation of these compounds were carried out on *Pseudomonas putida*, *Pseudomonas beijerinkia* and *Nocardia* [1].
The microorganisms have to come into contact with the carbon source (hydrocarbons) due to the low solubility of hydrocarbons in water as well as to the fact that the first biodegradation

step implicates an oxygenase tied to the cell membrane [2].
Therefore two common biological strategies are found which increase contact between microorganism and water-insoluble hydrocarbons: the first one makes use of specific mechanisms which implicate a link between hydrocarbons and a specific receptor placed on the cell membrane; in the second one, microorganisms produce surface-active substances, called bioemulsifiers or surfactants, which do not degrade the contaminants but may increase their mobility and bioavailability. These strategies can be accomplished by indigenous microorganisms only if they are members of an heterogeneous consortium able to degrade the pollutant [3].
The aim of the present study was to identify indigenous microbial species from an agricultural soil in order to determine the main microorganisms capable of biodegrading, in aerobic condition, two different aromatic hydrocarbon mixtures. This biodegradative capability was related both to the chemical-physical characteristics of the solid matrix and to environmental conditions (temperature, degree of humidity, pH) in a lab-scale reactor.

2 Materials and Methods

2.1 Pilot Plant

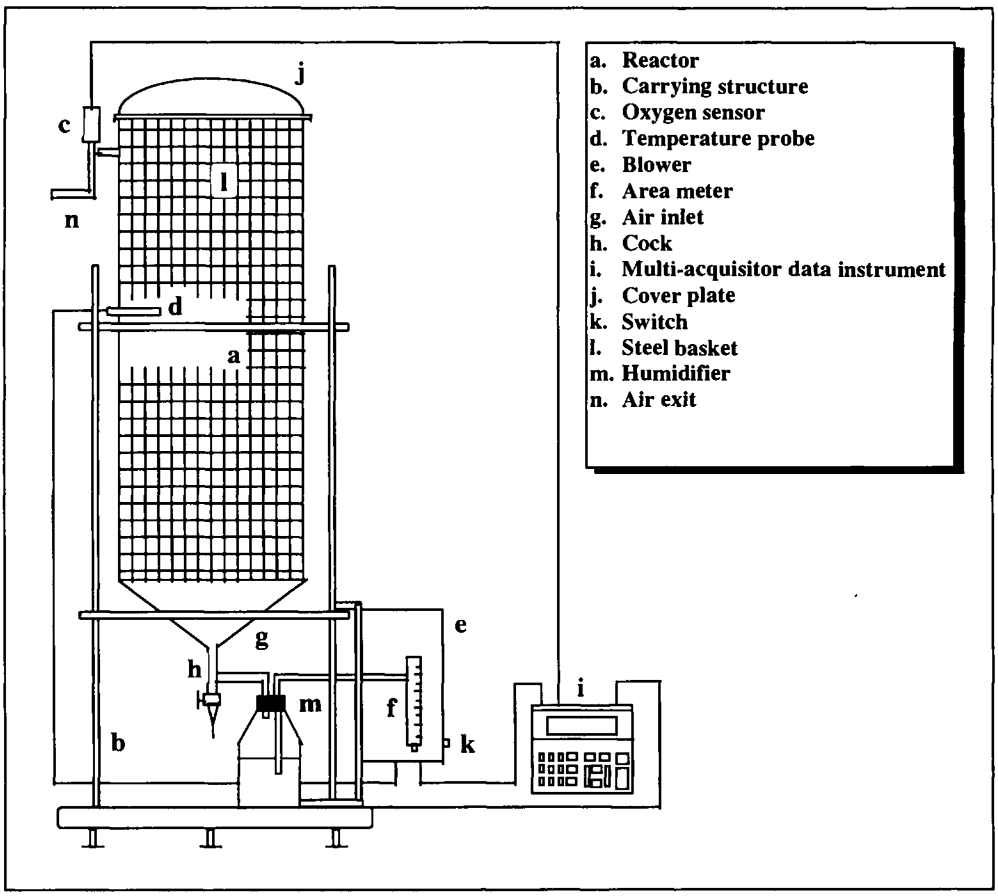

Figure 1: *Experimental Apparatus*

The plant comprised a plexiglass cylindrical reactor 70 cm high whose internal diameter was

20 cm. The reactor had a cover plate and three emery sleeves which permitted the air to exit on the top part, a stainless steel basket which held a temperature probe in the middle part and aeration by means of a blower at the toot of the reactor. The air was blown upwards into the reactor to obtain aerobic conditions inside the pilot plant.

The reactor was covered with a black isolating material to prevent photosynthesis.

The pilot plant was furnished with a multi-acquisition data instrument (mod. Babuc/A of the Industrial Facilities Laboratory) which permitted the registration of the temperature values and the oxygen concentration in the gaseous flow emitted from the reactor as well as the registration of the blower working time.

2.2 Chemical-physical Analysis

The soil sample was characterized by the following analyses: pH, humidity, TOC (Total Organic Carbon), COD (Chemical Oxygen Demand), TKN (Total Kjeldahl Nitrogen), P_{tot} (total phosphorus) [4,5].

The samples drawn from the bioreactor were characterized by chemical-physical analysis: humidity degree, pollutants content. The latter value was determined by HPLC (High Precision Liquid Chromatography) analysis . The conditions for HPLC were as follows: column, Nova Pak® C18 (Waters) 3.9 mm i.d. x 150 mm; eluent, methanol/water/acetic acid/acetonitrile; flow rate, 1 ml/min; detector Photodiode Array 996 UV/VIS Detector; temperature 25 °C. The extraction of these compounds was done at 30° C in an ultrasound temperature bath with acetonitrile for about 30' [6].

2.3 Microbial Analysis

Microbial species identification

The following culture media were employed to evaluate both the total microflora in the soil and those microorganisms capable of degrading the tested compounds:

1. Plate Count Agar (PCA) to determine the total microflora in the soil;
2. Minimum Salt Medium (MSM; composition (g l^{-1}): 2.4 Na_2HPO_4; 2.0 KH_2PO_4; 0.1 NH_4NO_3; 0.01 $MgSO_4$ $7H_2O$ pH 6.9) added to 10 ml micro-elements solution (stock solution (mg l^{-1}): 200 $CaSO_4$; 200 $FeSO_4$ 7 H_2O; 20 $MnSO_4$ H_2O; 10 $NaMoO_4$ 2 H_2O; 20 $CuSO_4$; 5 H_3BO_3) and 107.1 mg l^{-1} (in the first experimental run) and 138.5 mg l^{-1} (in the second run) hydrocarbon mixture. To the minimum salt medium 0.1 g l^{-1} cicloeximide was added to inhibit fungal growth.

The microbial species were identified by means of the following API tests (bioMérieux): API 20NE to identify non-enteric Gram negative rods; API 20E to identify enterobacteriaceae and other Gram negative rods, and API CHB to identify microbial Gram positive strains belonging to Bacillus genus.

Moreover, the microbial species were observed through an optical microscope in order to determine both the morphology of the microorganisms (rods, cocci) and the presence of spores.

Microbial count

Microbial counts were determined both in the agricultural soil and in samples drawn from the bioreactor at regular time intervals.

Three gram of soil were suspended in 30 ml phosphate buffer (25 mM) and were stirred for about 45' at room temperature. After sedimentation, 10 ml supernatant were drawn and serial dilutions 1:10 were done. One hundred microliters of each dilution were spread out on the cultural medium surface and incubated for about 72 h at 22 °C.

3 Experimental Study

A soil drawn from an agricultural factory where pesticides and artificial fertilizers were not used, was utilized as the solid matrix.
The chemical-physical characterization of this uncontaminated sample was done only during the first run, because of the short time elapsed between the two essays (Table 1).

Table 1: *Chemical-physical Characterization of the Agricultural Soil*

TOC (g/kg*)	15.16
COD (g/kg*)	15
TKN (g/kg*)	1.25
Phosphorus (g/kg*)	0.2
Humidity (%)	15
pH	6.3

* dry weight

Microbiological tests were accomplished in both experimental runs in order to study the total microflora as well as the biodiversity beginning from time t = 0 (uncontaminated sample) (Tables 2 and 3).

Table 2: *Microbiological Characterization of the Agricultural Soil (first run)*

CFU*/g	PCA	$340 \cdot 10^4$
CFU*/g	MSM + hydrocarbon mixture	$7 \cdot 10^4$
Microbial species	PCA	*Pseudomonas fluorescens, Pseudomonas spp., Pseudomonas chlororaphis, Pseudomonas aureofaciens, Sphingomonas paucimobilis, Xanthomonas*
Microbial species	MSM + hydrocarbon mixture	*Pseudomonas spp., Flavobacterium oryzihabitans,* Gram$^+$ Cocci and rods

* CFU = colonies forming units

Table 3: *Microbiological Characterization of the Agricultural Soil (second run)*

CFU/g	PCA	$800 \cdot 10^4$
CFU/g	MSM + hydrocarbon mixture	$3 \cdot 10^4$
Microbial species	PCA	*Pseudomonas fluorescens, Flavobacterium oryzihabitans Pseudomonas spp, Bacillus subtilis, Bacillus megaterium*
Microbial species	MSM + hydrocarbons mixture	*Flavobacterium oryzihabitans, Pseudomonas fluorescens, Sphingomonas paucimobilis, Bacillus megaterium,* Gram$^+$ Cocci and rods

* CFU = colonies forming units

Tables 2 and 3 show that the soil sample placed on the minimum salt medium containing the hydrocarbons mixture led to the isolation of Gram positive rods and cocci. Because of failure in identifying Gram positive species by means of biochemical tests, they were identified morphologically only.

3.1 Operating Methods

First experimental run

24.2 kg of soil were put into the reactor, at a density of approximately 1.3 t m^{-3}. The soil was contaminated by means of micro-injections of 2.5 g l^{-1} hydrocarbons mixture having the following composition:

- phenol 700 mg l^{-1};
- p-nitrophenol 579 mg l^{-1};
- pyrocatechol 609 mg l^{-1};
- orthocresol 643 mg l^{-1}.

The starting pollutants concentration was 235.3 mg/kg$_{dry\ soil}$ and the humidity was 21.4%. The starting concentration of each phenolic compound in the soil is shown in table 4.

Table 4: *Pollutant Concentration in the Soil*

Pollutant	Concentration (mg/Kg$_{dry\ soil}$)
Phenol	65.1
Pyrocatechol	56.6
o-Cresol	59.8
p-Nitrophenol	53.8

The aeration of the reactor was held continuously with a constant flow (1 l min^{-1}) of damp air. During the experimental run the temperature inside the reactor was 20±1 °C. The soil in the reactor was sampled at regular time intervals by extracting a core sample of the same height of the soil in the reactor with a diameter of 3.2 cm.

Second experimental run

20 kg of soil were inserted into the reactor, as a density of approximately 1.23 t m^{-3}. The soil was contaminated by micro-injections of 2.5 g l^{-1} hydrocarbons mixture having the following composition:

- phenol 1248 mg l^{-1};
- p-nitrophenol 1253 mg l^{-1};

The starting pollutants concentration was 277.5 mg/kg$_{dry\ soil}$ and the humidity was 24.1%. The starting concentration of each phenolic compound in the soil is shown in table 5.

Table 5: *Pollutant Concentration in the Soil*

Pollutant	Concentration (mg/Kg$_{dry\ soil}$)
Phenol	138,5
p-Nitrophenol	139

The aeration of the reactor was intermittent (14 hours per day) to limit volatilization of the pollutants as much as possible. During the experimental run the temperature inside the reactor was 20±1 °C

4 Results and Discussion

4.1 First Experimental Run

Figure 2 shows the p-nitrophenol concentration trend in the soil.
During the first 12 days the p-nitrophenol concentration decreased (6.61 mg/kg$_{dry\ soil}$) showing a removal of about 88 %. The pyrocatechol, phenol and o-cresol concentrations were below detection limits. After 26 days the experimental run was stopped because p-nitrophenol concentration were below detection limits.
The p-nitrophenol biodegradability curve was interpreted by means of a first order kinetics, obtaining the following values:

- kinetics constant k (g^{-1}) = 0.108;
- correlation coefficient $\rho = 0.901$.

Only in the case of p-nitrophenol it was possible to determine the biodegradation curve because this compound is not oxidized by the laccase enzyme and does not react with humic compounds in the soil [7].
Phenol and o-cresol are both readily biodegradable compounds; it is also possible, during the experimental run, that a fast enzymatic cleavage of the aromatic ring or the incorporation of these substances in the humic compounds of the soil occurred [7, 8, 9]. Pyrocatechol can be oxidized by iron, manganese and copper oxides which catalyze the reaction, causing secondary compounds to be formed which may react with natural substances in the soil or may be used by indigenous microbial species [10].

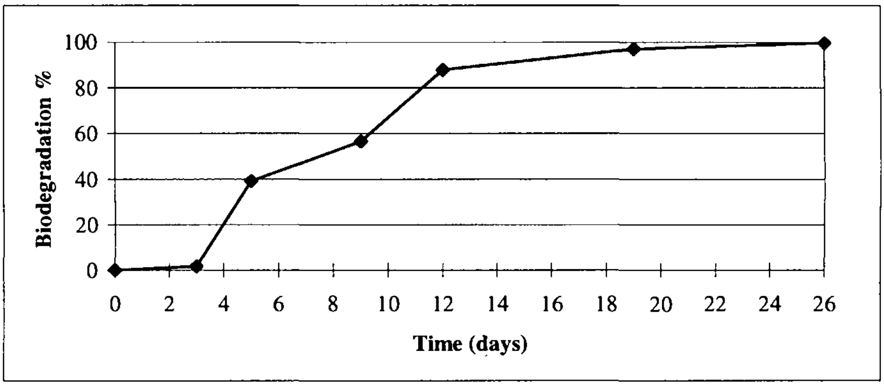

Figure 2: *p-nitrphenol Biodegradation Trend (first run)*

The most plausible hypothesis is that the above mentioned compounds disappeared from the solid matrix due to the microbial activity; in fact figure 3 shows the microbial growth curve both on PCA, and on MSM plus hydrocarbons mixture, as the only carbon and energy source. On PCA the colonies forming units (CFU) were about ten times greater (40 10^6) compared to the growth on uncontaminated soil (3.4 10^6), while on MSM plus hydrocarbons mixture the biomass, capable of metabolizing the pollutants, they were about thirty times greater (270 10^4) than those observed in the same uncontaminated sample (7 10^4).
Moreover, the microbial species placed on MSM plus hydrocarbons mixture were able to clarify the cultural medium that, at the beginning, resulted yellow colored. Therefore, these microorganisms are able to take up the aromatic hydrocarbons as the only source of carbon and energy.
After an acclimatization time of about five days, microbial species such as *Pseudomonas aureofaciens, Chriseomonas luteola, Xanthomonas* and *Flavobacterium oryzihabitans* were

identified on PCA. On MSM containing the hydrocarbons mixture the Gram$^+$ species grew prevalently, while on PCA Gram$^+$ and Gram$^-$ species grew indifferently.
Other studies reported in the recent literature show that the same above mentioned microorganisms are capable of degrading aromatic hydrocarbons [11, 12, 13, 14].

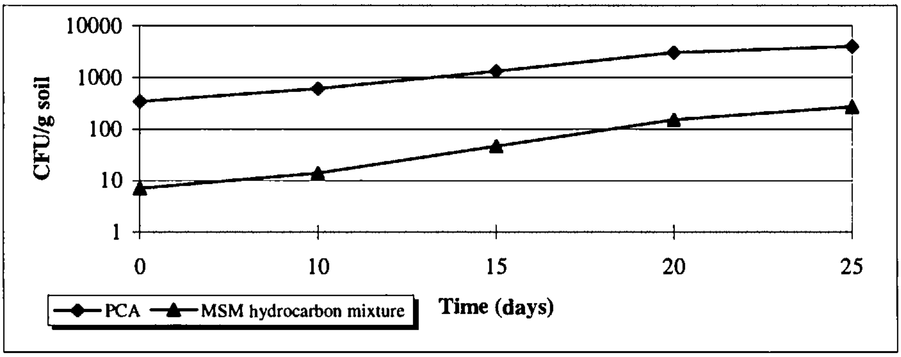

Figure 3: *CFU Trend (first run)*

4.2 Second Experimental Run

In this experimental run the co-oxidation of the readily biodegradable phenol and the slowly biodegradable p-nitrophenol was simulated. Neither the pyrocatechol nor the o-cresol were used, because of their fast disappearance time.
On the second day the phenol concentration in the solid matrix was below detection limits.
Figure 4 shows a progressive p-nitrophenol concentration disappearance until the eighteenth day with a biodegradation value of about 98.1 %. The essay was stopped after 18 days when p-nitrophenol was not detected.
The p-nitrophenol biodegradability curve was interpreted by means of a first order kinetics, obtaining the following values:

- kinetics constant k (g^{-1}) = 0.124;
- correlation coefficient ρ = 0.966.

The most valid supposition, as in the first experimental run, is that the above mentioned compounds disappeared from the solid matrix owing to microbial phenomena; in fact figure 5 shows a microbial growth curve both on PCA and on MSM plus hydrocarbons mixture as the only carbon and energy source. On PCA, the CFU was about 10 times greater (98 10^6) in comparison to the growth on the uncontaminated soil (8 10^6), while on MSM plus hydrocarbons mixture the CFU were about 200 fold higher (7.5 10^6) then those recorded in the same uncontaminated sample (3 10^4).
After 4 days from the beginning of the essay the microbial species grown on PCA were resulted *Pseudomonas* spp and *Flavobacterium oryzihabitans*, while among Gram$^+$ strains (not verified by biochemical identification), *Pseudomonas fluorescens* and *Flavobacterium oryzihabitans* species were isolated on MSM containing the hydrocarbons [15].
In the second sampling *Pseudomonas fluorescens* and *Pseudomonas spp.* were identified on PCA cultural medium while *Sphingomonas paucimobilis, Flavobacterium oryzihabitants* and other microbial species, not biochemically identified, were isolated on MSM plus hydrocarbons mixture.
Bacillus subtilis and *Bacillus megaterium* were the main microbial species selected both on PCA and on MSM plus hydrocarbons mixture in the last two samples, while species such as *Flavobacterium oryzihabitants, Sphingomonas paucimobilis* and *Pseudomonas fluorescens* were not identified anymore.

Studies reported in the literature show that *Bacillus subtilis and Bacillus megaterium* are capable of degrading aromatic hydrocarbons by means of biosurfactant production [16, 17, 18, 19].

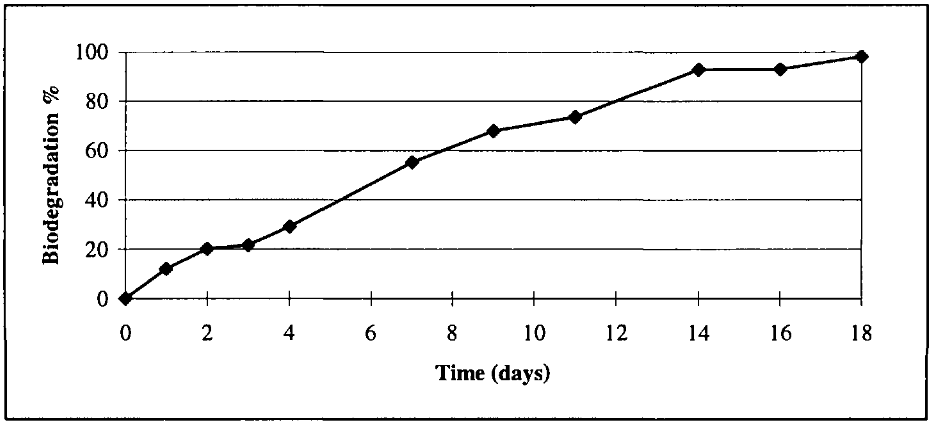

Figure 4: *p-nitrphenol Biodegradation Trend (second run)*

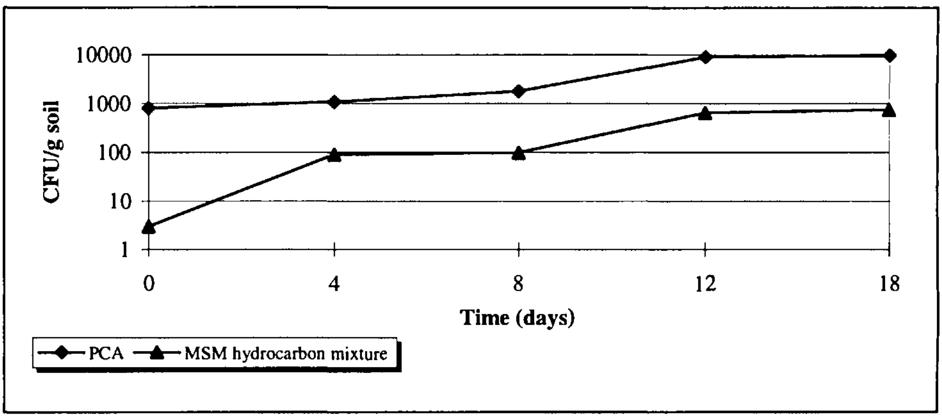

Figure 5: *CFU Trend (second run)*

5 Conclusions

The microbiological results showed that the biomass from an agricultural soil is capable of degrading aromatic hydrocarbons.

The microbial species capable of degrading the tested compounds were increased in number. In fact, the Gram positive species were selected on MSM plus hydrocarbons mixture; numerous species belonging to *Bacillus* genus (*Bacillus megaterium* and *Bacillus subtilis)* and other microbial Gram negative species belonging to *Flavobacterium* genus and *Pseudomonas fluorescens* and *Sphingomonas paucimobilis* strains were identified. The second run showed that the microbial species belonging to *Bacillus* genus were the main isolated microorganisms.

As regards to the phenolic compounds biodegradability in aerobic conditions, the results confirmed that the nitro-substituted compounds are more resistant than phenol [20]. Moreover, previous studies showed that p-nitrophenol concentration in a autoclaved soil and in aerobic conditions was not changed significatively by time [21].

The high correlation coefficient values showed that the studied phenomena may be interpreted by means of a first order kinetics.

This work shows that a preliminary study of the microbial biodiversity and of the limiting factors in a particular site must be the first step in a bioremediation approach.

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LANDSLIDE CONTROL: A SUMMARY OF SUGGESTIONS FOR ENGINEERING CODE WRITERS

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Abstract

Landslides affect large portions of the territory and their occurrence can be a non negligible factor altering the environment and limiting the sustainable development. However, the circumstances governing local geotechnical situations are extremely variable and great difficulty persists in predicting the performance of mechanically complex large bodies of natural materials when the predictions are based on a limited amount of uncertain data. Besides the great number of specific fundamental contributions due to the geotechnical community, it seems that no attempt has been so far successfully accomplished to set up rules for a sound engineering code of practice on the subject. The target could be reached with a step-by-step approach starting from a few general objective concepts. The Authors propose a list of topics which may help in identifying the main objective factors which should be considered in a set of guidelines for engineers dealing with slope stability problems.

1 Introduction

The performance of civil engineering structures is largely governed by environmental boundary conditions, among which the ground supporting the structures is of paramount importance. Natural slopes are very sensible to the transformations that may occur as a result of building activity on the surface and underground; the mechanical interaction between ground and structures results inevitably in movements and these are typically time dependent. Under certain mechanical conditions of the soils and rocks involved, the displacements do not extinguish, but rather increase more or less rapidly with time, to the point that a critical event of failure, that is a slide, may occur.
The social and economic impact of landslides throughout the world highlights the importance of the problem; in recent years, there is a growing request to provide increased level of protection against natural disasters through *prediction*, *prevention* or *mitigation*. In this context, landslide hazard assessment [1] has received increased attention by the scientific

community and the general public. Evaluation of associated risk, i.e. expected loss of life and damage to properties, public utilities and economic activities due to a potential landslide is a fundamental step of landslide hazard assessment. Quantitative risk assessment is still rare due to the need of using complex models, to evaluate the recurrence of triggering factors on a regional scale, and the difficulty of an interdisciplinary approach including geology, geomorphology, geotechnics, monitoring. Unlike hazard and risk assessments which are relative or qualitative, geotechnical engineering predictions with the goal of preventing or mitigating slope movements must be quantitative and referred to a specific slope performance.

A code is a set of rules or regulations which are accepted by a community, class or group; an engineering code of practice should contain the criteria for design, obtained from theory or practice, which are recommended to obtain a product fulfilling given requisites. In recent years, there is a growing request for common international codes of practice. This results partly from the increased objective need for protection against natural disasters and partly from a growth of environmental awareness, but also from the search of common principles for design in countries which have established political or economical links (such as, for instance, European Countries) and from the need of common rules in the construction industry.

The European Code EC7, Section 9: Embankment and Slopes, and the latest draft version of the Italian Geotechnical Code of Practice, Section G: Stability of Natural Slopes and Cuts are recent examples of attempts to set up a set of guidelines for engineers. Both documents start with a brief section outlining the "scope" of the document. For the EC7 this is open to embankments and slopes, even though no distinction is made between natural and slopes and cuts; dikes and dams are explicitly excluded. In the Italian draft code, the scope of the guidelines is restricted to natural slopes and artificial cuts. Both documents take into consideration ultimate and serviceability limit states under various actions and in different design situations. They stress the importance of the recourse to experience and the need of monitoring even though the attempt of dealing with both natural slopes and embankments is a serious limit of the European Code in the present issue.

The aims of the present Symposium are not specialistic. In this context, it would not be appropriate to discuss in detail every aspect of a code of practice for engineering decisions in the field of slope stability. It seems useful, however, to identify a list of items which may be helpful in identifying the important factors that need consideration in tackling the problem from an engineering standpoint. The main topics are listed in a more or less logical sequence as encountered by the designer during the design process. Some of the proposed topics are, or should be, relatively obvious or self-evident; therefore, it is surprising to find how often they are ignored or contradicted in practice.

2 List of Topics

Approach : An unified cultural approach comprehensive of the contributions offered by different disciplines susceptible to tackle the complexities of a slope stability problem is advisable. The different contributions should be conceived as different *components* in the *geotechnical design process.* The main components are historical, topographical, geological, hydrological, seismic, climatic, territorial, environmental, and computational.

Geotechnical investigations, computations, checks and monitoring should be developed harmonically and be proportionate to the importance of the problem, to the state-of-the-art of the design research and to the degree of complexity of the subsoil. The compatibility of the design with all other non geotechnical design components (architectural, structural, hydraulic) should be verified during the process to define unitarily every design aspect.

A cultural approach demonstrating awareness of the complexity of the problem and of the uncertainties that are going to be faced is strongly recommended.

Slopes: Situations where landslides have been ascertained and situations where landslides are only envisaged require different design approaches. Moreover, landslides in natural slopes should be dealt with differently from slides induced in artificial cuts or in earth fills. Natural slopes, as distinct from artificial slopes, either earth-fills or cuts, may have reached their present shape in different manners. They may result from the long-term action of processes which are still active, or a set of processes may have acted for a relatively short time, while successively less active processes may be still acting on the slope. The reasons for dealing differently with natural and artificial slopes are multifold and relate to the volume of the slide, to the geotechnical characterisation, to the required values of the factors of safety, to the remedial measures that may have to be implemented.

Experience on small slides cannot easily and promptly transferred to large landslides, as the mechanics of large landslides is presumably altered by unknown scale factors.

The stability analysis of an intact slope requires an approach that is different from that deemed appropriate in areas affected by previous landslides.

Investigations : Geotechnical investigations are an essential part of the design activity and should be specified and supervised by the designer or by geotechnical engineers under controlled and repeatable conditions, with the assistance of qualified personnel, within a reasonably extended technical time scale.

Geotechnical site investigations should be planned taking into due consideration the geometry of the slope identified on updated maps and preliminary information on the geology of the site, accounting for the worst credible localisation of the sliding surface. Geological and geotechnical profiles of the subsoil should be obtained both within and outside the unstable area, as they can give useful hints on the location and geometry of the slip surface.

Localisation of the slip surface is probably the most difficult and critical step of the site investigation. This aim can be achieved by indirect methods, by measurements of surface and subsurface displacements, or by direct logging of faces and cores. Joints of the geological formations and weak layers should be adequately described.

Geomorphologic studies and investigations aiming at ascertaining whether the landslide originates from a re-mobilisation or is the result of a first time movement, are also very important.

Adequate geotechnical instruments to measure pore water pressures and displacements should be installed at the site.

Whenever possible, a critical review of the former performance of the slope from historical documents should be included in the investigation programme.

Laboratory investigations should include conventional tests on undisturbed samples, with special attention to the assessment of peak and residual strength. Experiments on joints, in the centrifuge or electrochemical testing are exceptional.

Actions : Triggering actions (loads, cuts, reservoirs, rivers, rainfall, earthquakes, water table, etc.) and their temporal combination should be carefully considered. In general, it is difficult to identify a single cause of instability; this results from a combination of factors, which can be classified as: ground conditions, geomorphological processes, physical processes, and man-made processes [2]. Any factor may have a preparatory or triggering function. Be aware that responses of the slope to actions is rarely instantaneous; in general, the response is more or less delayed, according to the properties of the soils or rocks involved.

Interactions : Interactions of ground movements (actual, potential) with natural obstacles, such as rivers, valleys, hills, etc. and with artificial objects such as buildings, highways, tunnels, pipelines, etc., should be carefully considered and analysed. Obstruction of a valley resulting in a lake formation with possible downstream disastrous consequences in case of overtopping should be given special attention. A rough estimate of the extension of the territory that presumably would be invaded by debris in case of landslide is advisable. The failure consequences of any type of interaction with natural obstacles and with engineering structures and infrastructures should be anticipated in the first design stages in different scenarios, taking into account the vulnerability of different parts of the territory.

Movements: Attention should be paid to the history of ground movements.

Beside special cases where the landslide may be caused by exceptional events (e.g.: earthquakes), it is generally the case that ground movements in a slope are exhibited in advance of failure. The measurement and control of *pre-failure* movements may be important in practice as it can give useful information for the prediction of failure. Generally, the rate of pre-failure displacements increases with time; a few days before failure the average rate of displacement may be of the order of a few hundreds to a few tenths of metre per day.

The magnitude and rate of movements *during failure* depend primarily on the mechanical properties of the sliding materials and on the inclination of the surface of rupture. For materials with very high values of fragility index (expressed as the ratio of peak shear strength to post-rupture shear strength) the initial acceleration of the displaced material can be very large. The rate of displacement during failure is generally rapid to extremely rapid; recorded values of rate of displacement during failure can be as high as a few tens of metres per second.

After failure, the shear strength along the surface of rupture may be very close to its residual value; in these conditions the factor of safety of the slope is close to unity and small variations of the external actions or of the pore water level may be sufficient to originate *post-failure* movements; these are generally extremely to very slow, or, exceptionally, slow.

In the areas where past slides may have occurred, very slow long-term deep seated creep movements have been reported.

Movement prediction can only be attempted on the basis of a thorough knowledge of the mechanical properties of soils and rocks involved in the landslide.

Mechanism: The identification of an existing or a potential failure mechanism is an essential step that is preliminary to the selection of the method of analysis. Other than the supine adoption of one of the several proposed classification criteria [3, 4, 5, 6], a detailed and competent description of the local situation is suggested.

According to the terminology proposed by Varnes [4], movements are described by the words *topplings, falls, slides* (translational or rotational), *lateral spreads*, and *flows*; a mechanism is called *complex* when it results from the combination of more than one of the elementary mechanisms listed above. It is also important to identify the *activity* of a slide in terms of its *state*, *distribution*, *style* and *stage*. The state of a slide can be: *active* (strictly active, suspended or reactivated), when it moved less than 1 year from the present time; *quiescent*, if the last movements happened more than a year from the present time; or *stabilised* (naturally, artificially or relict) if no further movements of the slope are envisaged under unchanged conditions. The distribution relates the location of the slide to its evolution in space; a slide can be *moving*, *retrogressing*, *advancing*, *widening*, *diminishing*, *enlarging* or *confined*. The repetition or combination of mechanisms within a slide are described by its style, which can be *single*, *complex*, *composite*, *successive*, and *multiple*. Finally, the degree of evolution of the phenomenon is identified by its stage, which can be *incipient*, *advanced*, *senile* and *extinguished*.

It is important not to forget to specify whether the mechanism is an actual or a potential one.

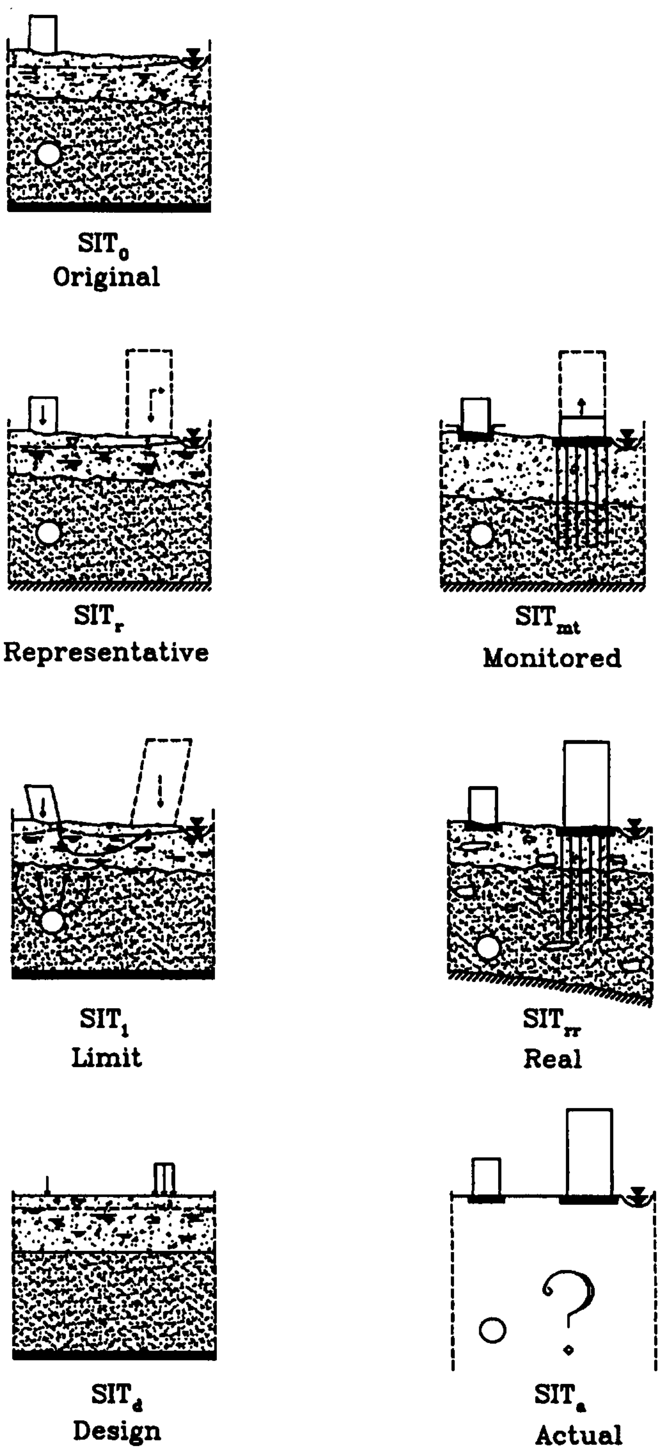

Figure 1: *Situations in the Design Process*

Requisites: Design analysis should be based on a preliminary assessment of the engineering requisites that are expected to be fulfilled during the operation of the slope. Requisites should be expressed either in terms of failure (ultimate limit state) or of displacements (service limit state) with due account of their time evolution. Requisites should take into account the rapidly transforming features of the territory and of the related building activity.
Situations: Different situations resulting from engineering predictions should be defined and sketched as follows (see Figure 1): (a) *original,* describing the territory with classes of selected parameters; (b) *representative,* resulting from an act of characterisation including actions and responses; (c) *limit,* showing the mechanism contemplated in scenarios of undesirable events; (d) d*esign*, introducing partial or global safety coefficients; (e) *monitored,* adjusting the parameters to the results obtained by monitoring; (f) *real,* described during construction by a *post mortem* prediction; and (g) *actual,* idealised.
Each situation is derived by the preceding in a logical sequence along the design process.
Analysis : The main purpose of a geotechnical analysis is the theoretical interrogation of the slope in order to ascertain its mechanical response to assigned classes of values of the actions and predict its performance under the presumable boundary conditions. The analysis includes interpretation of data; characterisation of the physical system; identification of failure mechanisms; modelling (physical or numerical); computation with the necessary numerical experiments; prediction of performance.
The analysis is referred to the design situation with the aim of demonstrating the effectiveness of the proposed stabilisation or remedial measures.
Model: An effort to conceive a slope model representing the results of the analysis is recommended. The different theoretical and experimental quantities with their ascertained or reasonably estimated range should be entered in the model. The model should be clearly and promptly readable and open to modifications supported by new data and information on performance during operation. The model should be capable of providing a consistent explanation of actual slope moments, if any, and a basis for the design of remedial measures.
Safety: The assessment of the safety of a slope should refer to the various configurations that the slope will assume in the different construction phases and in operation, under the expected actions in ordinary and exceptional conditions and for a reasonable design life.
Safety assessment requires a clear distinction between ultimate and service limit states.
An ultimate limit state represents an actual or an undesirable situation in which the slope is or is imagined on the verge of failure. This situation requires the introduction of an appropriate factor of safety. The value of the factor of safety should be assessed by the designer and justified by the degree of reliability of available data, complexity of the representative situations, local experience gained in comparable situations, and consequences of failure.
The class of service limit states reproduces the situations that can be still hardly accepted in operation with due account of the scenarios involving natural features and engineering constructions. In the operation of a slope it is often necessary to accept limit states with large residual displacement values.
Factors of safety must be defined relative to the limit state under examination; their numerical values must be justified with requirements of safety and economy.
Computations : The computation method should be appropriate to the design situation and its appropriateness well documented; it should take into account the structural features and the mechanical properties of the soils and rocks involved, the geometry of the potential sliding surface; it should be referred to reasonable and conservative assumptions on pore pressure distribution.
The common methods for slope stability analysis fall in the category of limit equilibrium methods. In any limit equilibrium method it is postulated that the slope may fail by a mass of soil sliding on a failure surface. It is conventional to introduce a factor of safety defined as the ratio of the shear strength available along the failure surface and the shear strength

required for stability or mobilised shear strength. In case of an ascertained landslide the computational model should be adjusted to the actual sliding surface as evidenced by site investigations. In other cases numerous different potential sliding surfaces shall be examined in order to identify the surface associated to the minimum value of the factor of safety. In a seismic zone, potentially triggering seismic actions should be considered in the computational method.

As a rule, stresses (total, neutral, effective) and displacements in different points in the slope can be computed using the finite element method of analysis. However, the recourse to finite element analyses is only recommended in exceptional situations. Examples are the analysis of the behaviour of large bodies of soil in states of stress far from failure, the evaluation of the stability of a slope under progressive failure, in which the assessment of the level of deformation in different areas of the surface of rupture is mandatory, and the prediction of the evolution of the displacements with time in slow movements. Sophisticated calculations, taking into account complex loadings, geometries, and soil conditions should not be substituted for careful geotechnical investigations. The risk is that of ignoring, overlooking or simplifying vital features of the slope, such as the location of joints or weak layers and of the surface of rupture or the regime of ground water pressures, that determine safety and performance of the slope, even if the calculations have been carried out considering a range of assumed values.

Even though not yet entered in the professional practice, the recourse to the concepts of statistics and probability in the definition of a safety factor is recently more and more recommended.

Design : Design activity related to slopes is a fully geotechnical design process including investigations, analyses, decisions, execution, checks, surveillance, maintenance. Therefore, design decisions should be inspired essentially by Soil and Rock Mechanics principles.

Design should be adequate to the reliability of the predictions that it is possible to develop within the time and cost limits imposed by the client. The risk associated with areas of uncertainty, which the designer should identify, should be taken in due account. Often, some of the uncertainties cannot be solved but during construction or operation. Therefore, steps of the design process should not be conceived as a conventional but rather as a *continuous design process* susceptible of modifications based on an observational approach extended to operation.

Uncertainties: As a rule slope stability problems are affected by a high degree of uncertainty. The main uncertainties arise because of: (a) the intrinsic difficulty of ascertaining the geometrical features of a landslide; (b) the aleatoric nature of possible triggering actions; (c) the limits imposed to any geotechnical investigation; (d) the prediction of the type and evolution of ground movements; (e) the lack of awareness of the need of an unconventional design approach; (f) the persisting ignorance of the mechanisms governing some types of ground movements. The design decisions should be taken in the awareness of such limitations that should be whenever possible identified and stated.

Strategies: Alternative strategies can be adopted when dealing with slope stability problems; they range from *avoidance*, *correction*, *desensitisation*, and *acceptance* [7]. In all cases where correction or remediation are pursued, different design strategies can be recognised: *conventional*, *observational* (at the design stage, best way out, progressive modification), *prescriptive*.

The observational procedure is a decisional process continuously supported and oriented by in situ observations and/or measurements. For an appropriate and rational application of the observational method one should: identify the main factors and corresponding parameters that significantly control the mechanical response and the safety of the slope, develop extensive numerical computations in order to search for the limit values of such parameters, demonstrate that an acceptable probability that the actual behaviour is comprised within the admissible values exists, predispose one or more alternative design solutions corresponding to the eventuality that the admissible values be attained or surpassed, prepare a full plan of monitoring susceptible to be put in action at the construction or operation stage with special concern for critical parameters [8]. When the level of uncertainty is exceptionally high, the observational method turns into a continuous design approach.

The best known strategy liable to success in controlling large landslides is the observational approach. The method should be applied as *best way out* or *progressive modification* and associated to a continuing design process extended to operation.

Measures : Decisions on stabilising measures should be taken after a reasonable evaluation of the risk, covering consequences of a failure, whenever the factor of safety resulting from the analysis is not sufficient to ensure a satisfactory performance of the slope in the representative situation. The geotechnical *function* of each proposed measure should be clearly stated to demonstrate that the proposed measures are effective for any ultimate or service limit state which can reasonably be foreseen in the geotechnical design situations. Note that the same measure may have more than one function: generally it is possible to recognise a *primary function* and a set of secondary functions.

Stabilisation measures should be fully described with reference to soil/rock properties and potential failure mechanisms. The choice should be documented and justified by recourse to the computation model adopted in the slope stability analysis. Design should cover details and construction sequence. Safety should be assessed for each step of the construction sequence.

Any stabilising measure is based on a physical principle that affects the factor of safety of the slope, either increasing the shear strength or reducing the mobilised shear strength along the slip surface. Experience shows that the most successful stabilisation methods are based on pore pressure control and/or load redistribution along the slope. Small slides in rocks can be stabilised with the installation of ground anchors. More sophisticated methods, based on soil treatment, or on the reduction of pore pressures by electro-osmosis or soil thermal treatment, are still seldom applicable.

In addition to the mentioned remedial measures it is also important to pay attention to land reclamation, reforestation, surface water drainage systems, etc.

Enforcement: Materials, technical details, equipment, construction sequence should be appropriate to the geotechnical situation and their control. Urgent remedies, provisional and temporary measures should be given great importance in view of the permanent provisions, with which they should be fully compatible.

Checks: Geotechnical checks should be systematically specified for different purposes, before, during and after construction, particularly in cases of high degrees of uncertainty. In situ and/or laboratory quality controls (*continuous, discontinuous, a posteriori*) during construction should be performed in accordance to a programme defined at the design stage and adapted to the real situation.

Measurements: The aims of in situ measurements are: (a) the provision of specific data in known unstable slopes; (b) the validation of design hypotheses; (c) the control of the permanency of the safety level during a construction process; (d) the adjustment of data entering the model; (e) the advance warning of movements for emergency or alert.

The main quantities that can be fruitfully observed belong to the two classes of surface and subsurface displacements and pore pressures. The frequency of monitoring should be carefully selected and related to the rate of evolution of the phenomenon.

Few simple and reliable are to be preferred to numerous and sophisticated automatic instruments. Instrument life is limited; the monitored situation should be periodically and critically reviewed.

Maintenance: It is essential that the aspect of maintenance of the slope be not overlooked. This may include: (a) flushing of tubular drainage pipes and cleaning of ditches; (b) maintenance of the effectiveness of the collection points for drained water; (c) cleaning of wells; (d) regular checks of the cleanness and of the rate of flow of the drained water; (e) ground profiling to facilitate water flow; (f) sealing of cracks; (g) maintenance and watering of vegetation; (h) maintenance of instruments; (i) frequent visual inspections.
Emergency: Advance warning of movements for emergency or alert may be provided by instrumentation installed on the slope. Emergency plans should include a sheet of prescriptive operating measures, a selection of instruments and, consequently, of critical parameters which are kept under observation (such as absolute displacements or rates of displacement, piezometric levels or rates of flow), and the definition of classes of alert based on threshold values of the monitored parameters. Often, it is not the absolute value of any particular parameter which defines the boundary between one class of alert and the following, but a critical combination of them. In the definition of the critical instruments and parameters to be kept under the interrogation of the model may help.
Competencies: Great confusion may arise from wrong attribution of qualifications in design involving a number of professionals belonging to quite different areas of knowledge. Each of these professionals should deal with his/her area of knowledge co-operating for the common goal. Roles of different operators (Designer, Client, Contractor, Consultants) should be clearly outlined.
Reports: Reports should be accompanied by the following documents: (a) factual reports such as results of site investigations, results of laboratory tests, results of computations, and specifications; (b) interpretative reports, such as geotechnical characterisation, proposed model of the slope, sheet of prescriptive operating measures and measurements.
Records: To refer to typical geotechnical situations with an adequate degree of confidence, local experience must be documented. To this purpose it is necessary that any available data on local soil/rock properties and on the performance of local slopes be quantified and turned objective. A systematic collection of case records on a regional scale is recommended.
Comprehensive information includes: (a)general description of the area (topography, geology, hydrology, geotechnics); (b) description of the landslide; (c) identification of soils and rocks involved; (d) identification of the prevailing mechanism; (e) stabilising method (load redistribution, pore pressure control, retaining structures, other); (f) performance of the slope before and after stabilisation (successes and failures).
Nomenclature: A non ambiguous nomenclature should be introduced for description and classification of the phenomena. *Crown, main scarp, top, head, minor scarp, main body, foot, tip, toe, surface of rupture, surface of separation, displaced material, depletion, accumulation, flank*, are some of the technical words adopted to describe the different parts of a sliding mass of soil, debris or rock. Quantitative description of the features of a slide should be expressed in terms of the *level* of characteristic points (crown, head, toe), *length* (total, mid-line, horizontal), *width* and *depth* (of the displaced material or of the surface of rupture), *slope, azimuth, area, volume* (initial and final).
The nomenclature adopted in the landslide classification proposed by Varnes [4] and modified by other Authors is still recommended.

3 Conclusions

The philosophy of current regulations is to treat geotechnical questions from a general methodological standpoint with the aim to draw the attention to the most important principles of design, investigation, verification, evaluation of the safety conditions, control of the ground-interface structures-superstructure unit. Accordingly, the prescriptions give the

maximum responsibility to the designer for the selection of design hypotheses and of the procedures for safety and performance predictions.
Attention is called on the necessity of extending investigations, evaluations and controls throughout the various phases of the construction and operation processes and of taking in due account the effects of the differences between forecasts and actual performance of the ground-structure system.
The need of a quasi-research *observational approach* is particularly evident in the field of slope stability, where the great variety of geotechnical situations and the complexity of the mechanical response of soil and rock masses to actions triggering landslides discourage the introduction of a rigid prescriptive code. As a matter of fact, in the experience of the Authors, in most cases, a conventional design approach is not successful. Rather, there is a need of flexible legislative and regulatory provisions which take into account the uncertainties inherent in the difficult topic, supporting a *continuous design process* oriented to solutions that safeguard the public safety and the environment without discouraging building activity and scientific advancement.

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NUCLEAR ENERGY AND THE ENVIRONMENT

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Abstract

Nuclear energy and its environmental aspects are described in this paper from publications of the International Atomic Energy Agency and other organization. Comparative environmental risks for various energy sources are considered and show the nuclear energy is cleanest energy at present and in future. The hybrid nuclear systems for energy production and long lived radioactive waste management are presented.

1 Introduction

The problem of energy source is one of the most important issue to solve by the mankind. Today the electricity energy is generating from following fuels: coal, oil, gas, water, atomic nuclei, traditional, and some sources called renewable energy (Fig. 1). All fuel chains within the electricity generation technology involve some health risks and environmental impacts. Carbon dioxide (CO_2) and other greenhouse gas emission to world atmosphere are most unexpected impacts *(See box in Fig.2)*. Taking into account the entire up-stream and down-stream energy chains for electricity generation the nuclear power emits 40 to 100 times less CO_2 than currently used fossil-fuel chains. Ultimately, the only way to restrain CO_2 emissions is to develop nuclear power or other alternative energies. Currently, the nuclear power provides about 17% of the world's electricity and avoids more than 8% of the worldwide CO_2 emissions.

2 Green Sides of Nuclear Energy [1,2]

In the energy field, nuclear applications carry significant environmental benefits, and they go beyond the clean production of electricity. Nuclear power may be viewed as the least

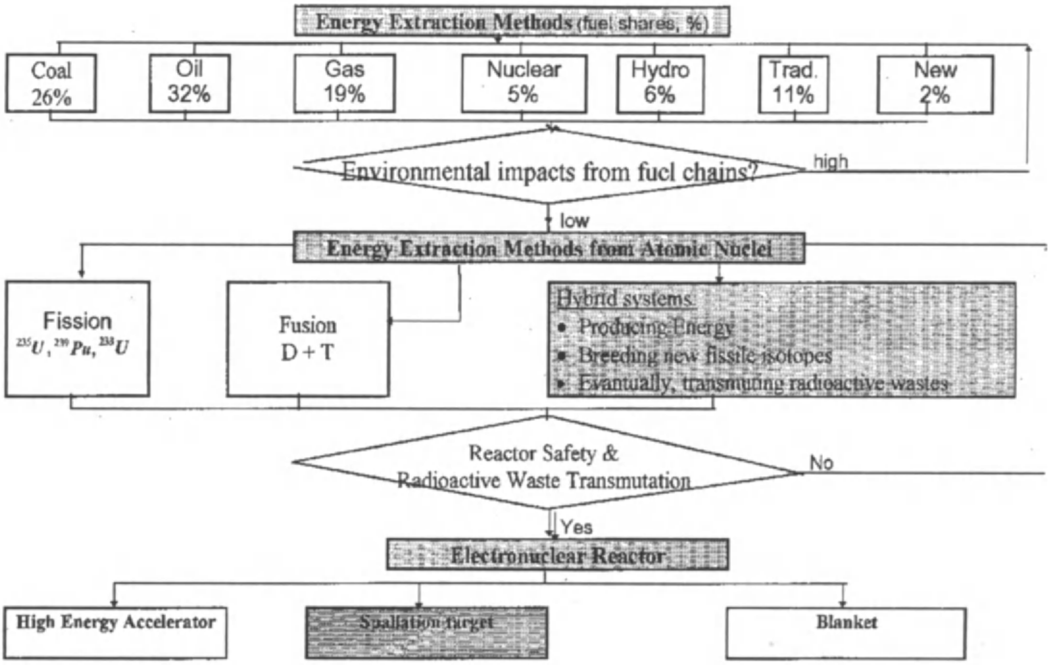
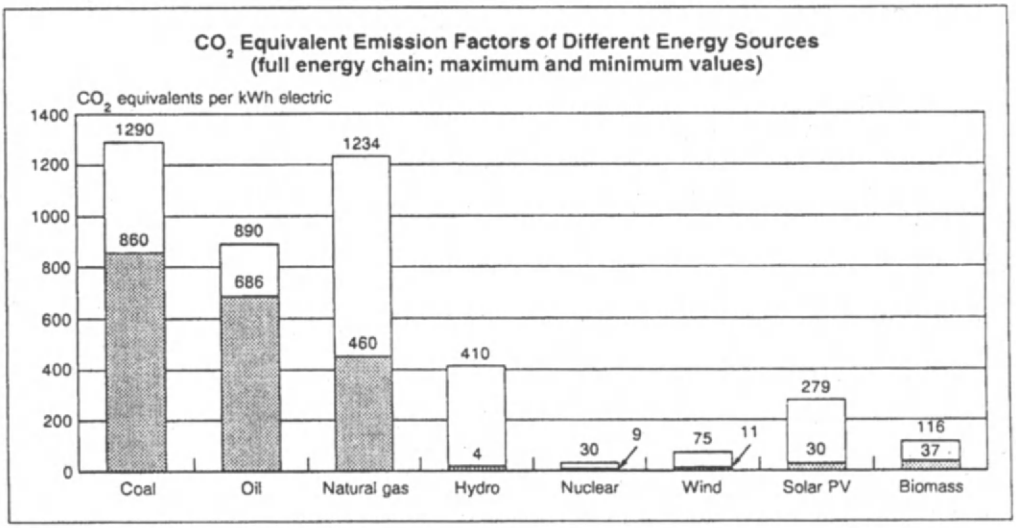
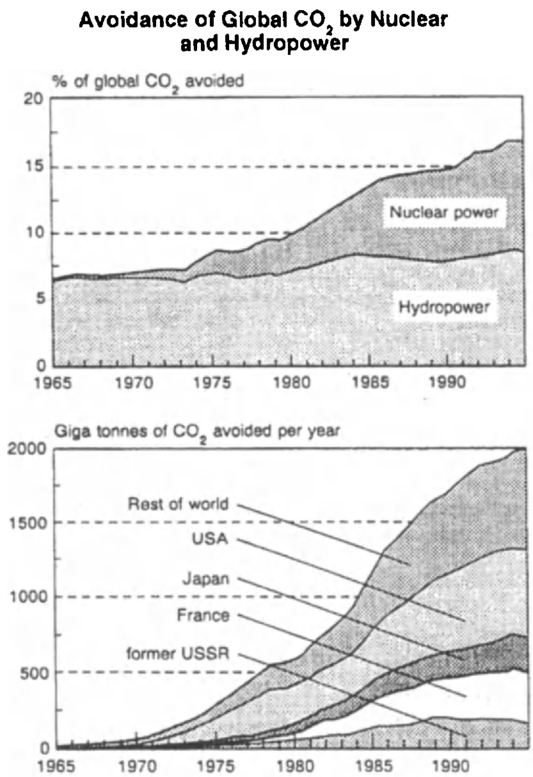


Figure1: *Block Diagram on the Significance of the Theme*

damaging, most emission-free of the realistic energy options. Nuclear power does not generate airborne emissions, and helps fight global air pollution. Indeed if the world's 437 nuclear power reactors were to be replaced by coal plants of equivalent capacity, some 2600 million tons of CO_2, and millions of tons of associated sulphur and nitrous oxides, would be added to the world's atmosphere each year. Using nuclear fuels, rather than burning fossil fuels, to power electricity plants may be part of the answer to the threat of global warming. Nuclear's role is already sizeable in helping countries to cut back or hold in check their emissions of CO_2 , a gas linked to global climate changes. Avoided CO_2 emissions are demonstrable greater in countries that have substantial nuclear shares in their electricity production-those like France, Sweden, Belgium, Spain, Switzerland, and the United States. In France, CO_2 emissions have been reduced by a factor of eight and sulphur dioxide emissions by a factor of ten between 1980 and 1993. During that time France's total electricity generation roughly doubled, owing mainly to the increase of nuclear's share in electricity generation from some 25% to more than 75%. Similarly, in Sweden, a drastic reduction of atmospheric emissions was obtained mainly by substituting nuclear power for oil and other fossil fuels for electricity generation. In the United States, if nuclear energy would not have been used between 1973 and 1994, some additional 1750 million metric tones of CO_2 would have been released in the atmosphere. Overall for industrialized countries of the OECD, it's been reported that nuclear power accounted for the greater part of the lowering of carbon intensity of the energy economies over the past 25 years.





Trends in CO_2 Emission Rates 1965-93

	Emission rate in 1993 (Pg/y)	Annual increase (Pg/y per year)	Percentage increase (%)
European Union	3.5	0.025	0.8
OECD countries	12.1	0.15	1.4
Non-OECD Europe	5.5 (1988)	0.11 (1965-88)	2.6 (1965-88)
Less developed countries	7.7	0.21	4.4
World	24.0	0.39	2.1

Trends in CO_2 emission rates vary regionally, reflecting differences in development of nuclear power programmes since the mid-1960s. Overall, nuclear power production has increased much faster than hydropower, and their present contributions to avoidance of CO_2 are nearly equal. Comparing the emission of all greenhouse gases from all energy sources reveals low emission factors for nuclear, hydro, and wind power. The top bar graph shows maximum and minimum values as compiled from studies conducted by the IAEA and other organizations. The low CO_2- equivalent emission factor for nuclear power is an international consensus value.

Source: British Petroleum Statistical Review of World Energy, 1995.

Figure 2

The developed countries shoulder most of the burden for the carbon dioxide problem under the current Framework Convention on Climate Change concluded in 1992. But even if there are few legal obligations on developing countries, their consumption of energy is increasing, and much of this energy comes from fossil fuels. Indeed, fossil fuels provide for about 90% of the world's total energy consumption, and Japan Institute of Energy Economics forecast shows [2] the volume of CO_2 emission in Asia will close to double by 2010. Reduction of

CO_2 emissions is therefore a global task, and one that developing countries will have to be involved in, too.

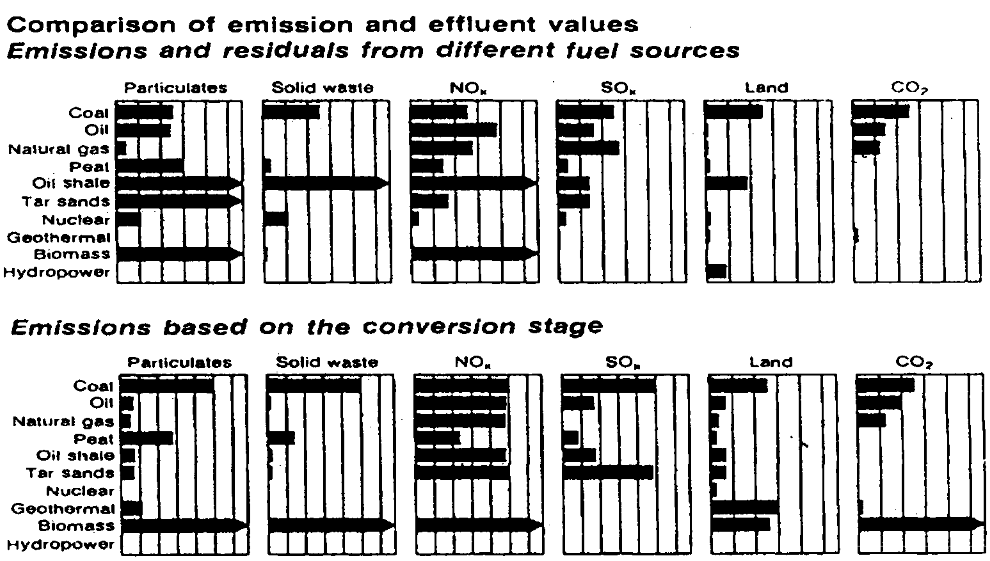
The issue in carbon dioxide is "joint implementation," or the question of how efficiently the world as a whole will be able to reduce CO_2 output. There are large costs involved in trying to reduce CO_2 emissions by say, 1 ton, in the developed countries, but it is extremely cheap to accomplish the same reduction in developing countries. It therefore makes sense to use funding and technology from the developed countries to reduce CO_2 output in the developing countries.

3 Comparison of Environmental Risks for Various Energy Sources [3]

Environmental effects are not susceptible to the same comparative treatment, from fuel cycle to fuel cycle, as health effects. The large number of target organisms, the fact that particular ecosystems rather than individual organisms, populations, or species are the relevant units, and the need to distinguish between the effects of different substances on the functions and structure of ecosystems, mean that direct numerical comparisons may be virtually impossible. So far, there is no agreed functional characteristic or structural characteristic which, if changed, could be used as a numerical measure to make effective camparisons. It is for this reason that suggestions for other means of comparison are made.

Assessment by ranking. The method allows general comparisons to be displayed. No attempt is made to give an overall measure of effect; rather, environmental impacts due to different perturbations from the various steps of the different fuel cycles are qualitatively presented in a matrix form. To some extent, this is a valuable feature of such representations because the differences in a single number are exposed rather than concealed.

Emission values and ambient quality indices. Emission and effluent values may be used to assess the potential impacts of various fuels and technologies. *(See graphs in Fig.3.)*



Notes: Graphs are not drawn to absolute scale. Carbon dioxide emissions for peat, oil shale, and tar sands have not been evaluated. In terms of mass, solid wastes from nuclear conversion cycle are three to four orders of magnitude less than those for coal.

Source: After "The Environmental Impacts of Production and Use of Energy", Part IV. United Nations Environment Programme, Rep. ERS-14-85, Nairobi (1985).

Figure 3

This aggregation of emissions highlights some interesting observations, including the fact that the total airborne emissions in terms of mass per unit of energy are almost identical for any of the fossil fuel energy groups (coal, oil, and gas), and that the SO_2 emissions are relatively high from the natural gas fuel cycle compared with other energy sources, with the exception of coal. The total CO_2 emission per one gigawatt-electric per year (GWe/y) for the entire fuel cycle of the fossil fuel group used for electricity generation is about two order of magnitude higher than the total CO_2 emitted from any other energy source fuel cycle. Within the fossil fuel group, total CO_2 emissions per 1 GWe/y (for entire fuel cycle) for coal burning electricity generation cycles are approximately twice those emitted for oil or gas.

The critical and target load approach. This approach uses critical or target load (or level) values, assigned to areas in a region and then compared with the actual deposition (or concentrations) of a pollutant. Excedence of the critical (or target) load by deposition, for example, can be taken as a quantitative measure of the impact or effect. This approach may be developed further. The outcome of various abatement strategies can be compared in terms of excedence. This could then be compared with excedence maps where other strategies have been simulated. *(See table. 1)*

Table 1: *Sulphur Emission With Implementation of Maximum Achievable Abatement by the Electricity Sector in Europe in the Year 2000*

Country	Unabated	Sulphur removed	%	Cost
Albania	200	64	32	23
Austria	186	68	37	90
Belgium	282	90	32	137
Bulgaria	1151	630	55	256
Czechoslovakia	1303	723	55	301
Denmark	193	121	63	192
Finland	203	36	18	119
France	697	130	19	354
German Dem. Rep.*	3224	2166	67	668
German Fed. Rep.*	1499	799	53	1214
Greece	523	396	76	255
Hungary	805	479	60	189
Ireland	100	55	55	74
Italy	1311	612	47	939
Luxembourg	18	0	0	0
Netherlands	210	65	31	117
Norway	71	1	1	3
Poland	2182	1006	46	618
Portugal	205	66	32	84
Romania	1322	725	55	325
Spain	2126	1556	73	600
Sweden	219	29	13	111
Switzerland	54	7	13	16
Turkey	1755	700	40	301
USSR	10890	6241	57	2075
UK	1765	974	55	1474
Yugoslavia	1891	1209	64	536
Total	34 385	18 948	55	11 068

Notes: Emissions are in thousand of tonnes. Costs are in millions of US dollars (1985).
Source: M.J. Chadwick, Stockholm Environment Institute (1990)
* These data were estimated before the unification of Germany in October 1990.

Integrated comparisons of environmental impacts. The lack of a well developed methodology for environmental comparisons of the impacts of various fuel cycles within the electricity generation energy system does not mean that no useful comparisons can be made. Furthermore, as data are collected a reliable methodology will emerge. Development of critical load excedence assessments, and the gradual recognition of dose-response relationships for these excedences, will enable progress towards quantitative comparisons to be made.

At present, emission values, or a combined index of these, allow qualitative comparisons. The scale of difference between emissions to the atmosphere ranging from fossil fuel use to solar technologies, and nuclear, is evident. Similarly, within a fuel category the scale of difference between fuels is quite evident. In the same manner, the excedence values allow ranking of impacts, and where a comprehensive attempt at this is made, the main thrust of impacts for various technologies is evident. For example, the potential global effects of fossil fuel use, through CO_2 emissions, are evident compared with other technologies, as are the potential regional impacts to the atmosphere. Such representation allows planners to focus on the main areas of concern.

4 A long-term Perspective of the Nuclear Energy [4]

Over the long-term, nuclear fuel resources and existing industrial infrastructures can support a broad deployment of nuclear power programmes in many countries. If the barriers to the implementation of nuclear power were alleviated, nuclear electricity generation could grow steadily from now on and throughout the next century. The long-term nuclear scenario developed by the IAEA in co-operation with the OECD/NEA for the IPCC illustrates this point.

This scenario was set up in the context of the global energy and electricity demand projections outlined in IPCC's Scientific Assessment Report chapter on energy supply mitigation options. It assumes that nuclear power would be deployed widely for alleviating the risk of global climate change and would penetrate the matket on grounds of its economic competitiveness. It implies that the present policy barriers to nuclear power deployment-such as maratoria on construction of new nuclear power plants and political decisions to ignore the nuclear option-will be progressively removed, and that nuclear projects in developing countries will be facilitated by enhanced technology adaptation and transfer, and financial support from development banks.

The assumption adopted for estimating the penetration rates of nuclear power in different regions reflect the need for diversity of supply and the availability and competitiveness of alternative options. The options include oil and gas in the Middle East and, in the long-term, biomass and other renewable sources. Potential uses of nuclear power for heat and hydrogen production have not been taken into account because of the uncertainties regarding the competitiveness of nuclear power for such applications.

By 2100 in this scenario, the share of nuclear power in total electricity generation would range from less than 20% in Africa, Australia and New Zealand, and the Middle East to 75% in Western Europe. The total installed nuclear capacity would grow from the present 340 GWe to some 3300 GWe in 2100 and nuclear power would provide 46% of the worldwide electricity consumption, as compared to 17% today.

The technical constrains taken into account in estimating potential nuclear capacity growth rates include construction lead times and industrial capabilities for building nuclear power plants and fuel cycle facilities. The availability of sites for nuclear installations, including radioactive waste repositories, was also considered by region, taking into account seismicity, cooling water requirements and need to build nuclear facilities in areas with relatively low population density. The availability of natural resources for nuclear fuel would not place any major constrain on the development of nuclear power, taking into account known uranium and thorium resources and expected technological progress in fissile material utilization. This scenario would require the deployment of breeder reactors by 2025 in order to support nuclear electricity generation over the period up to 2100 with the presently known uranium resources.

However, within that time frame, additional uranium resources would likely become available whenever necessary. Moreover, other type of nuclear power plants, such as thorium fuelled reactors, hybrid systems, and even fusion reactors, might be developed and commercially deployed.
The implementation of this nuclear scenario would allow reduction in CO_2 emissions worldwide by a factor of three as compared to the present level. A similar reduction would be feasible without nuclear power only if renewable energy sources, which have not yet reached the level of commercial development, would enter into the market early in the next century and would be deployed at very high rates throughout the next century.

5 Hybrid Nuclear Systems for Energy Production and Radioactive Waste Management

Carlo Rubia [5] recently made the headlined by proposing to use hybrid systems to produce energy. A hybrid system associates a high intensity proton or deuteron accelerator to a neutron multiplier assembly. Such systems might have a number of advantages when compared to standard fission reactors. If correctly designed, they would make critical accidents, such as that of Chernobyl, impossible. The number of neutrons available for breeding or waste transmutation is larger in hybrid systems than in fission reactors. Systems based on the Thorium-Uranium cycle, be they hybrids or traditional, would produce much less Plutonium and higher actinides than those based on the usual Uranium-Plutonium cycle. The interest in hybrid systems based on the Thorium-Uranium cycle originates, to a large degree, from the wish to make nuclear power more socially acceptable by reducing operating hazards as well as waste production.
Hybrid systems [5-13], generally aim at producing energy, breeding new fissile isotopes and, eventually, transmuting nuclear wastes. For transmutation applications, the value of the neutron flux is, also, of paramount importance. Indeed, the lifetime of a nucleus in a neutron flux is inversely proportional to the magnitude of this flux. As an example, nuclei with absorption cross-section of one barn, rather typical for fission products, would have a half-life of 200 days in a neutron flux of $10^{14}/cm^2/sec$. Such figures explain the high neutron flux values reaching $10^{16}/cm^2/sec$ involved in projects like that of C.D. Bowmann et al. [6] which give priority to waste transmutation and incineration. It is interesting to note that very high fluxes also allow a more efficient incineration of some actinides like ^{237}Np and ^{241}Am. It is also important that the breeding process at work with hybrid systems is of an electrical nature. An energy producing hybrid system, where the concentration of the fissile ^{233}U had reached its equilibrium value, could operate several similar systems with fresh ^{232}Th fuel. After a few months, these daughter systems would have built up enough ^{233}U concentration to become energy self-sufficient, and they would reach the final equilibrium ^{233}U value after around two years. Thus, such electro-breeding does not require the costly and potentially hazardous fuel reprocessing which is necessary for reactor breeding. With hybrid systems, if found necessary, it would be possible to rapidly switch to a Thorium-Uranium economy from the current Uranium-Plutonium one.

6 Conclusion

We are left, therefore, with the need for an increased use of fission power. However, it seems that a large increase in the number of fission reactors will face strong social opposition, due to the fear of major accidents (Chernobyl effect) as well as a deep concern about the treatment of nuclear wastes. In this context, it appears that the development of safer and less polluting means of using fission energy may be the key to the dilemna. Hybrid systems based on the Thorium-Uranium cycle are quite promising here. Although these concepts are not new [7-

13], it is true that they did not lead to large scale realizations. This was not a consequence of technical impossibilities, but of the lack of economic incentive.
Today, the situation is different, characterized by a reexamination of well-established nuclear policies like fuel recycling and fast neutron reactor breeding. Even if liquid metal fast breeder reactors face a difficult situation, it is clear that a large increase in the use of nuclear energy requires breeding systems. In this respect, hybrid systems are unbeatable. They would allow a fast move from a Uranium-Plutonium economy to a much less polluting Thorium-Uranium one. They might allow an advanced combustion of Thorium fuel without recycling. They could, also, allow the realization of intrinsically safer systems than those of current fission reactors.

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PROPERTIES OF UNSTABLE STRUCTURAL SOIL OF MONGOLIA

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Abstract

The Mongolian characteristic of the soil is uninterruptable continue of engineering- geolocal various events such as the soils deep freezing, permafrost for many years, high seismic level, location of collaption and swelling soils, many number of crumbles and rocks in the mountain area, the popularises of soil break off and removement. All these above mentioned aspects are influenced from the reason that Mongolia is laying in the changeable continental climate zone and on high level of Asian mainland.
In order to deside probems we made research work learned on Mongolian unstable structure soils.We developed and generelized all information on phisical-mechanical characters and stability of buildings of Mongolian soils withunstable structure. And made theoretical and practical conslutions.

1 Special Conditions of Soils of Mongolia

Specific condition of soil notably influences on the economy of Mongolia. For the purpose of keeping the nomadic of live of Mongols and consider the huge territory with a low density and a few number of population there is a big need of development of infrastructure, communication, transport and providing more efficient technical and technological research. There is potential need of increasing efficient development of complex geo-ecological research and taking the precautions from the devastation caused by seismic effects in the framework of the exploration works in mining field, creation of the cities and settlements, improvement of market supply and niche , pure water supply, confident of soil withstand.
The Mongolian characteristic of the soil is uninterruptable continue of engineering- geolocal various events such as the soils deep freezing, permafrost for many years, high seismic level, location of collaption and swelling soils, many number of crumbles and rocks in the mountain area, the popularises of soil break off and removement. All these above mentioned aspects are influenced from the reason that Mongolia is laying in the changeable continental climate zone and on high level of Asian mainland.

Much capital and labour resources are spent on earthworks of autoroads, railroads, mines,foundation of industrial and civil buildings. For instance, cost of bases and foundation of buildings on normal soil is usually 15 per cent of total construction works cost, labour cost- 10-20 per cent , concrete concumption-20-25 per cent, metal consumption-10 per cent, while the cost for permafrost, deep-freezing and higly heaving soil is 25-40 per cent of total construction cost. It is necessary to consider this fast when forming economic development strategy. Some explanations follow:

1.1 Permafrost

The permafrost areas are counted 15% of whole territory of Mongolia and 61,7 % of it is semi permafrost areas. About 25% of urban area or about 70 sumyn centres are situated on permafrosted soil, of which about 30 sumyn centres are located directly on permafrost.
Although the permafrost soil in Canada, USA and Russia are usually located continuosly, in Mongolia the situation is different- permafrost soil is spread loosly and mostly it is not very compact it is plastic , with low content of ice and higher temperature. Consider these specifics, caused by highly unstable nature of soil it is difficult to plan the construction, agriculture, water supplyng, mining and infrastructure.
Numereous buildings in Songino sum of Zavxan, Erdene sum of Gobi-Altai, Umnudelger of Hentei, Undurulaan and Tariat sums of Arhangai, Hatgal, Hanh sums of Huvsgul, Bayanbulag and Gurbanbulag sums of Bayanhongor were damaged due to the permafrost phenomenon. Therefore it is necessary to investigate permafrosted soil characteristics of Mongolia, and to apply the results in practice and industry.

1.2 Collapsive Soil

Easy collapsed soil under moisturizing effects is spread over the territory of Darkhan-Selenge, Bulgan and north of Tuv aimag of Mongolia. Buildigs in the centre of Bayanharaat farm of Selenge aimag, hospital with capacity of 30 persons in Jargalant farm of Tov aimag and Technical College in Darkhan all suffered from soil collapsion because no detailed exploration of collapsive soil had been made as well as no preventive engineering measures had been taken aganist damage. At present moment many buildings in Darkhan, Selenge, Khotol, Erdenet are being damaged and their repair causes ineffective expenditures. This caused loss of tens of millions tugrugs.

1.3 Swelling Soil.

Soil swelling under moisture effects is common for the south of mongolia: Choir, Sain Shand, Zuun Bayan and Zamiin Uud. Only in Sain Sand about 20 buildings -kindergarten, shool building, construction materials plant, shop and hotel caused much losses because of swelling soil effects. Soil in these regions is diagonally biased, it 's structure is unstable and swelling.

1.4 Deep-freezing and Heaving Soil

In Mongolia soil freezes very deeply (1.7-5.5 m) expands, sweels and causes and causes damage to construction, auto- and railroads, ets. The freezing and heaving soil are spread out in the territory of our country in the areas with contents of clay, sand and dust breakin rock. Nearly 23 per cent of urban areas are situated in the regions with higly heaving soil, and only in the capital constructions , in some central parts region Nogoonnuur, basens of river Selbe and Uliastai, Baynhoshuu, Songino, Gachuurt suffering construction deformation and damages. Frost heave tests performed under laboratory conditions and in site measurements . In Ulaanbaatar Frost heaving of soils 10-20 cm and force reaches 0,7-1,2 kg/cm2.

Soil freezing occurs both in seasonal and permafrost areas, covering geographically all territory of Mongolia. The resulting freezing and thawing effects are relevant to number of fields of activity such as agriculture, geology, hudrology and construction technology.

2 General Conclusion and Results

In order to deside these problems we made research work learned on Mongolian unstable sructure soils:

- We developed and generelized all information on properities Mongolian soils in spesial conditions with unstable structure and stability of buildings . Made theoretical and practical conclusions .
- Together with the defining of selection of construction princip in permafrost condition we have made scheme how to creafe optimal design of bases and foundation.
- We have prepared a recomendation on calculation of bearing capacity, during thawing of frozen soils and research the influence factors for settlement of thawing bases of buildings.
- We made laboretion research works do explore deformations, normal and tangent tension on frozen heave soils and determined their relation ship between freezing temperature and soil structure and drew theoretical and practical conclution.
- We have developed a new calculation method, mathematical pattern of frozen heaving normals and normative levels of tangent tension that influence on construction bases, underground structurs and size of frozen heaving of soil surface in Mongolian towns and settlements depending on climate and soil structure.
- Having a conclussion on experience of construction in loese soil which is doing additional frost heaving and study of buildings we have made a rersion of optimal design of bases and foundations and recommendation on construction technology. As well, we have elabrated a method of determination of negative force uring settlement of loese soil to the foundation of buildings.
- We have work out a research and recomendation on a possibility of using of sand pillow in frost heaving and setteing loese soils. On the base of own of own theretical and experimental research work for the geotechnical condition of Mongolia, the authors this report, have determined the heaving coefficient of the frost heaving ground. And using this coefficient of the frost heaving soils. And using this coefficient he worked out the new method for calculation of the size of lift of foundation on the sand pillow. Peculiarity of this method is that that the factors like a changing of effort distribution, stiffness of sand pillow and size of footprint of foundation taken in to consideration for determination of the size of frost heaving.

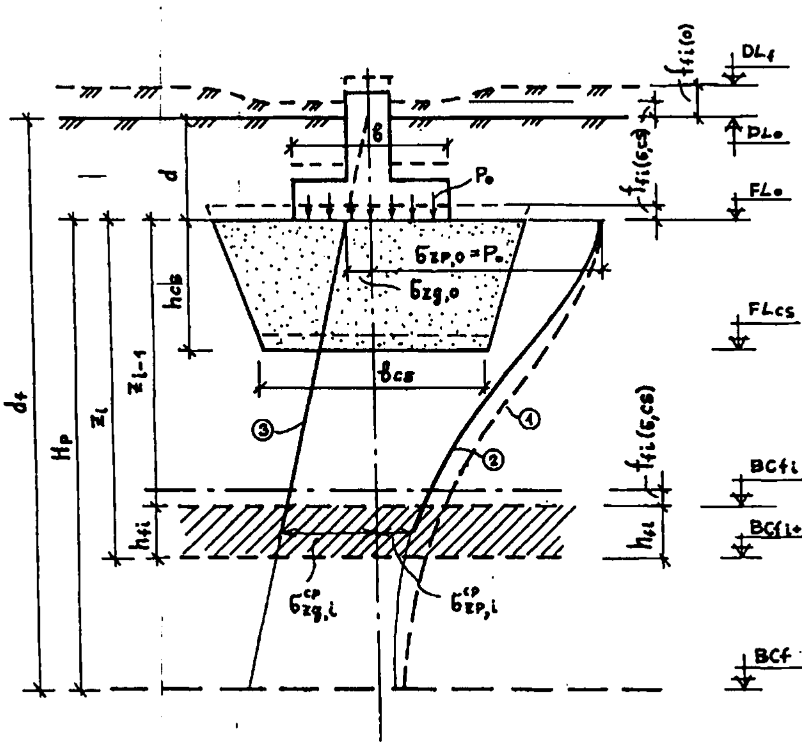

Figure 1 : *Scheme of Bases on the Sand Pillow*

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REHABILITATION AND DIRECT FIRING CONVERSION OF MONGOLIA COAL FIRED BOILERS

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Abstract

In October 1995 ABB CE SpA was awarded with the Order for the Rehabilitation of Power Plant No. 3 in Ulaanbaatar. The Scope of Work consists in the rehabilitation of No. 5 coal firing boilers having each a steam capacity of 220 t/h: conversion of the firing system from indirect to direct, new design of economizer and tubular air pre-heater and the replacement of other pressure parts (water wall and superheater). The Project is financed by a soft loan of ADB (Asian Development Bank). The first two units completed the rehabilitation and are in operation since spring 1998. The other units rehabilitation is in progress.

1 Existing Boiler Description

The power station N. 3 (called TES 3) is situated in Ulaan Bataar, Mongolia, and owned by CES (Central Energy System Government of Mongolia). The power station, whose construction dates back to the 70 'S (last unit completed in 1981), consist of a low pressure section (6x75 t/h boiler and 4x12 MW turbines) and an high pressure section (7 x 220 t/h boilers - 4 turbines of 25 MW each). The plant, designed and manufactured by former USSR companies, is used for power generation and district heating. The dependence of district heating by TES 3 boiler availability makes the power station strategic for the Mongolia country. The boilers subject to the rehabilitation (TES 3 HP section) are of balanced draft type, coal fired with opposite burners, natural circulation with single drum, water cooled furnace enclosure and top supported. The main steam flow of 220 t/h is superheated at 540 °C and 100 bar pressure while the feed water enters into economizer at 215° C temperature. The boiler configuration is shown in fig. 1. The furnace is a vertical water cooled enclosure with six burners arranged opposite on the two furnace sides. The three sections steam superheater is located in the upper horizontal gas pass and is equipped with a two stage desuperheaters. The two section economizer and the three sections tubular air heater are located in the second vertical down-flow gas pass. The combustion air is delivered to the air heater by two FD fans while the flue gases are aspirated by one ID fan located at the outlet of a four parallel section Venturi wet scrubber separator. The existing indirect firing system has the following characteristics:

- Two coal bunkers, from where the raw coal is fed to two screw type feeders and delivered to the two horizontal axis tube ball mill pulverizers.
- Hot primary air, partially tempered by cold air, is introduced at the mill inlet as drying and transport agent.
- Two classifiers, located externally at the top of power house building, separate the coarser coal, which return the mill, from finer coal.
- Two cyclone separator, also located externally, separate the conveying medium from the pulverized coal.
- Two pulverized coal bins store the coal dust separated by cyclones.
- Two fans suck the separated primary air and deliver the same to the pulverized coal feeders.
- The pulverized coal and primary air mixture flows through six coal pipes to the six burners.

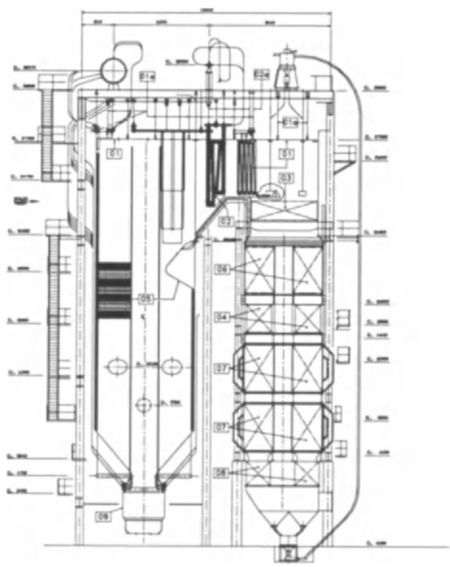


Figure 1

The boilers of TES 3 power station have been in operation for about 20 years with low utilization factor corresponding to an average yearly operation of about 4500 hours.
Despite the relatively low operating hours the boiler status before rehabilitation was extremely poor and characterized by very high deterioration. Availability and reliability data of the last two three years were peculiar of boilers approaching their life end, while complete subsystems were completely failed. The boilers status before rehabilitation can be summarized as follows:

- Capacity limited at about 65-75 % (170 t/h out of 220 in the best case).
- Extremely low efficiency (about 80%).
- High environmental impact (uncontrolled particulate and NOx emission)
- Furnace, pressure parts and air heaters highly deteriorated (superheaters damaged, partially over heated with materials at metallurgical end of life; Furnace with deformation and misalignment, corners openings and framing system damaged; Roof gas leakage as high as 30% of combustion gas; Refractory damaged or missing; air heaters infiltration as high as 100%.
- All main auxiliaries damaged (FD & ID fan at 70% of original performance and with major mechanical failures; sootblowing system no more operable).
- Instrumentation failed at about 80%

- Control system no more operating

The above situation was leading not only to very poor availability and reliability but also to poor operability and major safety and environmental risks. Moreover since 92 the fuel fired was changed from the original coal to a high volatile, high moisture, low rank sub-bitominous coal (called Baganuur) showing many lignitic characteristics. The new fuel led to increased explosion risk of high reactive fuel in indirect firing configuration and several explosions were experienced in the recent past.

2 Rehabilitation Project Analysis

The rehabilitation project started at the beginning of 1996 and it has been completed for two units in spring 1998. The main activities included in rehabilitation are given here below:

- Conversion to direct firing
- Partial pressure part replacement
- Milling / Drying system refurbishment
- Firing system replacement
- Instrumentation and control system upgrading

The scope of work of rehabilitation was selected in accordance to Central Energy System Specification. The extent of rehabilitation is limited due to the limited funds availability and in fact it is characterized by the minimization of intervention and by the conservation of existing main equipment. Nevertheless the rehabilitation goals and customer expectation were high requiring recovery of efficiency, availability, reliability, operational safety, environment quality, plant life. At the very beginning of the project an analysis of rehabilitation and an analysis of the technical risk involved was carried out, in two parallel directions, in order to answer two basic questions:

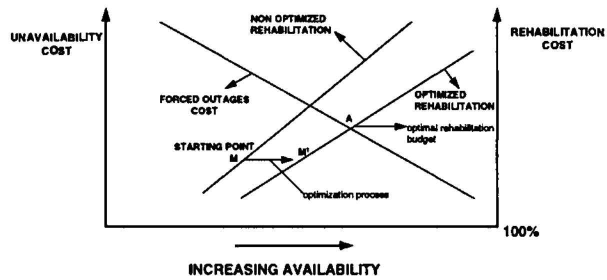
a) Is it possible to fulfill the rehabilitation goals and to successfully overcome the involved technical challenges, taking into consideration the status of the boilers and the rigid frame of rehabilitation scope ?
b) Is the rehabilitation scope optimized (in a Paretus way), i.e. is the rehabilitation designed to get the best possible results on the basis of existing constraints and no improvement are possible without causing detriment to overall benefit ?

To give an answer to the above questions it was necessary to start the basic design and also to make a deeper analysis of the boiler and environment conditions. The assessment of boiler status was made by a site survey and by a baseline performance test. The result of assessment and of the preliminary analysis gave the following result:

a) The limitation connected to the existing system gave an uncertain basis for the design work; that means it was not possible to design the new system using reliable data at the boundary; this situation was worsened by the lack of original design data and by the unreliability of part of the data obtained during baseline performance test (jeopardized by the extremely deteriorated condition and by the complete lack of permanent instrumentation). Henceforth one of the main goal of the design became the flexibility of the new system. The design guideline followed and the basic design results are outlined at points 3,4,5.
b) The rehabilitation was not fully optimized and the governing factor was the limited budget. The situation can be represented in a unavailability vs. rehabilitation cost curve as shown in fig. 2. The optimum rehabilitation is in point A; the starting point for TES 3 rehabilitation is in point M. It means that the budget was below the optimum one but also that scope was not optimized.

A big effort was done in strict cooperation with Central Energy System in order to shift the rehabilitation point to M'. Significant improvement was made by some scope modification obtaining some savings on non critical systems and extending works on critical systems.

REHABILITATION OPTIMIZATION



Note : based on marginal costs

Figure 2

Further improvement in direction of point A were obtained by some additional scope. Especially the instrumentation and control system of existing equipment has been identified as crucial (since it would have become more and more critical after conversion to direct firing) and a more complete upgrading has been agreed. It has also to be considered that in some cases on-off choices were to be faced; that means the choice not to make one action would have jeopardized the complete rehabilitation. All these choices were discussed with the customer and in the majority of cases successfully resolved coordinating ABB rehabilitation scope and CES maintenance and restoration activities.

3 Modified Coal Drying, Pulverizing and Firing System

The main scope of rehabilitation consists of the conversion from the existing indirect firing system to a direct one. With the new configuration the pulverizer operation, working under negative pressure, is directly connected to the boiler load and there is no more pulverized coal storage.

The system modification included as a base:

- Elimination of cyclone separator, pulverized coal bin and pulverized coal feeder
- Direct connection from classifier outlet to a new pulverized coal exhauster.
- Direct connection from exhauster outlet to burners through a new coal distributor
- Installation of new variable speed volumetric type feeder.
- Redesign and modification of control system.

In addition to the above points other modification and new system/component installation were needed in order to satisfy drying and explosion safety requirements connected to the new high moisture/high volatile coal. The main ones are:

- Hot and cold gas mixed with air to make the primary mixture drying and conveying the coal
- New downgoing dryer situated between feeder and mill
- New pulverizer by pass system.

The Baganuur coal characteristic are summarized here below:

• Total moisture	30% max 37%	• Nitrogen	0,6%
• Inherent moisture	7-10%	• Sulphur	0,4%
• Ash	14,8	• Oxigen	11,5%
• Volatiles daf	43%	• Low Heating value	3300 Kcal/Kg
• Fixed carbon	31%	• Grindability Index	60 HG
• Carbon	40%	• Silica in ash	58%
• Hidrogen	2,7%	•	

The existing ball tube mill are not the best equipment for direct firing of high moisture and high volatile coal. In fact:

The mill is sensitive to the moisture at the mill inlet

It shows a significant reduction of capacity and high plugging probability when the moisture is around 30%. The existing ball tube mill characteristic curve, as far as the coal moisture is concerned, were obtained experimentally during the baseline performance test .

The tests conducted at different capacity showing the reduction of drying capacity, with constant inlet moisture, is shown in fig 3; it has to be noted that the points of maximum capacity were reached with the mill starting to plug and it was not possible to get higher capacity (moreover the coal used during test was only 24% moisture).

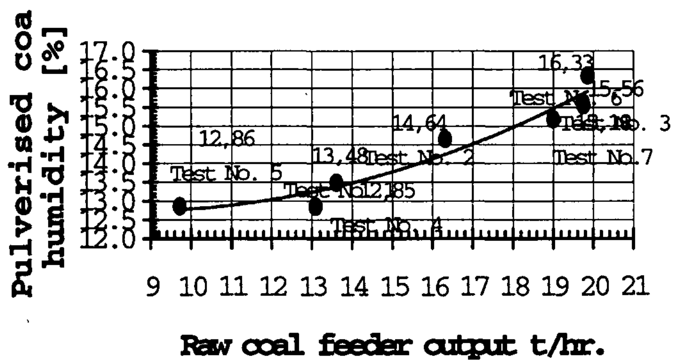
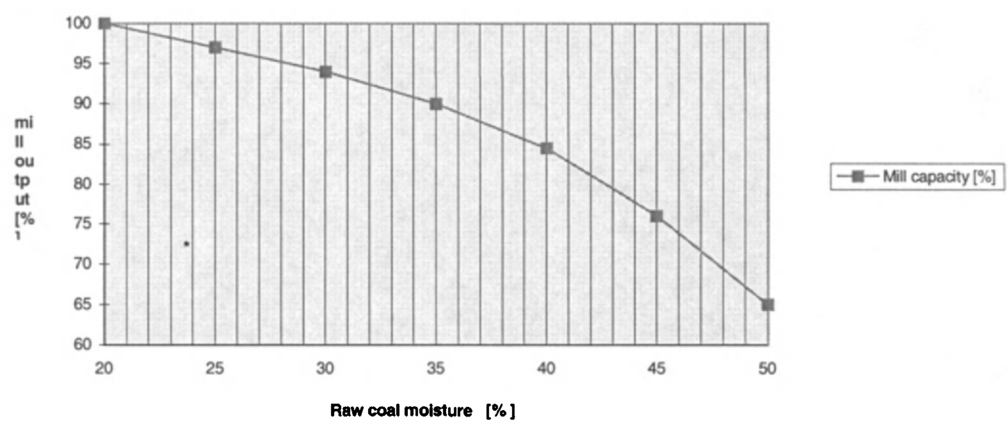


Figure 3

The capacity reduction Vs coal moisture at inlet, with constant residual moisture at outlet, is given in fig 4. The derived capacity Vs coal moisture curve (with optimum outlet fineness and moisture) is given in fig 5. In this curve it is included the corrected test point, the expected curve after mill refurbishment using air as drying agent and the expected curve after rehabilitation using also gas as drying agent. (note that difference between corrected test point and expected curve with air drying is related to the very high infiltration [about 50%] at mill experienced during test).

Figure 4



If we consider that to get the boiler full load more than 20 t/h per mill are required we can see that the air drying is not sufficient to obtained required capacity.

Normal operation of ball tube mill with indirect firing is at constant load

Different loads can be achieved at different feeding rates keeping ventilation (that is the amount of air sweeping the mill) at constant value but allowing air/coal ratio and filling volume inside the mill to vary accordingly to the load. In other words the mill is operated at high load with higher level in the mill and at low load with lower level (and higher ball/coal volume ratio). Such way of operation is not acceptable with direct firing because:

- The load variation can not wait for the mill to fill up or to be emptied before getting coal feed rate variation
- The load variation is limited.
- At maximum load the mill is continuously working close to plugging condition.
- The pulverized coal can not be kept with constant residual moisture and fineness parameter in order to allow proper firing.

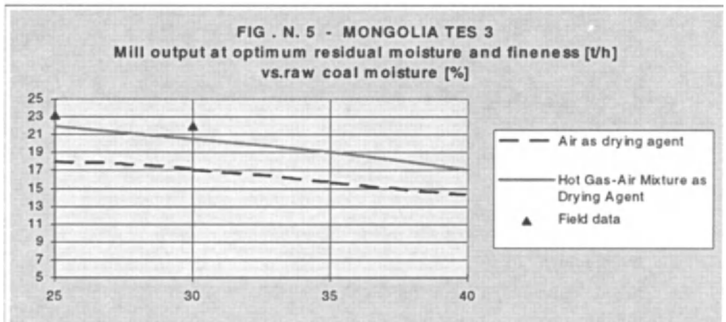


Figure 5

c) The ball tube mill is a reservoir containing a big amount of coal that is ready to generate explosion and to take fire. This is particularly true during load variation when the variable air-coal ratio, variable air temperature entering the mill and the variable dynamic of air/balls/pulverized coal/not pulverized coal inside the mill can generate optimum condition for explosion.

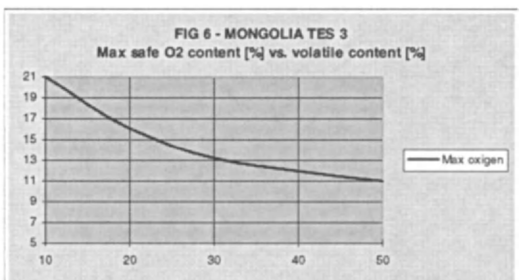


Figure 6

The oxygen content in primary air is not compatible with the safety requirements needed when firing BagaNuur coal. A curve showing safety limit of oxygen in primary medium versus the coal volatile content is given in Fig. 6 . It can be seen that the Bagannur coal requires about 12 % max. oxygen to be kept inside the mill. Unfortunately, this limit is in conflict with the oxygen content in primary medium required by the burners in opposite firing. Despite the high reactivity of the Baga Nuur coal, the burners selected for the project require to have about 12 % oxygen content as a minimum in primary medium. This limitations, and the conflict between them, guide the design choice of gas drying and mill bypass. In order to overcome the problems outlined above the new system was designed with the characteristics as

- Hot Gas used for coal drying
- Downgoing dryer device in the coal chute to mill
- Primary air gas mixture Mill Bypass provision
- Cold gas use for oxygen control and inertization in transient condition
- Different oxygen content at mill and at burners

- Mill air/gas flow and bypass flow controlled by load
- Mill level control by acoustic/vibrational method

The new system is shown in fig 7 while an arrangement drawing is shown in fig 8.

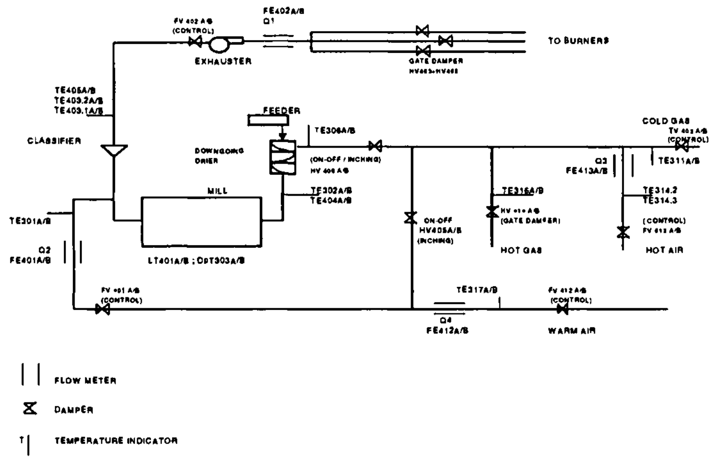


Figure 7

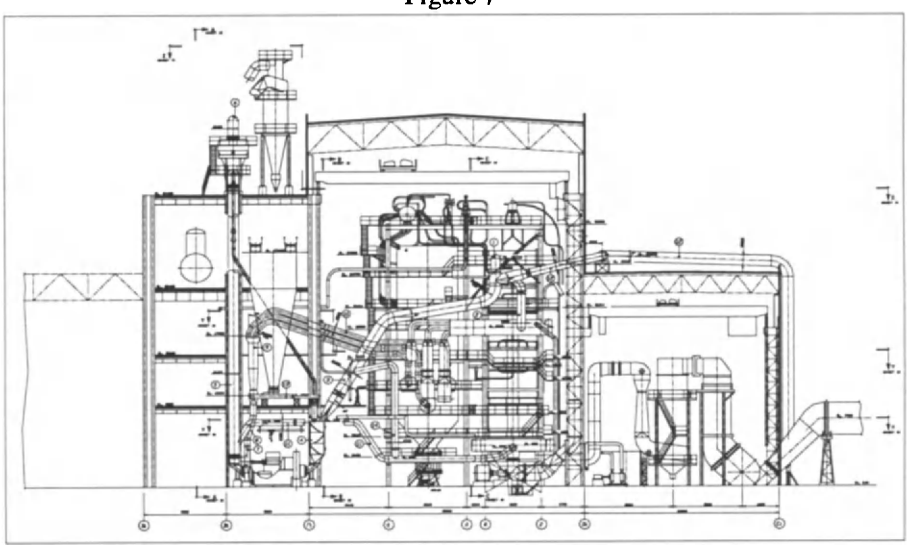


Figure 8

Hot gas for coal drying are sampled from the boiler main cavity at low temperature Superheater outlet (about 650 °C). These gases are mixed with cold gas taken from the ID fan discharge and with hot air taken from the air heater outlet. Temperature of drying agent entering to downgoing dryer with different coals are given in Fig. 10. Such mixture reaches the downgoing drier where coal falling from the feeder is dried before entering the mill.
A portion of the air / gas mixture is taken before entering the downgoing drier and, tempered by warm air taken at first stage air heater outlet, by pass the mill and is injected at mill outlet duct to classifier. The coal/air/gas mixture is sucked from the mill and sent to burners by the exhauster fan through the coal distributors and coal pipes. With the new system it is possible to achieve the following conditions:

- Constant and variable air/coal ratio operation at the mill
- Operation with constant mill level

- Oxygen at mill at 10% constant at different loads and oxygen at burners at 13 % constant at different loads, when firing Baga Nuur coal.
- Different oxygen content when different coals are fired.
- Optimum drying of coals up to 38% moisture keeping required residual moisture in pulverized coal.
- Inertization during transient operation

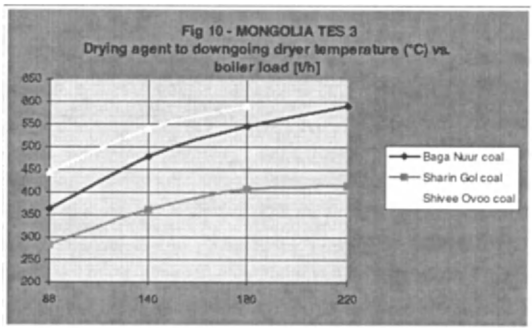


Figure 10

The new milling / drying and firing system operation operational philosophy and basic control system, as designed in order to achieve above mentioned conditions are described here below.

4 Direct Firing System Performance and Control

The direct firing control system has been designed to govern parameters such as; coal flow to the mill, mill level, the air/gas coal mixture flow, air gas coal mixture temperature, the mill bypass flow, air to gas ratio at mill, air to gas ratio at burners. The coal flow to the mill is governed by the load demand via the feeder motor speed; such control is constantly corrected by the mill level indication. Since the operation is based on constant level at the mill, the flow of primary medium sweeping the mill is the governing parameters for boiler load. The coal flowing to the burners can be considered proportional to the flow of primary medium entering the mill; This means that the system has to be governed very close to constant air/coal ratio at the mill. Fig. 9 gives a curve showing the total primary medium divided in the two components, the first one going to the mill and the second one bypassing the mill.

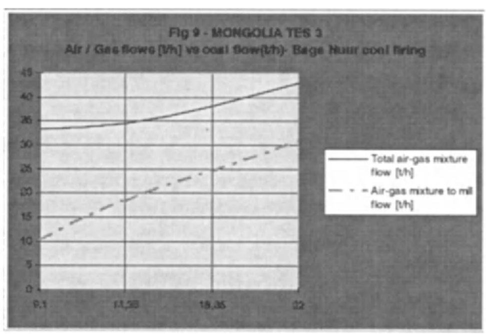


Figure 9

It can be seen that the curve chosen is slightly different from the full constancy of air coal ratio and that is related to the load effect on the transport effectiveness of air/gas flowing through the mill. It is foreseen to tune the curve at site during commissioning.
The coal flow to the burners will follow load demand by the control of the total primary flow by exhauster damper and the bypass flow through the bypass damper. The air gas ratio in the primary medium is given in order to keep low the oxygen at mill while the hot gas/cold gas

share control the coal drying keeping at selected value the temperature of primary mixture after the classifier. The primary medium bypassing the mill is enriched of air in order to have the total air/total gas ratio at the burners in accordance with the minimum oxygen required at the burners. Special care has been taken in control system design in order to create a low oxygen condition inside the mill during transient operation; that is obtained by forced increasing of cold gas in the mix and taking out hot air supply during mill start up and in all transient characterized by high pulverized coal mixture temperature (coal overdrying symptom).

5 Boiler Performance Verification and Other Design Check Related to the New System

On the basis of requirements of the new milling/firing systems, that requires to have gas recirculated in the furnace at all loads, a boiler thermal performance analysis has been carried out. The thermal calculation were checked on the base of available original design data ; a check on the basis of the baseline performance test results was only partially successfully because of lack of data and because of some data inconsistencies.

As a result of thermal calculation it was decided:

- To keep the original superheater surfacing (in fact it was found out that a slight increase of low temperature superheater absorption was compensated by a slight reduction of radiant superheater absorption)
- To redesign the economizer with a in line arrangement and with a surface reduction (the original steaming economizer was staggered and was subject to fouling, bridging and significant erosion [after the coal change to Baganuur])
- To redesign the tubular air heater taking into consideration the new flow and temperature requirements together with the necessity to overcome plugging problems experienced in past operation

Other main critical aspect of design that were affected by the new direct firing system and the new coal are burner selection, hot gas duct erosion protection and insulation, exhauster fan selection (high pressure requirements and scroll/blades wear protection from high abrasive coal), downgoing dryer design, mill refurbishment with new sealing system.

6 Field Feed Back and System Tuning During Commissioning Stage

The new milling/firing systems required a very careful tuning and testing during commissioning stage. The boiler performance and its operational behavior was monitored during the first period of operation in order to verify the design prediction and to implement any modification necessary to make the system performant and safe. The field results showed a good consistency between the expected and the actual performance. Nevertheless some control system modification has been carried out to allow for reliable automatic operation. The main field feed back and the actions implemented are summarized hereby:

Milling & Firing System Performance

The recovery of mill capacity due to the mill refurbishment and due to the new system with gas drying and downgoing dryer before the mill is in line with the expectation. The new max. mill capacity is compared with the expected one in curve n. 5. The expected air/gas mixture entering the mill has been modified in order to further reduce the air content entering the mill. In fact it has been proven that proper firing of Baganuur coal can be achieved with lower air to gas share and therefore the air entering in the primary system is now mainly given by the warm air duct taken at first stage air heater outlet. Such modification allow for improved drying efficiency upstream the mill and lower oxygen content in the mill. The share between total air/gas and bypass air/gas has been kept according to curve n.9.

Coal system inertization

The use of cold gas as inertization agent during transient operation (combined under emergency situation with steam inertization) proved to be a very effective way to prevent explosion risk.

After an anomalous trip leading to an explosion in the burner during commissioning stage the sequence has been modified in order to achieve in any condition the following:

◊ Automatic steam inertization and cold gas system purging at coal system startup

◊ Automatic coal system insulation and inertization under trip condition

◊ Automatic cold gas inertization and prevention of air entering in the system under any dangerous transient condition

Coal system control

The coal system philosophy summarized at par. 5 has been successfully tested and tuned implementing the following modifications:

◊ The coal flow to the mill is governed by the vibration mill level indication with a feedforward action by boiler load demand to change coal flow immediately during load variation and to minimize mill temperature problems.

◊ The mill bypass flow to achieve the ratio shown in Fig.9 is controlled by two dampers in split range instead than one. In fact at low load the bypass damper is open and the damper at downgoing dryer inlet start to close to control the bypass flow. Such modification allow for a better bypass flow control at low loads were the response was found to be not effective with previous control mode.

7 Rehabilitation Results

The boilers of unit n. 7 and n. 8 are in operation after rehabilitation since spring 1998. The results achieved are hereby summarized:

Performance

The two boilers have been taken back to the original design capacity allowing to reach a steam capacity of 220 t/h each. The original boiler efficiency has been also recovered.

Availability

Statistics about boilers availability & reliability after rehabilitation are not yet available. Nevertheless the two rehabilitated units are today the main power & steam resources for TES 3 power plant due to their low failure rates and higher reliability than the other units. A significant number of forced outages in the rehabilitated units were experienced during the very first period of operation, but only a few of them were connected to the rehabilitation. After the tuning of control system and some weak point removal in auxiliary equipment, the availability/reliability of the boilers is constantly improving and it is expected to reach typical values for non higly deteriorated boiler of similar age (forced outage impact on availability below 5%)

Safety

The new milling & firing system have been proven much safer than the previous system because of removal of the potential risk area and the improved mill inertization system. Moreover the upgraded control system with the implementation of new burner management system allow for flame protection avoiding the major risk of furnace explosion.

Environmental impact

The recovery of boiler efficiency, the refurbishment of the dust separator (Venturi wet scrubber type), together with the correction of the heavy boiler gas leakage, allowed for a significant reduction of pollutants dispersion in atmosphere. The reduction is evaluated in 35% of dust emission and 30% of NOx emissions. The plant internal environment itself has been significantly improved, removing the gas leakage and the dust emission in the boiler area, allowing reduction of personnel health hazard.

REVITALIZATION AND NATURAL TREATMENT SYSTEMS IN THE VENETIAN LAGOON: LAZZARETTO NUOVO ISLAND CASE STUDY

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Abstract

Lazzaretto Nuovo is a small island of approximately ten hectares (4 acres) located in the northern lagoon of Venice .It is currently the property of la Soprintendenza ai Beni Ambientali e Architettonici di Venezia. The island has a long history of settlements that can be traced back to the year 1015. Currently, Lazzaretto Nuovo is maintained and used on a regular basis by two recreational groups: Ekos Club and Archeoclub d'Italia. Together with «Ekos Club,» Archeoclub embarked on a project entitled «The Rebirth of An Island» in 1975. Since then the island has been transformed from the wild remains of a long abandoned settlement to a working camp. A variety of social, cultural, and educational groups currently use the island for meetings, overnights, and longer camps throughout the year.
This publication presents the experiences encountered in the design of a small scale, constructed wetlands treatment facility and in the planning of the principals components for the revitalization on the island of Lazzaretto Nuovo. The suitability of this technology for application to an island community was evaluated in technical, economic, legal, and practical terms. The need of the community for an operationally simple, aesthetically pleasing, and reliable wastewater treatment system is presented based on the physical realities associated with its island status. It is believed that this experience may be useful to others faced with the need to provide cost effective, efficient, wastewater treatment services for island, or other isolated communities.

1 General Introduction

1.1 Premise

In its existing configuration, wastewater generated on the island is collected in eight, old, crumbling, concrete cisterns that date back to the early twentieth century when the island was

used by the military. Wastewater is detained briefly in the cisterns before it is dispersed into the island soil. The level of treatment provided by this setup is minimal.
The proposal embodied in this document, which represents the fruition of one year's research by a five person team (see sub-chapter 2.1), calls for the replacement of the existing cisterns with a constructed wetland. The new configuration calls for septic tanks connected in series to two, subsurface flow wetland beds. Natural treatment systems like constructed wetlands provide low cost, low maintenance alternatives to centralized wastewater treatment. Aquatic plants and other microorganisms consume, break down, and reuse the constituents of domestic sewage in their natural growth processes. These systems consume less energy and require smaller capital investments than conventional treatment facilities.
The wetland system, besides addressing the wastewater treatment needs of the island, has important scientific and educational dimensions. In collaboration with local research institutions, a three year monitoring phase is planned during which the performance of the wetlands system will be assessed and various experiments on the plant species, flow patterns etc. will be conducted. The selection of Lazzaretto Nuovo as a station along a new alternative tourist itinerary being implemented by a local environmental group guarantees publicity for this innovative and sustainable approach to providing wastewater treatment. The camp activities sponsored by both Ekos club and Archeoclub also increase the educational potential of the plant. In its current configuration, the island can comfortably house approximately forty people.

1.2 Birth of Project Team

The Lazzaretto Nuovo project team was born from coincidence. All of the Italian team members were initially members of the *Forum per la Laguna di Venezia*, a grass roots, volunteer run organization dedicated to raising public awareness to environmental issues facing the Venetian Lagoon. Fabio Carrera, a Venetian engineer, and co-founder of the *Forum*, became fascinated with natural treatment systems during a recent trip to the United States and had been personally searching for a way to apply the technology to Venice. Erich R. Trevisiol, an environmental planner, and Stefano Parancola, a recently graduated landscape architect, both members of the *Forum,* had been separately studying the technical, administrative, and landscape features of natural treatment systems since 1994 at the MURST-CNR research unit of the Venice Architecture University. Davide Tagliapietra, also a *Forum* co-founder, and a biologist from the Venetian island of Mazzorbo, had been conducting research on the ecological problems facing lagoon at the University of Venice.
In the meantime, on the other side of the world, the recently graduated, Italian-American environmental engineer, Franco Montalto was searching for a way to get involved in an ecological design project in the land of his ancestors. Searching for a contact in Italy, Montalto was put in contact with Carrera because of the latter's involvement in other environmental conservation projects. A brief telephone conversation revealed common interests in natural treatment systems. Montalto applied for, and won a Fulbright Research Scholarship to investigate the possibilities of applying the technology in Venice. After arriving in Italy, he was introduced to the *Forum*, uniting the team for the first time.

1.3 The Venetian Sewer System

As stated in the 1995 EEA Dobris Assessment, while about 95% of European city dwellings are connected to a sewer system, «wastewater treatment [in European cities] is still a major problem.» Venice is a case in point. It is one of two large European cities that still *has no sewer system...* Or does it?
The answer is yes... and no. For over a millennium, Venetians have discharged their wastewater directly into the City's canals, relying on the Lagoon for natural purification.

Underground collection systems were installed in some parts of the City in the 1700's. In the middle of the nineteenth century, however, other Italian cities started to install modern sewer systems. A hot debate grew on how the Venetian sewer system should be upgraded. The technical debate, which continues today, has produced about thirty different studies, investigations, competitions, plans, and small scale test projects proposing a myriad of sewer technologies popular during the last century and a half. Today Historic (or island) Venice finds itself nearing the 21st century with: a) a decline in the self-purifying capacity of the surrounding lagoon, b) canals full of sediment as a result of discontinued canal excavation and c) a mixture of traditional, experimental, and modern sewer tracts that all continue to discharge into the surrounding waters.

Throughout the long debate, several conclusions have been made. First and foremost, the self-purifying capacity of the lagoon must be restored. To approach the problem, the City must be divided up into areas where «modern» sewer systems like those used on «terraferma» can be installed, areas where existing systems should be restored, and areas where the lagoon's natural purifying capacity should continue to be relied on. A study completed at the end of the last century concluded that «every sewer system must be designed according to local conditions. Our special City can not always adopt technologies that work well for others.» These conclusions became the basis of the *Forum* research (2).

2 The Revitalization Project

2.1 Team, Components and General Aims

The Forum Project Team for the pre-feasibility phase consists of: Erich R. Trevisiol (co - ordinator) (3), Pier Francesco Ghetti (aquatic biologist)(4), Stefano Parancola (architect), Franco Montalto (environmental/civil engineer), Davide Tagliapietra (biologist), Fabio Carrera (engineer), Gerolamo Fazzini (President Ekos club, Archeoclub). *The feasibility phase* is in charge of the Magistrato alle Acque e Consorzio Venezia Nuova. Other partners are Thetis Centro Servizi, ASPIV and the University of Venice Cà Foscari.

The Lazzaretto Nuovo Project is a joint effort building on contemporary and past research conducted by IUAV, LIFE - FORUM , Worcester Politecnic, and on projects coducted by Magistrato alle Acque and Consorzio Venezia Nuova, Soprintendenza ai BB. AA. AA and Ekos-Archeo Club. The result is a holistic approach to emproving the environmental condition of the island. Its principal components include the following:

a) planning of integrated green areas - with garden and orchard areas, nature trails (both inside and outside the walls) passing through areas planted with native plant species, a system of informative panels describing to island visitors the various components of the environmental campaign (stage of implementation: carried out during 1997);

b) enhancement of existing trails on the island - through the construction of walkways, improvement of existing small bridges (like that on the NE corner), installation of educational panels and anti - splattering lights, where appropriate. These internal trails will link various items of interested on the island, including the historic buildings, original venetian well, the gardens, the observation points and several of the ongoing excavation sites like the Church of S. Bartolomeo (1997, not including light fixtures);

c) reconfiguration of island debarkation points, (together with the ACTV) - work will included improvements to the existing dock (currently without boat bus service) and rebuilding of another floating dock to the west of the former (stage of implementation: restoration of existing dock, 1997);

d) reconstruction of island edges - work, to be conducted by Consorzio Venezia Nuova, will use wooden piles and backfill (1997 - 1999);

e) restoring and putting back into use existing island structures - according to earlier proposals developed by, among others, prof. G. B. Stefinlongo and Dott. G. Fazzini. The roofs of many of the island's structures have already been repaired. Future plans for the «Tezon» include its conversion into a museum or its use as crafts workshop (specifically, ceramics). The «Tesetta» could become a place to duplay artifacts uncovered during excavation, while the powder towers, since they do not allow in much light, could be used for lectures or small conferences. The two buildings currently used as a dormitory and kitchen could be reconfigured to also include a library open to island visitors. The Soprintendenza has restored the southern portion of the island's perimeter walls. Inside these walls an observation trail will be built with raised lookout points facing the north - east. Lightweight elevated platform will lean against the perimeter wall at each lookout point (incomplete restoration. Ongoing during 1997 and in the next few years).

f) redefinition of the island water cycle - through the construction of the sewer system and installation of a constructed wetland treatment system on the island. Wastewater treated in this system may be suitable for irrigation of the gardens. Rainwater will be collected from rooftops to keep the wetland saturated during periods of low island activity. The constructed wetland system was sized to treat all watewater generated by a community of 40. Pretreatment will be accomplished through the use of septic tanks. The «wetland» portion of the system is composed of two subsurface flow, gravel beds, planted with emergent aquatic macrophytes found in and around the Venetian lagoon. Post - treatment will be provided by a small pond impoundment before final discharge into the lagoon. Pathways will be constructed along the perimeter of the system providing maintenance access points and educational visits. Landscaping around the system will include native shrubs and hedges, fencing, non reflecting - lighting (in responce to the recent regulation passed requiring anti - splattering light fixtures) and other fixtures (started in 1998).

Project general aims included in short:

- simple solutions, with low - tech yet innovative solutions to environmental engineering problems. Instead of proposing many new solutions, previously proposed projects will be pulled togheter under the theme of environmental sustainability;
- fased works. The components of these project will be implemented in sequence over a period of time;
- joint effort. These projects will be sponsered by various groups but will always involve the island community leaders and the project's main sponsors. The involvement of CVN and of Venetian Magistrato alle Acque, for example, guarantees the necessary regulatory approvals will be sought and achieved for every project;
- grass roots projects, proposed by the community which they involve. The support of the local community is commonly viewed as essential for any project's success;
- restoration projects with a positive environmental impact. The effort to preserve the historical patrimony of the Venetian Lagoon must be joint with the search to find ways of addressing contemporary environmental and socio - economic problems faced by the area;
- self sufficiency. Since its island status precludes the linkage to existing municipal sewer, water, utility etc. closing resource cycles is more than just a good idea, it is a necessity;
- replicability. It is believed that the Lazzaretto Nuovo project will prove exemplary to others isolated communities faced with the need to provide cost effective, efficient community service, like wastewater treatment.
- cross financial baching provided by National government, private business sectors, private funds, membership funding (NGO)

3 Natural Treatment System

3.1 The Lazzaretto Nuovo Connection

In the autumn of 1995, after both Parancola and Montalto completed university thesis projects on natural systems, the team initiated a pre-feasibility study for a constructed wetlands system on the island of Lazzaretto Nuovo. The island was already a part of other *Forum* projects (specifically, the EU sponsored Project LIFE) and was in need of an upgrade to its hardly existent wastewater treatment system. Interest in installing a natural treatment system was expressed by Gerolamo Fazzini, president of EKOS Club, the volunteer-run recreation/cultural association responsible for the island's maintenance. A constructed wetland system was chosen initially because of the known suitability of these systems for use in small, isolated communities with available open space. The simplicity associated with the construction and operation of a constructed wetland system seemed a perfect match considering the island's needs and available resources. Other characteristics of natural systems that suggested suitability for the Lazzaretto community included:

- ***Positive Environmental Impact:*** Natural treatment systems, since they are essentially «green» spaces, contribute to the environmental restoration of the landscape. Although these systems are designed primarily for the treatment of wastewater, many aesthetic and recreational characteristics also characterize natural systems.
- ***Reliability and Treatment Capability:*** Experience in both Europe and North America indicates that these systems produce very high effluent qualities. Thousands of systems are up and running in the United States, Germany, and Scandinavia alone.
- ***A Simple, «Rustic» Technology:*** A natural system requires very little specialized work and can be easily constructed by local, small-scale contractors.
- ***Low Construction Costs:*** Construction costs depend on scale. A recent EPA study indicates that while the cost of constructing a natural system for an isolated, *single* residence is high, competitive construction costs have been reported for community wetlands with flows greater than 38 m^3/day (Brown *et al*, 1994) (5).
- ***Low Operation and Maintenance Costs:*** Natural treatment systems are particularly adapted to areas where the construction of a central sewer system is not physically or economically feasible. (The sewer system alone may be responsible for 60 - 70% of the cost of a centralized treatment system (*Small Flows*, Winter 1996) (6). Maintenance of a natural system is minimal and does not involve specialized technical workers. Direct involvement of the local community in the management of the plant is possible.
- ***Demonstrative / Educational Function:*** Natural systems demonstrate the closing of natural cycles with eco-compatible technologies. Some local Italian governments award operators of small scale natural treatment system.

3.2 Methodology and Approach

The team chose to break up the project into three phases: *a research phase*, during which the Venetian ecosystem and wastewater problem would be studied and financing sought; *a construction phase*, during which supplies would be purchased and the plant installation completed, and *a monitoring phase*, during which the results would be analyzed and future applications explored. These phases are broken down in Table 1.

Table 1: *Preliminary Outline of Lazzaretto Project Goals*

Phase I: Research *Goals* • to better understand the dynamics of the Venetian Lagoon ecosystem • to review past approaches to addressing the Venetian wastewater disposal dilemma • to explore various site possibilities • to make a preliminary cost estimate • to seek financing	*Tasks* • territorial analysis • gathering of historical information • technology literature review • site investigations • geomorphological analysis • flora and fauna • legal context
Phase II: Construction *Goals* • to purchase supplies and commence construction • to start-up the facility	*Tasks* • selection of construction materials • out to bid (4) • selection of contractor • construction
Phase III: Monitoring, Analysis, and Other Applications *Goals* • to monitor influx and efflux conditions of Lazzaretto facility • to explore other applications of constructed wetland technology in the Venetian Lagoon	*Tasks* • start-up • monitoring

In the autumn of 1995, the team joined forces with ASPIV, the public body that manages the water and wastewater systems in Historic Venice and nearby «terraferma». ASPIV, which has been considering the use of constructed wetlands for polishing of effluent from its mainland treatment plants, was interested in all types of natural systems research. Prof. Pier Francesco Ghetti, of the University of Venice was contacted and invited to provide scientific guidance. A contract was drafted between ASPIV, EKOS club, and the *Forum* team members which established a preliminary time frame for the completion of work, secured financing from ASPIV, and required the *Forum* to produce a preliminary design. The Lazzaretto system, it was decided, is to be both a pilot project with flexible, changeable parameters and a functioning treatment facility.

Articles about the collaboration were published in local papers in accordance with the *Forum's* awareness raising goals. A conference was organized at the Architecture University in which American, German, and Swedish experiences in the use of natural treatment systems were presented. Research got underway.

3.3 Institutional Collaboration

In the Spring of 1996, an initial design was completed but the team was blocked by financial and administrative barriers. Although a «rustic» plant, constructed with the limited finances available from ASPIV was possible, monitoring and experimentation on the plant would be virtually non-existent. To fill this gap, the original partners decided to invite two other Venetian environmental groups, Consorzio Venezia Nuova (CVN) and Thetis Centro Servizi

(TCS), to participate in the Lazzaretto effort. The operation would now be managed as a public work, since CVN is a branch of the national Magistrato alle Acque.
It wasn't until July, 1996 that the final agreement between the new partners was drawn up. In the meantime, the team continued its scientific research. A conference entitled, «Rescued Water: Integrated use of the Water Cycle in Regional Planning» was organized at the Architecture University (DAEST).
The contract drawn up between the new partners identified several phases to the Lazzaretto project: a) the construction and start-up of the plant, b) monitoring and analysis of scientific results, c) information diffusion and scientific reporting, and d) overall coordination and management. The final design, based heavily on the initial *Forum* project, was modified slightly by CVN. The constructed wetlands will be constructed in the Autumn of 1998 by CVN as part of a series of other environmental protective measures scheduled to be carried out on the island. Table 2 summarizes the responsibilities of the final project partners.

Table 2: *Individual Responsibilities of Lazzaretto Nuovo Partners*

	CVN	ASPIV	FORUM	EKOS	TCS	UNIV
1. System Start-up						
construction	X					
installation of macrophytes	X					
final technical adjustments	X				X	
2. Monitoring / Experimentation						
sample taking					X	
measurement					X	
chemical laboratory analysis						X
microbiological laboratory analysis						X
on-site analysis			X			
reporting of results		X	X		X	X
3. Maintenance of Plant						
general surveillance				X		
landscaping				X		
minor technical adjustments				X		
4. Analysis of Results / Reporting						
scientific, technical, and operative evaluation		X	X		X	X
operative management		X		X	X	
administrative management		X				
exportation to other applications			X		X	
5. Diffusion of Information						
coordination of plant visits			X	X		
publications	X	X	X	X	X	X
awareness raising			X			
6. Coordination and Management						
control, coordination, and management					X	
reunion of Coordinating Committee	X	X	X	X	X	X

3.4 Why a Constructed Wetlands on Lazzaretto Nuovo ?

Even if natural systems do carry all the benefits listed in the previous section, the construction of such a system on a small island community in the middle of the lagoon at first glance may not seem justified. The small, residential community generates a very small quantity of domestic wastewater which can easily be treated with a septic tank. It is well known that wastewater inputs from lagoon islands make up a very small percentage of the overall Lagoon contamination. Furthermore, constructed wetlands, even if suitable for use on a small island with a lot of free space, may be not represent a feasible alternative for larger, more developed islands like the Historic Center of Venice, Burano, and Murano .

What then, specifically, were the motivations for proposing a constructed wetland system on Lazzaretto Nuovo?

- To offer a **service to the island community (Archeoclub/EKOS Club)** and to **upgrade the existing wastewater collection and treatment system.**

The dispersion cisterns receiving wastewater generated on Lazzaretto Nuovo are crumbling remains of the military occupation of the island and do not provide adequate wastewater treatment according to modern standards. A simple and cost-effective upgrade was necessary. The installation of a wastewater collection system and a three compartment septic tank would have been sufficient to satisfy all existing *legal* requirements . However, installing the septic tank in parallel with the constructed wetlands introduced the possibility of comparing the two treatment options. It is anticipated that the wetlands system will produce a higher grade effluent than the septic tank. Lazzaretto could, therefore, set a precedent for the use of this technology in other small communities in Italy.

- **Experimentation and Knowledge**

The Lazzaretto facility is intended to be an experimental pilot project as well as a functioning treatment facility. Adaptability and flexibility were built into the design. Wetland performance will be analyzed under varying stress loads, growing naturally out of the seasonal usage of the island. The flexible hydraulic configuration of the Lazzaretto system facilitates the experimentation and testing of constructed wetland dynamics. The two bed design makes possible the comparison of two different plant species. The use of *Phragmites australis,* for which abundant performance data exists, allows comparison of the Lazzaretto system with other constructed wetland systems. *Puccinellia palustris*, for which performance data was not found, suggest a high potential for use in constructed wetland systems in coastal environments.

- **Pathogen Removal**

The high pathogens removal efficiency of natural systems, makes them particularly suitable for the treatment of domestic discharges in areas of the lagoon where fishing and shellfish collection are practiced.

- **Environmental Restoration**

The constructed wetlands systems will be constructed in an area used for many years as a dump by the island inhabitants. Clearing of the various debris is a costly task not easily undertaken by the current island caretakers. The installation and landscaping of the wetlands facility will ensure restoration and cleanup of the area as well as its re-insertion into the natural surroundings.

- **Cultural / Educational Motives**

The use of a natural treatment system involves an increased awareness of and attention to what is being flushed down the drain! Together with recycling, natural systems aid in raising the environmental sensibility of a culture that has become detached and disinterested in the origins and destinations of the elements that pass through their bodies. Visitor turnover on Lazzaretto Nuovo is substantial due to the cultural/educational activities of EKOS/Archeoclub. The island is also a station along a new, alternative tourist circuit, sponsored by the European Union (Forum/Life), that brings tourists away from the Venetian Historic Center and out into the Lagoon.

- **Institutional Collaboration**

The collaborative effort behind the construction of the Lazzaretto Nuovo system is composed of several public and private bodies: ASPIV manages all water services for the municipality of Venice; the Ministry of Public Works is represented by Consorzio Venezia Nuova; Thetis Centro Servizi is a consortium of private companies operating in the field of marine and coastal technologies; the Forum per la Laguna di Venezia is a non-profit, grassroots organization dedicated to increasing the sensibility of the public to lagoon environmental issues; Archeoclub is alone responsible for the survival of the island. This collaboration is, in and of itself, already a success!

3.5 Constructed Wetlands: Prospective Applications in the Venetian Lagoon

As stated in the Introduction, the author of this publication do not propose natural treatment systems as «the solution» to all the wastewater disposal problems in Venice. Lazzaretto Nuovo is an example of a very practical application of a very particular type of natural treatment system (the constructed wetland).

The potential applications of *other types* of natural systems in the Venetian Lagoon are numerous. The polishing of effluents from existing conventional wastewater treatment plants discharging into the Lagoon or its tributaries is one such possibility. ASPIV is currently considering this type of treatment for effluents from its Fusina wastewater treatment plant which currently flow directly into the Lagoon. Another obvious application of natural systems in the Venetian Lagoon is the construction of buffer wetlands along the lagoon borders to absorb contaminants of urban and agricultural runoff. An intervention of this type has already been undertaken by Consorzio Venezia Nuova. Spoils from canal dredging, conducted to improve circulation of lagoon waters, are being used to reconstruct natural wetland areas along the borders of the Lagoon.

The *Forum* team recognizes three realistic applications of *constructed wetlands* in the Venetian Lagoon:

- treatment of wastewater generated on lagoon islands with available open space
- treatment of discharges from isolated dwellings and developing areas along the lagoon borders
- treatment of discharges from isolated dwellings near fish farms

Due to their simplicity and low operation and maintenance costs, constructed wetlands are a reliable, cost-effective substitute to conventional centralized community wastewater treatment, as long as open space is available. Constructed wetlands represent a viable alternative to other on-site treatment technologies like septic systems. As explained in Chapter 3, the efficiency of septic systems depends heavily on soil characteristics. Effective septic tank treatment depends on further treatment of contaminants outside of the tank in the leaching area. Saturated soils and soils with a high clay content like those found in lagoon areas are not suitable septic leaching areas and often lead to contamination of receiving bodies with partially treated wastewater.

There are 34 minor islands in the Venetian Lagoon. Many of these islands like Historic Venice, Murano, Burano, Mazzorbo, San Michele, and Lido are completely developed with very little free space. The prospectives for use of constructed wetlands on these islands is slim. However, there are other islands that could conceivably host a constructed wetland system like the one to be built on Lazzaretto Nuovo. The table below is a partial list of the more prominent island possibilities, their suspected current usage, and populations as reported by the Comune di Venezia as of December 31, 1995.

Table 3: *Constructed Wetland Island Possibilities*

Island	Population	Suspected Usage
Isola S. Clemente	10	asylum with large garden
Isola S. Giorgio Maggiore	13	park
Isola S. Servolo	1	Provincia
Isola Sacca Sessola	0	abandoned, soon to be for sale
Isola S. Lazzaro	30	monastery
Isola Poveglia	0	
Isola Tessera		American scientific group
Isola S. Spirito	0	
S. Francesco del deserto	13	monastery
S. Erasmo	813	agricultural / residential
Vignole - Certosa	61	agricultural / residential
Torcello	31	agricultural / residential

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TOWARD SUSTAINABLE ENERGY FOR DEVELOPMENT: A MODERN APPROACH

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Abstract

Developing countries need rapidly increasing quantities of energy for their economic growth. The availability of energy is also essential for social development and to ensure an acceptable quality of life. There is now awareness that this energy must be supplied and utilized in forms that respect the principles of sustainability.
Sustainable energy technologies exist both on the supply and on the demand side; developing countries whish do not have heavy infrastructure and previous investment, as well as rapidly expanding markets, often have the opportunity to introduce advanced technologies that have difficulties of penetration in the industrialized countries.

1 Introduction

The importance of energy for development is certainly not new, but it may have failed to be recognized explicitely in the past. Moreover, the availability of energy influences development not only in a quantitative, but also in a qualitative way. In other words, energy means not only economic growth, it also means social development, improvement in the quality of life, effects on the environment. Such connections have been recently identified [1] and studied [2], and include, among others, the effect of energy on demography and population growth; on gender roles and the promotion of women; on undernutrition and food; on education; on poverty and on distribution of wealth; on job creation and employment; on investment and on foreign exchange; on urbanisation; on water availability; on land degradation, deforestation and desertification; on national security and peace. Each of these connections would deserve a deep analysis. For instance, the availability of energy for water sanitation or to reliably operate refrigerators where vaccines are conserved has a great impact on health. Freeing rural people (generally, mostly women and children) from the daily routine of collecting firewood or carrying drinking water over long distances makes them available for more productive work or for education - both a source of future income, but also a way of reducing demographic growth.
Conversely, the type of energy cycle which is used is not indifferent tyo the type of economic, social and environmental effects it will produce. It is not sufficient to have "enough" energy,

it should also be the right type of energy in that particular context. For instance, alleviating the pressure on utilisation of firewood by introducing more modern forms of energy in the rural environment conserves forests, prevents desertification and land degradation, improves the air quality inside the dwellings (smoke from cooking stoves is a major health hazard especially for women and children).

The importance of energy for development has been fully appreciated for a long time. Without the availability of sufficient energy, the jump in agricultural productivity brought about by the Green Revolution would have been unthinkable, and very little industrial activity could take place;.

Consequently, an important part (between 25% and 30%) of all the money devoted to aid to development programmes, both as grants and as loans, by bilateral, multilateral or international institutions as well as non-governmental organisations (NGO) go to energy-related projects. It has been mentioned, for instance, that in 1990 for Sub-Sahara African countries [3] 87% of World Bank loans were for the energy sector, with plans of 75% for the power sector alone in the following years; in the same period, the African Development Bank devoted 92% of its loans to the energy sector ; UNDP funding also targeted energy, which was its largest single category in 1990.

However, what has been missing until some time ago has been the link between energy, development and sustainability. Most of the energy projects that have been supported have been of the traditional type: first of all, they were supply oriented (i.e. directed to providing energy rather than to using it effectively); second, they were mostly directed to large-scale plants based on traditional technologies (fossil fuels or large hydroelectric plants); finally, environmental assessments were carried out for most projects, at least in the recent times, but a general evaluation and prioritization of projects in terms of sustainable development has generally been missing. It has been calculated [4] that between 1980 and 1991 only about 2.5% of official development assistance for energy from all donors has gone for renewable energy development.

The new possibilities to obtain energy services which are now available must be fully exploited and introduced in aid-to-development programmes not only because they are more benign to the environment and to global climate, but also because they are best suited to produce development.

New fresh thinking is needed, and developing countries must lead the way: if nothing else, because they are less conditioned by past history, investments, infrastructures, and of course they know better their own situation. It is important that developing countries acquire an independent capability of technology assessment; this process of "capacity building" can be helped by industrialised countries, but the centres of competence thus formed should not be donors-driven.

Sustainable development is based on three components: economic, environmental and social. The process in Western countries has concentrated on one of the components - environment and more specifically global climate, so that sustainability is sometime reduced to the problem of greenhouse gas emissions. On the other hand, in developing countries economic growth is understandably seen as the most important, if not the only, component. It is necessary that all three components are taken up in a consistent, balanced way.

Energy had not been singled out as a separate subject in the discussions of the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992, nor was reflected as such in the ensuing Agenda 21, where references to energy were made in several different chapters (most notably in the one on atmospheric pollution). The central position of energy for sustainability was however recognised by the United Nations General Assembly Special Session (UNGASS) [5] devoted to sustainable development in June 1997, which also decided that the 2001 session of the Commission on Sustainable Development will be devoted to energy problems.

This does not mean that energy policies have not been affected by considerations of sustainable development. Great attention has been devoted to energy cycles by the Intergovernmental Panel on Climate Chage (IPCC); the application of the Climate Change Convention, such as deriving from the protocol agreed upon in Kyoto in December 1997, will greatly influence the energy policies of the signatories. Although developing countries (DC) have not entered any definite engagement for the containment of GHG emissions, their attention to this problems is preminent.

2 Changes in Boundary Conditions

From 1980 to 1995, energy consumption at the world level [6] has increased from 7021 Mtoe to 8852 Mtoe (+26%). However, this growth is compounded very unevenly: an increase of 18.3% in OECD countries, a decrease of 21.7% in the countries of central and Eastern Europe and of the former Soviet Union (due to the serious economic crisis), an increase 108% in non-OECDAsia (including Middle East countries) and increases of 43% and 61% in Latin America and Africa respectively. It is perhaps even more instructive to look at the per capita energy consumption: this has actually remained constant in Africa at a level of 0.50 toe/person.year (against a world average of 1.56) and even decreased in sub-Saharan Africa (from 0.465 to 0.456) due to the massive population growth, while in China energy consuption per capita has grown from 0.54 to 0.83 and in India from 0.21 to 0.33. Differences in rates of development are thus reflected in per capita energy availability.

Energy intensity, defined as the ratio between (commercial) energy consumption and the gross national product in a given country, is a measure of the efficiency of energy utilisation; however it can be taken as a meaningful indicator for the comparison of two countries only when are at similar stages of development. The reason is that in the first phases of development and during the industrialisation process in particular, energy intensity tends to be quite higher than in fully industrialised countries, since production is concentrated on infrastructures and on instrumental goods, which have a high energy content, and in providing durable goods for the first time to the population. At the world level, the product has grown more rapidly than energy consumption: correspondingly, energy intensity has decreased from 539 toe/MECU(1985) in 1980 to 477 in 1995 (-11.5%). However, data are very different from one region to another. The energy intensity in the same has decreased by 17.1% from 291 to 241 in the European Union, from 550 to 446 in North America (-18.9%), but it has increased elsewhere, from 1923 to 2349 in the former Soviet Union, where the breakdown of the economy has been greater than that of energy consumption (and where the extremely high values point to a chronic inefficiency); in developing countries, it has dropped from 1469 to 1066 in Asia, but it has increased from 770 to 997 in Africa, and from 463 to 511 in Latin America.

Apart from the evolution of the energy production and consumption patterns, a great shift has occured in the instruments of energy policies. The main shift is from instruments of the command-and-control, compulsory planning type to market mechanisms.

All over the world, the move toward increased reliance on market mechanisms has progressed during the last years. In the field of energy, it was not only in the so-called Centrally Planned Economies that the governments played a direct and prevailing role. Energy was seen as a strategic sector, crucial to international competitiveness, economic and social development and national security, in which the most important decisions were to be taken by the government. State utilities for electricity, gas and soetimes also coal and oil products were instruments for implementing energy policies in many Western countries, such as the United Kingdom, France and Italy.

This concept was gradually abandoned in many countries, as it was recognized that market mechanisms could perform the same tasks with better efficiency. The introduction of elements of competition even in those sectors which were previously considered as natural monopolies, such as electricity and gas, is required by the directives of the European Union, and is being gradually implemented in the EU countries. Prices of oil products have been deregulated in most industrialised countries. Exploration and exploitation of oil and gas deposits are open to competition. The process of liberalisation in this field has made great progress also in the economies in transition and even in China.

However, the progress is slower in many of the developing countries. Reservations about foreign interference through investments; preoccupations about the fragility of their economic systems; reluctance to abandon instruments of control; lack of local capital to start energy enterprises have all contributed to delay the transition to free market mechanisms in most developing countries.

Financing institutions consider that the development of sustainable energy would greatly benefit from market and competition. For instance, the World Bank states that "one of the most powerful ways to improve energy supply is to ensure that the energy market is determined by consumers' choices. ... that means both that the price of energy should reflect its cost and that regulation of energy industries should encourage competition and choice." [7]

The European Union also encourages the introduction of market elements in all fields in its programme of aid to the ACP countries, both in terms of support to structural adjustment (including structural reforms and sectoral policies), and in taking into account in its priorities in allocation of funds the "performance" of the country, including the creation of an environment more favourable to the success of the project [8].

However, free market is not everything. Effective as market forces are in optimizing the allocation of resources for short- and medium-term objectives, the market is known to be short-sighted, not to respond spontaneously to long-term signals. As the World Bank puts it, "liberalizing energy markets, however important, may not be the complete answer.... private companies have shown little interest in extending electricity supplies to rural areas. {industrial and urban customers are more lucrative}."

Governments may provide corrections to the myopia of the market, by introducing long-term signals, correlated with sustainability, that adjust the perspectives of market forces, and allow them to be used in the best way to obtain strategic objectives as well as tactical ones. Accounting for externalities is one of these signals.

The diffusion of sustainable energy forms meets with many barriers, which in a certain sense can be refered to an insufficient or improper functioning of the market. The application of these principles meets a number of barriers, most of which have been identified since quite a long time. One of the most important barrier is the subsidy given by many governments to traditional forms of energy. Once recognized the importance of energy for development, many governments subsidize electricity or various fuels, so that their price to the final consumer is lower than the cost of production and delivery. In many developing countries, energy prices and tariffs are much lower than in industrialised countries, although the cost of producing and delivering energy is by no means lower. This has the double effect of discouraging energy conservation, by making interventions to increase efficiency artificially more expensive than the energy which is saved, and of creating a barrier to the introduction of new forms of energy, renewables in particular, which are not equally subsidized. Moreover, it has been observed that this kind of incentives, originally meant to alleviate poverty, actually favour the richer layers of the population, which can afford consuming much more energy in any case.

Another barrier - which to some extent is common to industrialized countries - is the dispersion of interventions in energy efficiency and distributed energy generation, in particular by renewable sources. The financing of very large scale supply-side projects (a gigawatt-size hydroelectric or coal-powered or nuclear plant) can find capital for investment at much lower interest and longer return times than the corresponding hundred thousand small projects of micro-hydro or wind installation or efficiency improvement. Banks and financing agencies are generally not equipped to deal with a myriad of microprojects, so that aggregation of demand is a necessity if a "level playing field" is to be established for the different kinds of interventions.

Many more barriers have been identified. Norms and regulations are often not adapted to innovations in the energy field. There is a lack of information to the public of the possibilities offered by alternative energy sources and more efficient devices. Many solutions are not available because equipment is not being distributed by retailers due to the small size of the perceived market, to lack of knowledge or to inertia (for example, compact fluorescent lights). Another barrier is the lack of skills, not only for installation and maintenance, but also for marketing. Well known are many cases of projects financed by donor agencies which were technically and economically sound, but which were unsuccessful or even counterproductive because they were soon abandoned for lack of appropriate maintenance, unavailability of spare parts, or even ignorance about operational procedures. Even when a project is successful, there is often no capability of replicating and diffusing it.

Finally, as in most industrialised countries, externalities are not reflected in the price of energy. Although there is no clear consensus on the way in which this "internalization" should occur, and that it would not be fair to expect developing countries to precede advanced countries on this route, it is clear that a gradual introduction of externalities would greatly improve the prospects of increased energy efficiency and of renewable energy sources.

3 The Choice of the Right Technologies for Developing Countries

Some criticisms have been expressed by developing countries on projects sponsored by donor agencies in the energy field which, they thought, were intended mostly for testing new technologies that had found no application in the countries of origin and which, in many cases, proved to be unreliable or unsuitable or uneconomic. Although very few technologies are independent of context, and most require at least some adaptation to the conditions of the country or the site of application, the criticism does have some element of substance.

Much discussion has gone in the past into the choice of "appropriate technologies" for developing countries; originally, the concept of "appropriate" applied only to very simple technologies developed locally. This concept has been refuted successively for a number of reasons.

Although some energy technologies can be based on simple, locally developed know-how, in most cases they require some advanced and sophisticated technologies that are not universally available. Even mature technologies, such as large-scale hydroelectricity, require a number of accessory knowledge, ranging from organizational methods for large works to maintenance of construction equipment, from training of personnel to quality control and commissioning procedures. Simple, traditional techniques can be vastly improved by the grafting of advanced technology: an electronic control of temperature and humidity can prevent spoiling a crop in a solar or biomass fueled drier; modern computer-aided design methods have been successfully applied to improving the performance of traditional cooking fire-places. Gas turbines cannot be designed or manufactured everywhere; but many developing countries have shown to be able to maintain jet or turbo-propelled planes, and can do the same for power plants employing aeroderivative gas turbines.

The choice of a technology is more successful when it is made in a broader context, taking into due account the general energy policy of the country; the priorities and modalities of economic development; the social and cultural characteristics of the country or region for which it is meant; the geographic and climatic conditions of the site. These factors are now being included in the selection criteria of many donor or lending agencies, including UNDP, the World Bank and the European Commission.

Most energy technologies have been developed and are available only in industrialised countries, and respond to the requirements and specifications of these countries. A process of adaptation of the technology to the particular needs and conditions of the receiving country is necessary, if not sufficient. This process of adaptation should be conducted in large part by the receiving country itself. In general, it is highly desirable that the transfer of a certain technology in given country corresponds to a well identified need: in other words, that it derives from a "market pull" rather than from a "technology push." Developing countries shoud strive to set up a capability of comprehensive technology assessment.

A negative aspect in some past experiences of energy technology transfer has been the limitation of the trasfer to some intermediate phase of the process, generally manufacturing: this has little scope if it is not followed by system design, system assemply, operation, maintenance, servicing, infrastructure arrangements; and also marketing and financing are key factors for the application and diffusion of a technology. It has generally proved to be more effective to start at the downstream, application end of the technology and proceed upstream rather than viceversa.

Giving proper attention to locally developed traditional technology has often paid back. These technologies have often passed through a long process of adaptation to local conditions, and they may respond to specific needs that it is not always easy to identify. They are often ineffective and uncompetitive: but sometime they have shown to have the potential of great improvements. "Blending" new advanced technologies into traditional systems may provide solutions which, while respecting local conditions and adapting to actual needs, are effective, economical and diffusible. Many examples are available, ranging from large earth dams to woodstoves. A further penetration of new technologies may involve the use of advanced materials in traditional ways of producing or using energy. Genetically engineered bacteria can be introduced in a traditional biochemical process (such as the production of alcohol or biogas by fermentation). Electronic control can be inserted to improve performance and facilitate operation and maintenance of a traditional process. Such a component can be seen as a "black box": it is not necessary for the operator to be familiar with its internal mechanism, provided its functions are well understood.

A concept which has been introduced concerning the choice of technology for developing countries is the so-called "leapfrogging," i.e. the direct adoption of an advanced technology without going through the intermediate steps, and even of technologies which have not been generally adopted in industrialised countries. The subject is delicate and has roused some controversy. It is quite obvious that it would not make any sense for a country aiming at producing computers to start building the electronic tube computers of the 1950's or the transistors or the integrated circuits of the following decades before adopting the microchip. On the other hand, looking for very advanced technology to solve a problem is sometime an excuse for not being able to fix a much simpler solution well at hand.

Leapfrogging makes sense when the developing country is not committed to particular solutions by its previous history, and can therefore make a choice less conditioned than an industrialised country. The most common case is the absence of infrastructures. As the prime choice in a sparsely-inhabited country that would set up a telephone system from zero would be to use cellular phones and radio links rather than setting up a wired network, so in the absence of an electricity grid, local generation may well be the most appropriate and economical answer for electrification. A survey conducted some time ago in Central Africa on the emerging technology perceived as the most useful for the region, saw at the first place the development of Zeppelins for transportation of goods: significantly, this is the transport technology that requires the minimum of infrastructure.

Another element which can possibly favour leapfrogging is the absence of previous investments, in terms of both money and cumulated experience. Certain technologies are used today in industrialised countries with preference to potentially more effective ones because of the great amount of money that has gone into building plants and equipment in former years and of the cumulated know-how. When starting from zero, it may be convenient to look for alternative technologies, more effective and perhaps less capital-intensive, which have become available in the meantime, and which have not been adopted on a large scale because of the reasons just mentioned.

Finally, a possibility of utilising relatively new technology comes from the fact that the market for many goods is expanding rapidly in developing countries, while it is stationary or shrinking in industrialised countries. One case-show example is steel making; essentially no new steel making plant has been commissioned in industrialised countries in the last decade, as steel consumption is slowly decreasing, while several new plants are set up every year in developing countries. New steel-making technologies have been developed up to the pilot scale which are less energy consuming and require less investment, but never applied on full scale yet; this may be an occasion for developing countries (and is actually being considered by China).

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DOMESTIC SOLAR SPACE HEATING IN MONGOLIA: DESIGN AND DEMONSTRATION

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Abstract

This paper discusses the work of a project involving collaboration between the Centre for Environmental Technology at Imperial College, London, and Dr. Galbaatar and 'Vertical' construction company in Mongolia. The project was to design and construct a demonstration house in Ulaanbaatar which optimises solar energy gains and hence minimises reliance on conventional fuels as a source of heat, by incorporating energy efficient techniques and passive solar elements into its design.
Mongolia is exposed to exceptional levels of solar radiation, but also temperatures which drop to -30℃. Consequently, there is great potential for utilising the solar energy for passive heating. This is particularly pertinent since the power stations of Ulaanbaatar are suffering from excessive loads, and new built houses will no longer be connected to the district central heating system.
The project comprises two parts:
1. *An investigation into the feasibility of domestic solar space heating in Mongolia. This was carried out at Imperial College.*
2. *The construction of a house in Ulaanbaatar, built according to the recommendations of (1). This is convened by Dr. Galbaatar and is currently under development.*

The paper describes the methodologies and results of (1) and describes the development to date of the demonstration house.

1 Introduction

Due to the relatively high contribution of the domestic sector to energy consumption, energy efficient measures can be effectively applied to this area. Mongolia has been recognised as one particular example where renewable resources and energy conservation may have great potential in domestic properties.

The task is to build a demonstration house in Ulaanbaatar which minimises its reliance on conventional fuels as a source of heat. In order to achieve this, it will employ energy efficient techniques and passive solar elements, which will respectively reduce the total heating demand and allow the sun to provide a greater than usual proportion of the heating requirement.

A feasibility assessment of the demonstration house was carried out with respect to energy performance and economic viability. This is a crucial process on which the success of the project relies, as the design needs to be tailored to the conditions in Mongolia. The assessment was achieved through the development of a computer model quantifying the solar gains and heat losses for a house of specified configuration, from which the total auxiliary heating requirement was deduced. The aim was to determine the configuration which offers the best energy performance whilst also being economically feasible.

Construction of the demonstration house is currently under development. Monitoring of the energy demand of the house will occur over the annual period following its completion. Successful completion of the project will lead to production on a larger scale.

The paper begins with a brief overview of the concept of domestic solar and energy efficient design of buildings. The current situation in Mongolia is examined with respect to assessing the suitability of this energy conserving technique for local dwellings. The aims of the model and its intended benefits are described. In the penultimate section, the results of the model are described. Finally, the potential of the model as a design tool and evaluator of energy performance is discussed at the end.

2 The Project: Purpose and Motivation

In cooler climates, energy expended on space heating can represent a significant proportion of total energy consumed by a dwelling. Steps can be taken to reduce this considerably through the employment of certain design techniques. Mongolia is one example of where there would appear to be great potential for utilising renewable resources and energy conservation in domestic properties: owing to the country's high elevation (averaging 1580m), Mongolia is exposed to exceptional levels of solar radiation (between 3-8kWh/m^2/day), but also temperatures which can drop to -30°C. In fact, the highest levels of radiation occur during the cloudless winter months, since the rainy season occurs during the summer. Consequently, a potential for utilising the abundant solar energy for heating houses is recognised, and motivation is provided by a particular problem which is presently facing the power supply of the country: the power stations of Ulaanbaatar are suffering from high loads as the population and development within the city increase. Moreover, hot water and central heating will not be available to new houses as they will not be connected to the district central heating system that is linked with the power station.

3 The Relevance of Domestic Solar Space Heating

What contribution do domestic buildings, and particularly their heating, have to energy consumption? In the UK and USA about a third of the total energy consumption is in domestic buildings. Correspondingly, it has been estimated that almost a third of UK CO_2 production results from energy use in housing. Within houses, space heating is the most significant end use, accounting for over 60% of the delivered energy and over 40% of energy costs in developed countries.

Although there is much scope for the reduction of energy use in all sectors, great potential can be seen to lie in the domestic sector. And because building stock has a much longer useful life than other large consumers of energy, energy efficiency is important, not just in the

management of the building, but also in its design and construction. Additionally, implementation in this sector incurs little extra expense, and can be introduced gradually due to the small scales involved.
It is now being slowly recognised that it can be greatly beneficial to occupants in the long term to take optimal advantage of a building's environment in its design and construction. If this approach is performed properly, past experience has shown that it is possible to reduce the energy consumption due to domestic space and water heating by as much as 50%, with solar energy providing up to a third of the heating requirement. The effect of energy conservation is to shorten the length of the heating season and reduce the heating load at any time.
Introducing energy conserving measures inevitably incur higher capital costs. However, over the lifetime of the building, these initial costs are likely to be off-set by the inevitable advantages for the occupiers, including reduced running costs and a diminished need for artificial lighting, and, of course, the consequential benefits for the environment. These trade-offs need to be fully analysed in the feasibility assessment.

3.1 Solar and Energy Efficient Design in Houses

The challenge is to design a house which meets the needs of the occupants in terms of thermal and visual comfort, whilst simultaneously requiring less auxiliary energy to achieve this, and consequently having a reduced impact on the environment.
First we need to understand the energy processes involved in order to be able to control them. Heat is lost from a building via conduction through its exterior walls and windows and via exchanges of air between the building and its surroundings. It is not possible to eliminate these losses. A house in cold weather will always cool to the same temperature as outdoors. The important issue is the amount of fuel needed to maintain it at the desired temperature.
Practically every decision in the design of the house affects the amount of energy consumed. Therefore, it is important to take energy efficiency into consideration at every stage of the design process. Aspects fundamental in the design of an energy efficient house include the site layout and orientation, the building form and internal layout, insulation properties, control of infiltration and ventilation, and passive solar design.
The precise details of the house design will depend on the individual context, such as the local climate and these are determined with use of the computer model developed.

4 The Mongolia Context

The current energy supply system was established by the Russians as part of their centralised planning ideals and it has many disadvantages. In particular, it is extremely inefficient, there is a lack in control of the temperature of the hot water and although the electricity is metered, the hot water is not. Both electricity and hot water are heavily subsidised, with electricity costing about 3p/kWh, and hot water and heating costs being negligible. With this charging structure, energy conservation is not encouraged and the lack of control and metering makes it impossible. There is capacity for reform and improvement with the new Government of Mongolia's intentions to gradually abolish the subsidies on energy, starting with those on heating and hot water.
Apartments in Ulaanbaatar, particularly those built in the 1960s are poorly constructed, with associated low levels of insulation and high infiltration rates, both leading to a high rate of loss of the heat indoors to the surroundings.
In Mongolia, new building methods and materials have only recently become available. Previously all construction materials had to be imported from Russia. Now, however, Mongolia is producing some of its own insulation materials, including ceramic, fibreglass, a

material comprising a mixture of sand and chalk with a cavity, and coal ash, evacuated double glazing is only now being introduced.
In view of the expanding population and the increasing urbanisation of Mongolia, energy efficient housing could play an important role in supplementing and substituting present Russian built apartments and the gers (traditional nomadic tents). Accompanying the development of Ulaanbaatar, there has been a recent desire to move away from gers and apartments towards a more western style dwelling. Despite the economies of scale that apartments offer, solar space heating, supplemented with auxiliary heating, could be a more economic alternative to the present habitats and certainly to the heating of a new house entirely with fossil fuels.

5 Model and Design of the House

An investigation into the feasibility of domestic solar space heating in Mongolia was carried out at Imperial College with the development of a generic domestic energy model which was subsequently applied to the specific case of Mongolia. This was done to aid the achievement of the optimal design for a dwelling in Ulaanbaatar which will be both the most energy efficient and the most cost-effective.

5.1 Aims of the Model

The demand is for a generic model which gives outputs relating to the energy and economic performance of a building of specified built form subject to certain climatic conditions, which can then be applied to the Mongolian context.
The form of the generic model can be schematically represented as shown in Figure 1.

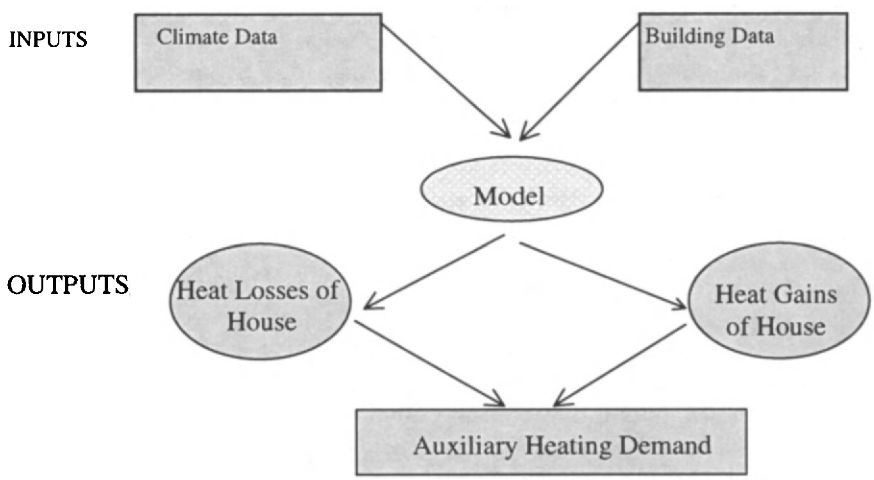

Figure 1: *A Schematic Representation of the Model*

5.2 Inputs and Outputs of the Model

The energy demand of a building is dependent on the interactions between the outside climate, the building envelope, and the internal loads. Therefore, details on these aspects are required as inputs to the model. The interactions comprise two processes, as illustrated in Figure 1. These are the rate of heat loss from the house and the rate of heat gained by it. The inputs required to quantify these two processes can be divided into two categories; climatic

inputs and building inputs. Climatic inputs include data on local solar radiation and outdoor temperature. Building inputs include dimensions of exterior facades, desired indoor temperature, infiltration rate, thickness of wall insulation, U-values of building materials, desired window areas, transmission and insulation properties of glazing and roof inclination.
Outputs of the model can be divided into two categories; those relating to the internal temperature of the house and those quantifying the heating supply and demand. The latter comprise of total heating demand, solar gains to house and auxiliary heating demand (equal to the difference of the previous two), and percentage of total heat load provided by solar gains, each in hourly, daily and annual units.
In order to achieve a level of accuracy and outputs of most interest, hourly outputs were chosen to be the most preferable option. However, the computer power available was insufficient to run the model on an hourly basis. Therefore, we chose to work with hourly data of every fifth day of the year. We decided that this procedure maintained the desired accuracy in the time scale of the model, whilst significantly reducing the strain on the computer.

5.3 Applying the Model to Mongolia

The company ABE worked in collaboration with Vertical to determine the basic structure and design of the house. The house will face south and have a length of 10m, a width of 7m and a height, excluding roof, of 3m. The intention is to build the house of brick with a central cavity filled with fibreglass, where the thickness of this insulation layer was to be determined using optimisation procedures in the domestic energy model. The window will comprise of three layers of glazing - one evacuated double glazed window and one single glazed window. This represents the best technology available to Mongolia. A veranda along the whole of the south facade of the house was proposed.
Because extra heating is essential and the demand for it will be potentially high, we are less concerned about the capital cost of the whole system than we are the long-term effectiveness of it. The most likely form of heating would be a coal or wood fuelled stove.

6 Results

The computational analysis has shown that the domestic design configuration predicted to give optimum energy performance and cost-effectiveness will consume around 16 MWh of auxiliary heating a year. This configuration allows solar gains to contribute to over 30% of the house's total heating requirements. However, the model assumes no storage of heat. Storage of some of the excess solar gains is highly probable and a fraction of this is likely to be re-radiated into the house at a later time in the day when it is required. Therefore, we can assume that the original result for the auxiliary heating demand of 16 MWh per annum is an over-estimate, and in reality the requirement will be lower.

6.1 Results of Optimisation

6.1.1 Roof Collector

A roof collector was found to be economically unfeasible, as it would be an all round consumer of energy. Because the roof is a significant source of heat loss, it is beneficial to install high levels of insulation here, and the solar gains from a roof collector, even with high levels of night insulation, can never exceed the losses. Minimising heat loss through the roof is achieved through reduction of the surface area and occurs at a minimum angle of inclination. For practical purposes, we chose the south and north aspects to be both inclined at 5° to the horizontal.

6.1.2 Window Size and Additional Night Insulation

Feasibility of the house's second passive solar element, the south facing window, was tested using two forms of analysis; one optimising the energy performance of the windows and the other an economic optimisation.

As window size increases solar gains to the house also increase, yet so do heat losses, as windows are less insulated than the walls. This trade-off effect was investigated by calculating the annual auxiliary heating load for increasing south window with varying levels of integrated night insulation, as measured by U-values. The results are graphed in Figure 2.

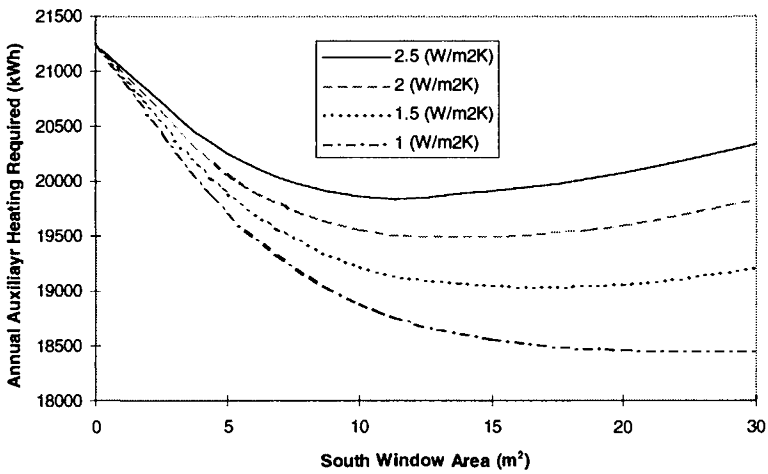

Figure 2: *Annual Auxiliary Heating Load against South Window Area for Various Levels of Night Window Insulation*

Additional insulation applied to the windows at night can be seen to make a large difference to the energy consumption of the house.

The window size which offers optimal energy performance can be seen to be highly dependent on the extent to which the window can be insulated at night.

The economic optimisation was then carried out. An illustration of how this was done is given in Figure 3, for the example of a night U-value of 1 W/m2K. In this instance, the optimal window area can be seen to be about 8 m^2.

The economic investigation was performed assuming that; the cost of fuel was £0.04/kWh, the discount rate was 10%, the fuel price escalation rate was 5% and that the secondary-glazed double glazing, which is to be installed in the demonstration house, costs £50/m^2.

6.1.3 Level of Wall Insulation

Heat losses from the house continue to reduce with increasing levels of insulation. However, an economic optimal configuration does exist, as at some point the cost of installing extra insulation will overcome the cost of the auxiliary heating that is saved. The results of the analysis deriving this point are illustrated in Figure 4.

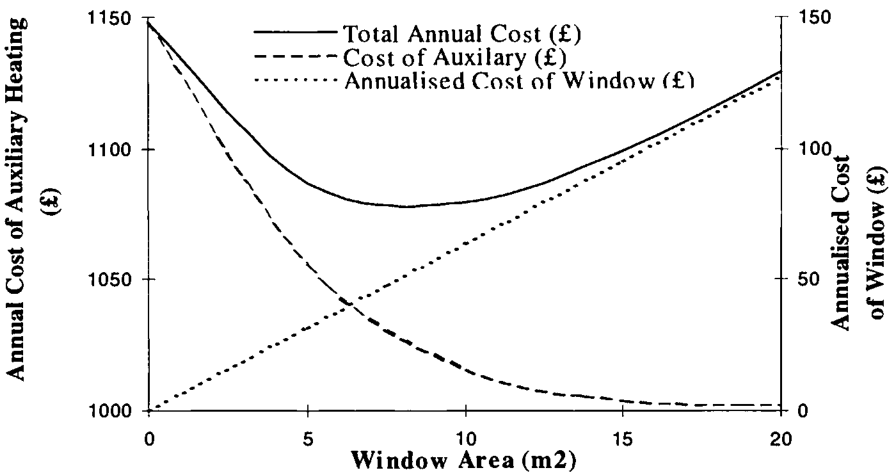

Figure 3: *Total Annual Costs against Window Area for a Window (with additional night insulation of 1W/m²K)*

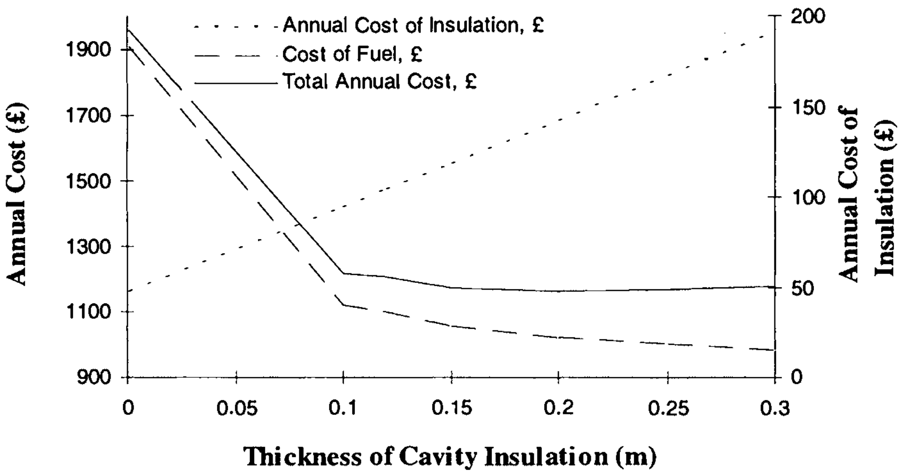

Figure 4: *Annual Cost of Heating and Insulation for Varying Levels of Wall Insulation*

Figure 4 displays two fundamental results. The first is that the first 10cm of fibreglass insulation installed in the wall cavity has the greatest effect on the reduction of the annual auxiliary heating demand. This is due to the non-linear way that the U-values of different materials combine. The second significant result that is illustrated by the graph, is the dip in the total annual cost, indicating the economic optimal thickness of fibreglass, and this occurs at about 20cm.

It was recommended that a glazed veranda was constructed on the south side of the house. This acts as a buffer space; decreasing the temperature gradient across the south wall of the house, resulting in a reduction in the rate of heat loss at all times.

After optimising the energy performance and cost-effectiveness of the main design components of the house, we have obtained the following results:

- With the technology that is available in Mongolia, a roof collector is an unfeasible passive solar element, and therefore, will not be incorporated into the house design.

- It is recommended that additional insulation is applied to all of the windows to reduce the U-value to 0.5 W/m^2K at night. This can be achieved using a layer of polystyrene 5cm thick.
- It is recommended that the south windows of the house cover a surface area of $15m^2$, which is equivalent to 50% of the area of the south wall.
- A layer of fibreglass, 20cm thick is recommended for the cavities of the exterior walls.

6.1.4 An Overall Look at the Annual Heating Demand and Solar Gains

What is the predicted total heating demand of the house, how much of this can be provided by the sun, and what amount of auxiliary heating needed to satisfy the remaining requirement? Figure 5 illustrates distributions of daily solar gain and total demand for heat throughout the year. The auxiliary heating requirement is the difference between the curves, indicated by areas marked 'A'. This graph shows that the heating gains provided by the sun are of a roughly equal magnitude throughout the year, due to the nature of the local insolation rates. The form of the heating demand distribution is as to be expected; peaking in the winter and reaching its nadir during the summer. The graph also tells us that the main heating season of the house occurs between the end of October and the end of March. It does not, however, allow us to know to daily variations in demand. The absolute amount of auxiliary heating required over the year was calculated by summing the auxiliary heating required in each hour throughout the year. This calculation shows us that night heating is required during the months of April, May and September.

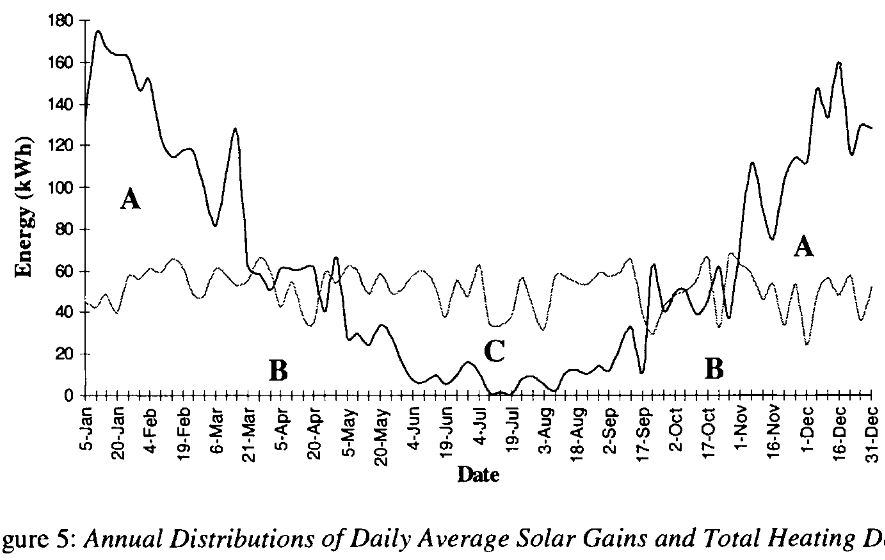

Figure 5: *Annual Distributions of Daily Average Solar Gains and Total Heating Demand*

6.1.5 The Savings in Energy Due to the Installation of Energy Efficient Measures

It is of interest for us to appreciate the order of effectiveness of the energy efficient and passive solar measures incorporated into the design of the house. Figure 6 illustrates the quantity of the savings resulting from the introduction of these measures.
Figure 6 clearly indicates that the reduction of the rate of infiltration is fundamental in the saving of auxiliary heating. The second most important step can be seen to be that of insulating the walls and reducing the indoor temperature of the house has a considerable effect on the auxiliary heating demand. It has been suggested by ABE. Co. Ltd that the demonstration house be kept at a constant temperature of 22°. By decreasing this to 18°

during the day and 16° at night, which is conventionally considered satisfactory, 4 MWh can be saved in the annual auxiliary heating load.

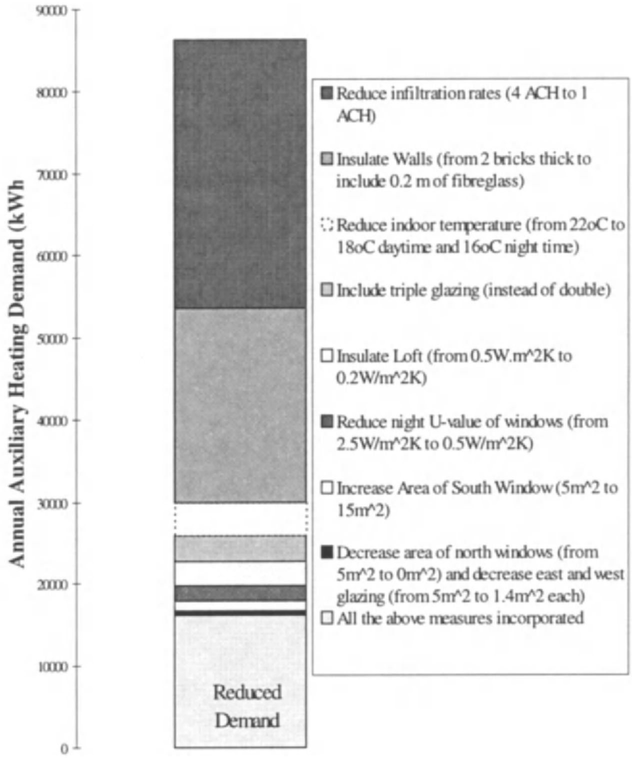

Figure 6: *Potential Contribution of Various Energy Efficient Techniques to Reduction in Annual Auxiliary Heating Demand*

We can see that after the orientation and layout of the house has been stipulated, control of infiltration and applying good insulation are the most essential techniques to be considered in energy conscious design. The installation of all of the above measures result in a total saving of almost 70 MWh a year.

7 Conclusion

7.1 The Capabilities of the Model

A generic domestic energy model has been developed and applied to the specific context of a house in Ulaanbaatar. The model can be installed on a PC and easily used by the non-specialist. It can be used as a design tool or assessment procedure and applied to buildings anywhere in the world for where the appropriate data is available.

7.2 Application of the Model to the House in Mongolia

At present, the model is installed and in operation in Mongolia. The model has been applied to the demonstration house, in order to assess its viability as an energy efficient and solar space heated house. Our work has lead us to believe that, assuming the house can be built and sold for a price affordable to inhabitants of Ulaanbaatar, the house will be viable and the

project should be a success. And in view of the expanding population and increasing urbanisation in Mongolia, solar space heated houses could play an important role in substituting and supplementing the present housing stock of Ulaanbaatar, although their success in other parts of Mongolia is doubtful due to the lack of maintenance infrastructure.
The incorporation of the above standards, allows solar gains to supply over 30% of the total heating demand, with the auxiliary heating being responsible for the remaining 16 MWh of the annual load. This is commendable when compared to an average three bedroom, detached house in England, which consumes about 20 MWh a year due to space heating [Allen, 1994].
In order to minimise heat losses from the heated space, there are a few factors that need to be carefully considered throughout the construction phase of the house. Particular attention needs to be paid to the built envelope of the house with respect to the potential leakage of air. For similar reasons, it is important to insulate the roof and exterior walls sufficiently. Windows should incorporate the best available technology, in this case, one layer of evacuated double glazing along with an adjacent pane. Additional insulation should be applied to the windows at night. The highest levels of insulations that are economically feasible should be applied.
A final assessment of the feasibility of such houses in Mongolia can only be made via detailed monitoring of the house's energy consumption, along with the comparison of this data to the corresponding outputs of the model.
The above result for the predicted annual auxiliary load was obtained by expecting the residents of the house to comply with certain assumptions that were made in the model. This includes the application and removal of the night insulation for the windows at the appropriate times. A further aspect in the occupant's behaviour that could perturb the predicted results would be the excessive use of ventilation to the house. In order to minimise the disruptions to the energy conserving plan, the inhabitants will need to fully understand and appreciate the impact of their management of their house, and how deviations from that recommended would influence the energy consumption.

7.3 Future Work

Future work would focus on increasing the accuracy of the model's inputs and outputs. This would include further developing the model to incorporate heat storage and consequently into the structure of the house. A more thorough investigation would adapt the design and form of the house and conservatory to protect against over heating.
In order to assess the true viability of energy-efficient and solar space heated homes in Mongolia, research would need to be carried out on a broader level. This would include an investigation on the demand for such houses in Mongolia, a deeper understanding of the economic and political prospects for the country, and future availability of electricity and hot water. However, the scope of this project was to investigate the feasibility of solar-space heating a particular house in Mongolia, and to this extent we have predicted success.

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ENVIRONMENTAL PROTECTION THROUGH SELF-POWERED PLANTS FOR ISOLATED COMMUNITIES

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Abstract

The possibility exists of creating wastewater-treatment systems with very low levels of energy consumption for areas with particularly high requirements from the environmental standpoint.
One low-energy system for small communities capable of meeting effluent standards involves the use of an Imhoff tank followed by a rotating biological contactor (RBC) and by another settling tank.
In such a system, the only energy consumption involved is connected with the rotation of the biological contactor disks. This energy requirement can be met by a system transforming solar energy into electricity by means of photovoltaic cells. The other phases of treatment involve gravity flow and settling and hence require no further energy, it being possible to harness gravity also for the extraction of sludge to be dried on drying beds.
One further advantage of such a unit lies in the reduced environmental impact involved, making an attractive option for use in parks or protected areas.

1 The Waste Treatment for Isolated Communities

The high costs involved in laying sewer trunk lines for centralized wastewater treatment and the substantial number of small, isolated residential, commercial and recreational centres as yet not equipped with suitable wastewater collection and processing systems make small wastewater treatment plants an undoubtedly interesting technological alternative. In addition to their practical simplicity (suffice it to consider the natural-type systems), fresh interest has been focused on small treatment plants employing complex technology (activated sludge or attached biomass) as a result of the increasing availability of reliable technologies for plant automation and remote control. This has made it possible to eliminate one of the main problems associated with small plants, i.e. operational discontinuity, and to design centralized control systems offering suitable economies of scale [1-10].
Attached biomass systems using rotating biological contactors (biodisks) prove to be particularly advantageous, above all with regard to energy.

Easy to construct and operate if compared with the activated sludge systems (see figure 1) , such systems can be used to treat the wastewater of isolated communities, using solar energy to supply their limited requirements.
Factors effecting the removal efficiency of RBC systems include the type and concentration of organics presents, hydraulic residence time, rotational speed, media surface area exposed and submerged, and pre- and post-treatment activities [11].

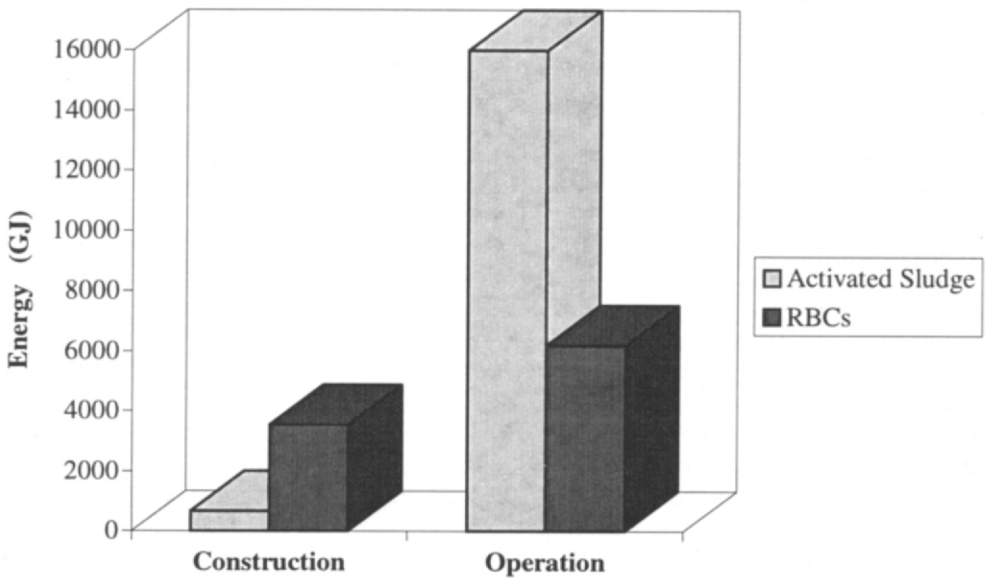

Figure 1: *Construction and Operation Costs for Activated Sludge and RBCs System. (Re-elaboration after [9])*

2 The Solar Energy

The use of solar energy is limited by its intermittent nature due to the alternation of night and day, to climatic and seasonal factors, and to low energy density at ground level (the maximum values being about 1 kW/m^2).

The heat of the sun can be used directly or through the transformation of solar energy into electricity.
The process is based on the photovoltaic effect arising from the properties of certain semi-conductors (including silicon, an element abundantly present in nature), which prove capable, after suitable treatment, of generating voltage when exposed to solar radiation.
The most elementary device capable of effecting this conversion is the photovoltaic cell, which typically generates 1-1.5 W when exposed to a radiation of 1000 W/m^2. Photovoltaic cells are assembled in modules. Each module consists of 36 cells and has a surface area of about 0.5 m^2.
The quantity of energy generated varies in the course of the year and depends on the site where the cell is installed. Irradiation is related to orientation and can be optimized by arranging the modules for a southern exposure and setting an angle of inclination or tilt with respect to the horizon according to latitude.

3 Technology Description

A typical RBC unit consists of plastic discs mounted along a horizontal shaft. The total disc surface area is normally 100,000 square feet for a standard unit and 150,000 square feet for a high density unit.
As the RBC slowly rotates through the ground water or leachate at 1.5 rpm, a microbial slime forms on the discs. These microorganisms degrade the organic and nitrogenous contaminants present in the waste stream. During rotation, approximately 40 percent of the discs' surface area is in contact with the aqueous waste while the remaining surface area is exposed to the atmosphere. The rotation of the media through the atmosphere causes the oxygenation of the attached organisms. When operated properly, the shearing motion of the discs through the aqueous waste causes excess biomass to shear off at a steady rate. Suspended Biological solids are carried through the successive stages before entering the secondary clarifier.
The RBC treatment process proposed is illustrated in figure 2. It may involve a variety of step: aqueous waste is transferred from a storage or equalization tank to a Imhoff tank where chemicals may be added for metals precipitation, nutrient adjustment, and pH control. In the tank the solids are separated from the liquid. The effluent from the clarifier enters the RBC where the organics and/or ammonia are converted to innocuous products [12].
The treated waste is then sent into a secondary clarifier for removal of the biological solids. After secondary clarification the effluent enters a storage tank where, depending upon the contamination remaining in the effluent, the waste may be stored pending additional treatment or discharged to a sewer system or surface stream.
Staging, which employs a number of RBCs in series, enhances the biochemical kinetics and establishes selective biological cultures acclimated to successively decreasing organic loadings. As the waste stream passes from stage to stage, progressively increasing levels of treatment occur.
In addition to maximizing the systems efficiency, staging can improve the systems ability to handle shock loads by absorbing the impact of a shock load in the initial stages, thereby enabling subsequent stages to operate until the affected stages recover.

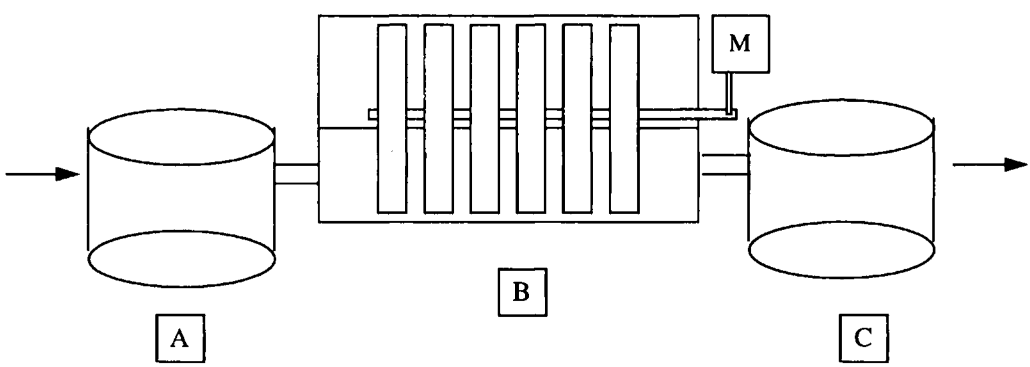

Figure 2: *Plant Skim (A: Imhoff tank, B: RBC system, C: Secondary settler; M: motor)*

4 Energy Consumption

In the system described above it can be supposed that the unique energy consumption is due to the biodisks rotation.

Considering a typical RBC system for 100 equivalent inhabitants the system requires an installed power capacity of about 0.37 kW.
The annual consumption of energy associated with such a system, operating 24 hours a day every day, is equal to 3241.2 KWh/year.
The energy output of a photovoltaic plant can be calculated by multiplying the voltage by the equivalent-hours of exploitation. The latter figure depends on irradiation and is thus strongly influenced by location [13].
We can therefore write:

Output (kWh/year) = Voltage (kW) x Equivalent-hours (2000 h/year). (1)

From equation (1) it follows that the power required if a photovoltaic plant is to supply the consumption needs of the biodisk system (RBC unit) is equal to 1.6 kW.
Given that a standard module (consisting of an assemblage of 36 cells) has a surface of 0.5 m^2 and generates about 50 W in optimal conditions, it is an easy matter to deduce that the energy demand is satisfied by a system of about 50 modules or 25 m^2 of solar panels.
This energy consumption can be reduced by using a double speed rotation system for the discs: in such a way in the night time, in conditions of low organic loadings, it can be assured a slower rotation speed for the discs (in order to avoid the anoxic conditions for the biomass), and consequently a little energy consumption. This solution can allow a reduction of the required solar panels surface up to the 30%.

5 Conclusions

The system proposed is structured in such a way as to minimize energy consumption. If the wastewater is transferred from the Imhoff tank to the RBC unit by means of bucket elevators driven by the rotation of the shaft to which the biodisks are attached, and if the wastewater itself arrives at the secondary sedimentation tank or clarifier by gravity, the only energy consumed is that required to drive the biodisks.
Roughly 25 m^2 of solar panels prove necessary for a system of this type designed to serve a population of 100 inhabitants.
As the biodisks must be kept functioning continuously, it will be necessary to install a system of rechargeable storage batteries to guarantee the supply of electricity also during the night hours or when the insolation is insufficient.
These must be sized in such a way as to ensure autonomous functioning for a number of days (at least two).

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MODELLING OF A HYBRID WATER HEATING SYSTEM FOR USING THE RURAL CENTER OF MONGOLIA

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Abstract

In this paper was presented the results of research work that to decade of energy supplement of rural centres in Mongolia for using hybrid water heating system by electricity and heat which has included solar and steam generator on based coal burning system.It has also shown that economical and ecological analysis of hybrid water heating system for climatic conditions of Mongolia.

1 Introduction of Energy Scenario

Mongolia has developed energy production based on coal burning thermal power plants.There are 6 major thermal power plants:3 of them are situated in Ulaanbaatar with capacity of 21 MW,134MW and 560 MW, and the others in Darhan,Choibalsan and Erdenet cities with capacities of 48MW,48MWand 36 MW,respectively.The Central Energy System provides power supply to one third of the territory and half of the population of the country.

In the eleven province centres there are 160 diesel stations with the capacity of 630-1800 KW and 300 soums (like villages) have about 600 small diesel generators with a capacity of 60-100 KW.There are also about 1000 steam generators and heating stoves namely DKBR,KBTS and KE with a capacity of 2.5-10 tonne per hour and NR-18-27,NR-18-54,BZUI-100 and S-240 with a capacity of 27-240 tonne per square meter of unit heating surface.[2]

In the rural area, where living about 200 thousand stock-breeder families of whom get electric power from small petrol,wind and solar PV generators.

Conventional heating system is water heating system on based coal burning. Mongolia has large reserves of coal .The rate of production and consumption of coal are very high compared with population.The total commercial energy production and consumption per capita in Mongolia are about 3000 kg coal equivalent only used coal.It means that Mongolian energy consumption is phase of mass consumption .Therefore,we have a constraint with economical and ecological reducing of coal consumption per capita.[1]

From above data redarding availibity of conventional fuel particularly coal in Mongolia will decrease in coming years due to rise in population .Hence,there is a strong need to find out solution to meet the increasing demand through solar energy.Solar energy is freely available and pollution free.

2 Hybrid Water Heating System

The basic thermal process for hybrid water heating system is shown in a simplified schematic in Figure.1.

Turbine -- Generator
Solar collector -- Storage -- Boiler --
Condenser -- Rural center heating system

Figure 1: *Hybrid Water Heating System*

Energy is collected by either flat plate or high operating temperatures collectors, stored and then used to operate a turbine.The maximum operating temperature for flat plate collectors are low relative to desirable input temperatures for turbines,and system efficiencies are low if flat plate collectors are used .Normally a boiler uses feed water from $5^{o}C$ to $100^{o}C$ and then this hot water is converted to steam .[3] It was decided to save this fuel by heating the feed water to higher temperature with the help of solar power. Feed water circulation was selected as closed loop forced circulation system. A storage tank of certain litres capacity was chosen from heating load.
According to the circulation of water through collector when water temperature increases.[4]

The water temperature depends of type of collector. The comparative instantaneous thermal efficiency results of one type flat plate collector,those have been manufactured in Mongolia ($F'\eta_o$=0.54 and $-F^{I}U_L$=-5.7) and an evacuated tube collector from Germany ($F_R(\tau\alpha)$=0.728 and $-F_RU_L$=-3.34) for heating the feed water of boiler are shown in Table.1.[1]
The Table.1 tells some important results for us:

* As per requirement ,feed water temperature of boiler is more than $100^{o}C$,the flat plate collector can't produce useful heat

- In summer ,the evacuated tube collector produces steam but its efficiency is very low
- As per requirement ,feed water temperature is low ,the evacuated tube collector generates hot water during whole year.Especially in summer its efficiency is very high

3 Economic Analysis

The use of solar hot water system depends on its cost effectiveness.The increase in the prices of conventional fuels is an important point to be considered while examining the viability of solar systems.In financial terms, an investment is made towards the cost of a solar system to reduce the recurring expenditure on energy bills.[5]
The return on investment will,therefore,depend on the savings in energy bills an the higher cost of conventional fuels. The economics of a solar system can be booked at in different angles:

- In the present context of increasing cost of energy and energy shortages,the other alternative ,apart from energy conservation
is the application of renewable energy sources like solar energy, etc.,whose operating costs are very little or nil.
- Solar systems do not pollute the environment, as no fuels are burned in such a system. This is very important ,in the light of the present high levels of atmospheric pollution.

Solar water heating system to give 10000 litre per day of hot water at 70 °C from 20 °C supplementing and coal fired boiler for boiler feed water.

Assumptions

Calorific value of coal : 3500 Kcal/kg
Cost of coal : 20000 tugric
Efficiency of coal fired boiler : 40%
Savings in coal consumption /day:

$$\frac{1\,\text{Kcal/kg}\,^{\circ}\text{C} * 10000 * 10^{-3}\,\text{m}^3\,10^3\text{kg/m}^3 (70\,^{\circ}\text{C} - 20\,^{\circ}\text{C})}{3500\,\text{Kcal/kg} * 0.4} = 357\ \text{kg/day}$$

Based on 330 solar days/year.,cost of coal save at 20 per kg

330 * 357 * 20 = 2356200 tugric

Savings in coal consumption /year

365 * 357 kg = 130305 kg/year

Saving in energy/ yr:

130305 * 3500 = 456067500 Kcal = 547281 KWh

1KWh produces (coal) : 0.33 kg CO_2

Unpolluted CO_2 / yr : 180602.73 kg CO_2

Table.1.*The Comparative Instantaneous Thermal Efficiency*

Feed water temperature		150°C		130°C		110°C		90°C		70°C		50°C		30°C	
		ETC	FPC	ETC	FPC	ETC	FPC	ETC	FPC	ETC	FPC	ETC	FPC	ETC	FPC
Ta	It(W/m^2)														
	250	-1.54	-3.32	-1.28	-2.87	-1.01	-2.41	-0.74	-1.96	-0.47	-1.50	-0.21	-1..05	0.06	-0.60
-20	500	-0.40	-1.39	-0.27	-1.16	-0.14	-0.94	-0.01	-0.71	0.13	-0..48	0.26	-0.25	0.39	-0.03
	750	-0.03	-1.29	0.06	-0.60	0.15	-0.44	0.24	-0.29	0.33	-0.14	0.42	0.01	0.51	0.16
	1000	0.16	-0.43	0.23	-0.31	0.29	-0.20	0.36	-0.08	0.43	0.03	0.49	0.14	0.56	0.26
	250	-1.28	-2.87	-1.01	-2.41	-0.74	-1.96	-0.47	-1.50	-0.21	-1.05	0.06	-0.60	0.33	-0.14
0	500	-0.27	-1.16	-0.14	-0.94	-0.01	-0.71	0.13	-0.48	0.26	-0.25	0.39	-0.03	0.53	0.20
	750	0.06	-0.60	0.15	-0.44	0.24	-0.29	0.33	-0.14	0.42	0.01	0.51	0.16	0.59	0.31
	1000	0.23	-0.31	0.29	-0.20	0.36	-0.08	0.43	-0.03	0.49	0.14	0.56	0.26	0.63	0.37
	250	-1.01	-2.41	-0.74	-1.96	-0.47	-1.50	-0.21	-1.05	0.06	-0.60	0.33	-0.14	0.59	0.31
20	500	-0.14	-0.94	-0.01	-0.71	0.13	-0.48	0.26	-0.25	0.39	-0.03	0.53	0.20	0.66	0.43
	750	0.15	-0.44	0.24	-0.29	0.33	-0.14	0.42	0.01	0.51	0.16	0.59	0.31	0.68	0.46
	1000	0.29	-0.20	0.36	-0.08	0.43	-0.03	0.49	0.14	0.56	0.26	0.63	0.37	0.69	0.48

4 Conclusion

On the basis of above calculations, it is infrarred that solar water heating system will also help in reducing coal consumption and CO_2 level in atmosphere contrast to use of coal for water heating.

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MONGOLIA WIND RESOURCE ASSESSMENT PROJECT

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Abstract

The development of detailed, regional wind-resource assessment maps and reliable estimates of other pertinent wind resource characteristics (e.g., seasonal, diurnal, and directional) is an important step in planning and accelerating the deployment of wind energy systems. This paper summarizes the approach and methods being used to conduct a wind energy resource assessment of Mongolia. The primary goals of this project are to develop a comprehensive wind energy resource atlas of Mongolia and to establish a wind measurement program in specific regions of Mongolia to identify prospective sites for wind energy projects and to help validate some of the wind resource estimates. The Mongolian wind resource atlas will include detailed, computerized wind power maps and other valuable wind resource characteristic information for the different regions of Mongolia.

1 Introduction

The U.S. Agency for International Development and the U.S. Department of Energy are sponsoring a program to help accelerate the use of wind energy technology in Mongolia. A key component of this program is a wind resource assessment project that will define the level of wind resource present across the different regions of Mongolia. The U.S. National Renewable Energy Laboratory (NREL) has the lead responsibility to conduct the wind resource assessment project. The Mongolian organizations participating in this project are the Scientific, Production, and Trade Corporation for Renewable Energy (REC) and the Institute of Meteorology and Hydrology (IMH).

The primary goals of this project are (1) to develop a wind energy resource atlas that depicts the estimated distribution of the wind resource in Mongolia, and (2) to establish a wind measurement program to identify prospective sites for wind energy projects and help validate some of the wind resource estimates. The atlas will include estimates of wind speeds and wind power densities on annual and monthly bases, prevailing wind directions, frequency distributions of wind speed (or Weibull k shape parameter), and diurnal and interannual variability of the wind characteristics.

IMH, who collects and archives the meteorological data in Mongolia, is responsible for preparing various types of specific meteorological data for use in the project and will be assisting NREL in the interpretation and analysis of these data. NREL is also using meteorological data obtained from other sources, such as surface and upper-air data transmitted via the Global Telecommunications System network (GTS) of the World Meteorological Organization. REC is primarily responsible for coordinating the wind monitoring activities in Mongolia, including identification of initial sites, installation of the measurement systems, and collection of the data. All the wind measurement equipment for the project is being provided by NREL.
The project began in October 1997. The wind resource atlas is scheduled for completion in October 1999. The wind monitoring activities may continue for an additional year after the completion of the atlas.

2 Project Activities – Wind Mapping and Atlas Development

Creation of the wind resource atlas will be accomplished by three primary project activities: (1) collection of existing data and information required for the study, (2) processing and analysis of the data to evaluate and characterize the wind resource, and (3) development of the wind resource maps and preparation of the atlas.

2.1 Data Collection

NREL has acquired, as part of its global database, considerable meteorological data from U.S. sources for areas in and near Mongolia. These include surface observations from the period 1973-1996 for stations that transmitted data through the GTS; upper-air observations from the period 1973-1997; and gridded upper-air statistics from the period 1980-1991. IMH has provided a list of all surface and upper-air stations in Mongolia, including periods of wind data collection at each station, observation times, heights of measurement equipment, and other important information useful to the study.
IMH has digitized records of wind speed and direction for over 200 surface locations in Mongolia, including data from both primary and secondary (post) stations. Primary station data are available eight times per day. Post station data are typically available three times per day or in monthly distribution form. IMH has provided NREL with monthly wind speed summaries for 70 primary stations and 157 post stations. NREL has selected some of the stations that appear to have moderate-to-good wind resource, and IMH will provide the detailed observation data for these stations.
IMH archives upper-air meteorological data from 14 locations in Mongolia, but these data have not been digitized. Upper-air observations are available two times per day. Eight of these stations use radiosondes (instrumented weather balloons) to measure upper-air parameters (including temperature and pressure), while others use pilot balloons to estimate only wind speed and direction. NREL's digital upper-air database includes data from the 8 radiosonde stations. Pilot-balloon data will be used if IMH can provide these data in digital form.
Digital terrain and geographic data are essential for use with the computerized mapping software at NREL to facilitate the interpretation of the wind and other meteorological data and to produce the computerized wind resource maps. NREL has, as part of its global terrain and geographic database, the Digital Chart of the World (1:1,000,000 scale maps) and 1-km average elevation data for Mongolia.

2.2 Data Processing and Analysis

The reliability of the meteorological input data is the most important factor in creating an accurate wind resource map. A recent NREL paper [1] describes the integration, analysis, and evaluation of different meteorological data sets for use in wind resource assessment. Known problems associated with wind observations taken at many meteorological stations include a lack of information on anemometer exposure, hardware, maintenance history, and observational procedures. An analysis of the meteorological data is performed using techniques developed by NREL specifically for wind resource analysis. A comprehensive data processing package is used to convert the surface and upper-air data to statistical summaries of the wind characteristics. The summaries of the surface station data include, where possible: the interannual variability of wind speed and wind power, the average wind speed and power on a monthly basis, the diurnal distribution of the wind resource, and the mean wind speed and frequency by direction sector. The upper-air meteorological data are processed and analyzed to evaluate the free-air wind characteristics at low levels in the atmosphere and to estimate the vertical distribution of the wind resource. This is useful in estimating the wind resource on elevated terrain features and for estimating the wind resource at exposed locations in areas without reliable surface wind observations.

Site-specific products are screened for consistency and reasonableness. For example, the interannual wind speeds are evaluated to identify obvious trends in the data, or periods of questionable data. Only representative data periods are selected from the entire period for use in the assessment. The summarized products are also cross-referenced against each other to select sites which apparently have the best exposure and to develop an understanding of the wind characteristics throughout the region. This is important due to the variable quality of the data, and the lack of documentation of the anemometer exposure and history. The goal of the data analysis and screening process is to develop a conceptual model of the physical mechanisms, both regional and local in scale, that influence the wind flow.

2.3 Development of Wind Maps and Atlas

An automated wind resource mapping system recently developed at NREL will be used to generate the wind resource maps for the different regions of Mongolia. This mapping system has replaced the manual analysis employed in previous mapping efforts conducted in the 1980's and early 1990's. The automated system was developed with the following two primary goals in mind: (1) to produce a more consistent and detailed analysis of the wind resource, particularly in areas of complex terrain; and (2) to generate high-quality map products on a timely basis.

The mapping system uses computerized mapping software known as Geographical Information System (GIS). The main GIS software is ARC/INFO a powerful and complex package featuring a large number of routines for scientific analysis. None of the ARC/INFO analysis routines is specifically designed for wind resource assessment work; therefore, NREL's mapping technique requires extensive programming in ARC/INFO in order to create combinations of scientific routines that mimic direct wind resource assessment methods.

The wind mapping system is organized into three main components: the input data, the wind power calculations, and output section that produces the final wind resource map. A description and application of NREL's wind mapping system in developing regional-scale wind resource maps can be found in recent publications [2,3]. The two primary inputs to the mapping system are gridded terrain data with 1 km^2 resolution and formatted meteorological data. The wind power density, rather than the wind speed, is used in the final analysis of the wind resource, since it provides a truer indication of the wind resource potential. A wind resource assessment handbook recently published by NREL [4] includes methods to compute wind power density and adjust the wind power to different heights above ground. The final meteorological inputs, following the data screening process, are vertical wind power profiles and wind power roses (which specify the percentage of total power from the wind by direction sector). These inputs determine the base wind power density of each grid cell. The

GIS is used to adjust the base wind power density value. The factors that have the greatest influence on the adjustment for a particular grid cell are the topography in the vicinity of a grid cell and a combination of the absolute and relative elevation of the grid cell. The primary output of the mapping system is a color-coded map of the estimated wind power, and equivalent wind speed, for each individual grid cell. The maps are designed to highlight areas that possess a favorable wind resource and where wind energy projects are likely to be feasible.

For Mongolia, it is advantageous to divide the country into several different regions in order to generate the wind resource maps. A composite for the whole country will be generated from a combination of the regional maps. Besides the annual average wind resource maps, the atlas will include information on the monthly and diurnal variability of wind resource, and wind direction characteristics for the major resource areas. The wind atlas will be a valuable document for use in identifying prospective areas for wind energy applications in Mongolia. However, because most of the wind resource estimates are preliminary, it is recommended that wind monitoring sites be installed in areas where wind energy applications may be considered.

3 Project Activities – Wind Measurement and Data Analysis

REC, IMH, and NREL are cooperating on a project to monitor the wind resource in specific areas of Mongolia. The data collected in this project will be useful to quantify the wind resource characteristics at specific sites where wind energy projects may be considered and to help validate some of the wind resource estimates in the mapping project. NREL has supplied the project with 12 monitoring systems, which REC will install in three regions of southeast Mongolia: Sukhbaatar, Dornogovi, and Omnogovi. REC staff will perform the system installation, data collection and initial analysis tasks. All data will be sent to NREL for further analysis and integration into the assessment project. IMH will also receive the data and assist with the interpretation of the site data and comparison to wind data collected at meteorological stations in the regions.

NREL conducted a training course in Ulaanbaatar from late June to early July 1998. This training course covered the fundamentals for conducting a successful wind monitoring program. These fundamentals are described in NREL's wind resource assessment handbook [4], which served as the handbook for the training course. The training course included procedures for the siting and installation of wind monitoring systems and the collection, processing, and analysis of the data.

3.1 Site Selection

Four sites within each region will be selected by REC for the installation of the wind monitoring systems. One site in each region will be designated as the permanent site, which will not be moved during the term of the project. The other three monitoring systems in that region can be moved during the project, after sufficient data have been collected to adequately evaluate the wind resource potential. The data from the permanent site will serve as a reference, allowing comparisons between different sites in different years or periods.

Each site will be assigned a unique site number, and its location will be well-documented. Latitude and longitude will be accurately determined with a Global Positioning System receiver, and a complete photographic record of each site will be made.

3.2 Schedule

In July to August of 1998, REC traveled to each region to select the sites and install the monitoring systems. In the first three months after installation of the systems, REC will visit each site on a monthly basis to collect the data and inspect the system and data for any problems. During the rest of the project, REC will visit each site at least every three months to collect the data and inspect the system. Periodically, new sites may be identified for re-location of some of the monitoring systems. As the wind mapping project progresses, NREL will offer guidance to REC to help with the identification of new areas for possible wind monitoring.

3.3 Monitoring Systems

NREL has supplied 12 Wind Explorer/Tall Tower monitoring systems from NRG Systems, Inc. (Hinesburg, Vermont, U.S.A.) for this project. Each system consists of a 20-m tubular tower (89-mm diameter), a Wind Explorer data logger, an anemometer, and a wind direction vane. The Wind Explorer is capable of recording three data channels at 10-minute intervals for more than six months. In this project, 10-minute averages of wind speed and wind direction measured at a height of 20 meters will be recorded. The maximum interval between visits will be three months. Data are stored on removable DataPlugs that contain 128 kilobytes of non-volatile memory. The DataPlugs will be carried back to the REC offices where they will be read and the data stored on the computer. Copies of all data files will be sent to NREL by electronic mail.

3.4 Data Analysis

Initial data analysis (i.e., computation of average wind speeds, wind roses, and quality control) will be performed by REC using the MicroSite program from NRG Systems, Inc. All raw data will also be provided to IMH and NREL. Detailed analysis of the data and integration into the assessment project will be performed by NREL. IMH will assist in the interpretation of the data and comparisons to other measurement sites and meteorological stations in the region. IMH will also assist in evaluating how representative the short-term measurement data is of the long-term average and advise on recommendations for adjustment to the short-term averages.

4 Summary

The wind resource atlas of Mongolia will be a valuable document for evaluating the wind energy potential in Mongolia and for facilitating the identification of prospective areas where wind energy projects may be viable. The atlas will contain high resolution wind resource maps for the different regions of Mongolia and provide information on other important wind characteristics (i.e., the monthly and diurnal variability of the wind resource, frequency distribution of wind speed, and wind direction frequency). The wind resource maps will be produced at NREL using advanced analysis techniques and a new automated wind resource mapping system.

The complementary wind measurement activity in Mongolia will gather data needed to accurately quantify the wind resource potential at specific sites where wind energy projects may be considered, in addition to providing data useful to validate and refine the resource estimates produced by NREL's wind mapping system.

The contributions of the participating Mongolian organizations, IMH and REC, to this project will help to achieve a considerably better wind resource assessment than would be possible otherwise. The additional meteorological data provided by IMH and their assistance with the interpretation of these data is beneficial to developing more reliable and accurate meteorological inputs for the automated mapping system. The efforts by REC to operate and maintain the wind measurement sites will provide data needed to accurately quantify the wind resource potential in specific areas and to validate some of the mapping results.

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ON *UNESCO*'S RENEWABLE ENERGY INFORMATION EXCHANGE PROGRAMME - THE INTERNATIONAL RENEWABLE ENERGY INFORMATION AND COMMUNICATION SYSTEM (IREICS) PROGRAMME -

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Abstract

Our coming activity, The International Renewable Energy Information and Communication System (IREICS) Programme, is introduced here. This programme aims to establish dynamic linkage between the needs of using renewable energy technologies and its users. The World-Wide Information System for Renewable Energy (WIRE) technology has been developed recently by the International Solar Energy Society (ISES) which is adopted as a core technology to realise the IREICS Programme. In this paper, I describe a conceptual feature of the IREICS Programme and the steps leading up its establishment.

1 Backgrounds and Motives

Global population has already exceeded 6 billion and 80 per cent of the population lives in the developing countries. In the population statistics, about 70 per cent of this population lives in rural areas. In 1987, only 20 per cent of the rural population in Asia has been estimated to have a chance of access to electricity[1]. In a recent study, roughly one-third of the global population may not yet have an electricity access[2].

To improve their quality of life by helping them free themselves of poverty, electrification of such rural areas has the highest priority for sustainable global development but it must be done without environmental damages such as emission of green-house gases, desertification, etc. Not only electricity but also other energy forms such as heat for cooking are also expected to be supplied without environmental damages. The use of renewable energy sources is one of the most important and promising options for supplying necessary energy forms.

A unique and remarkable feature of renewable energy technologies, differing from other technologies, is that any renewable energy technology must be made available to the public and can possibly be supplied free-of-charge or at a very low cost, so that anyone from any country in need of the technologies can use them freely. If this fundamental rule cannot be guaranteed, then the resolution of the environmental crisis through the use of renewable technologies could never be achieved globally. To this end, a programme within the framework of the World Solar Summit Process, entitled The International Renewable Energy Information and Communication System (IREICS) is being prepared to be launched in February 1999.

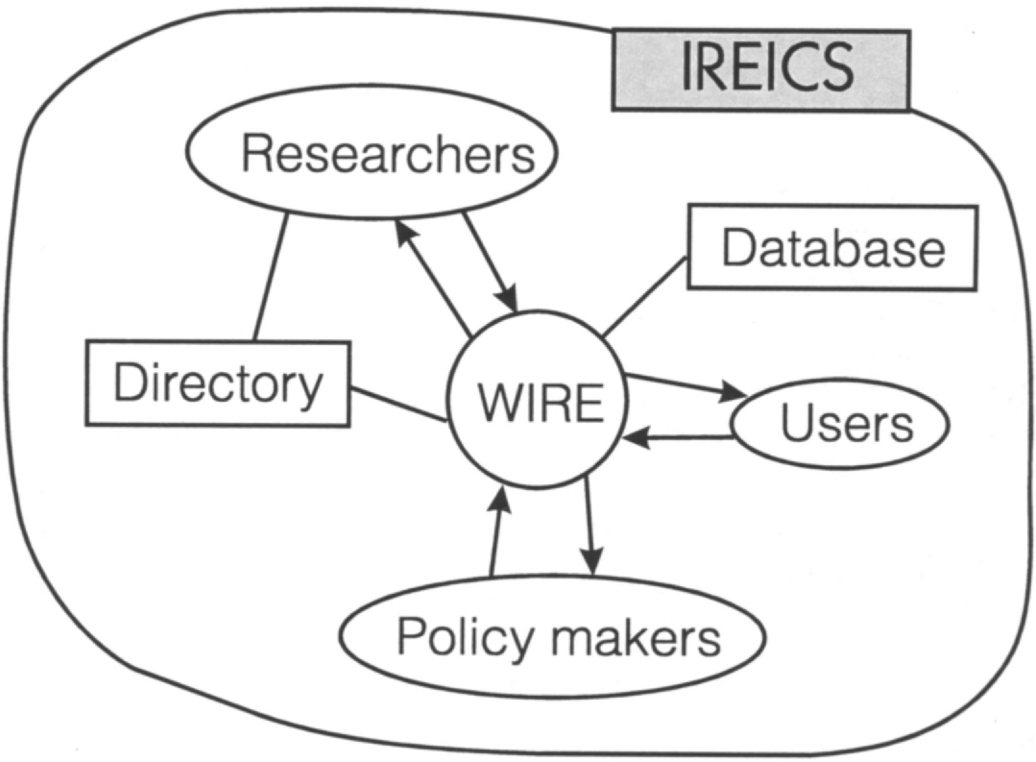

Figure 1: *Schematic Diagram of the Structure of the IREICS Programme*

2 The IREICS Programme

Recently, the International Solar Energy Society (ISES), developed a new communication technology on a computer network entitled The World-Wide Information System for Renewable Energy (WIRE). This technology has excellent features which enable it to carry out the method of active information exchange among people in the computer network. The IREICS Programme adopts this innovative technology to remove the present obstacles to disseminate and use renewable energy technologies globally in co-operation with ISES.

The WIRE technology is a core of the IREICS programme, which enables to connect dynamically among renewable energy researchers, renewable energy users, and policy makers (Fig.1). The IREICS includes a database regarding renewable energy technologies and a directory of researchers and research institutes. The database consists of technology information and learning and training materials on renewable energy technologies. Any users can extract what they need from the database. The contents of the database will be supplied by the co-operating researchers and research institutes.

Figure 2 shows a schematic diagram of construction and relationship between the functions which are components of the IREICS. The Steering Committee is the decision maker of the programme which will be organised by the core members of the programme. The Technical Committee will support the WIRE technology with respect to both software and hardware.

The Information Centre copes with the information exchange among researchers, users, and the IREICS components by use of the WIRE technology. The Authority Centre will function to support field activities technically; for example, a seminar or a workshop which it would be necessary to hold from an activity of a field work will be managed and organised by this centre. These two centres are managed by the Steering Committee.

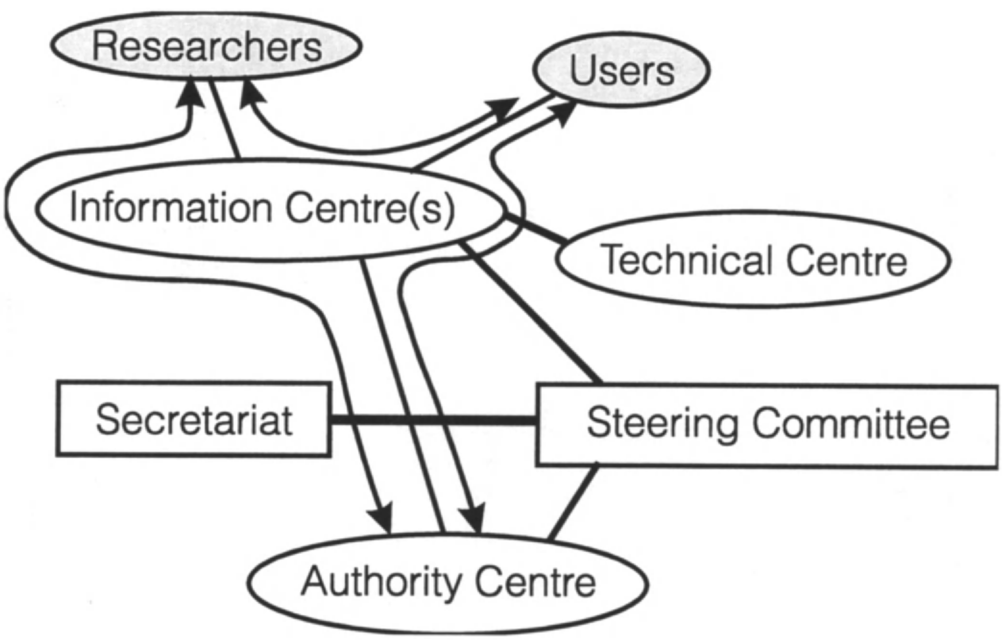

Figure 2: *Relations Among Four Functions; Steering Committee, Information Centre(s), Technical Centre, and Authority Centre*

3 Steps in the Implementation of The IREICS Programme

Step1. **To form the Steering Committee and to nominate the Secretariat:** Core participants of the Programme forms the Steering Committee. This Committee becomes a decision maker in the Programme. As soon as the Steering Committee is formed, the Committee nominates the Secretariat. The Steering Committee would invite other participants besides the core participants, if necessary. The other committee which could support activities in the programme could be called by the Steering Committee.

Step2. **To establish Information and Authority Centres:** The Information Centre is established to maintain the quality of the information on the network and technical aspects. This centre is not needed to be a centralised one. Several centres could work by covering the world in an organic way.

Step3. **To prepare the technical database and the directory:** The directory will be established on the basis of the outcome of the International System for Energy Expertise and Knowledge (ISEEK) Database which is also the activity within the framework of the World Solar Summit Process. This directory must be one of the most valuable on the network and all registered data should be revised and maintained by the registered organisations and/or individuals. The technical database could supply technical information and learning/training packages of renewable energy technologies. The concrete structure and contents of this database must be discussed in the special meeting held by the Steering Committee.

4 Conclusion

I have attempted here to introduce details about our activity to establish an information exchange system for the dissemination of the use of renewable energy technologies. The straightforward target of this programme is the direct connection between solar energy users and researchers/developers. We now have a trilemma; population explosion, energy-environmental crises, and poverty in developing countries. They intimately linked and we really have to undo them one by one.

To resolve the trilemma, this programme will play an important role to connect the persons who need to the persons who can supply what they need.

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PRETREATMENT INVESTIGATIONS AND FIELD TRIALING OF AN INNOVATIVE SOLAR-POWERED REVERSE OSMOSIS DESALINATION UNIT

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Abstract

The Remote Area Developments Group (RADG) at Murdoch University in collaboration with a local manufacturer, Venco Products Pty Ltd have developed a solar-powered reverse osmosis desalination unit ('Solarflow') specifically designed for remote areas. The unit has recently been commercialised with eighteen units presently in operation through Australia and South East Asia.
Several sites where units have been requested however, notably Central Australia and Indonesia, have feed water which is marginal in terms of its ability to be treated by reverse osmosis without some form of pretreatment. Guidelines for feed water pretreatment generally apply to large scale commercial units which operate at high recovery ratios and thus have limited applicability to the Solarflow unit.
Research at Murdoch University's Environmental Technology Centre (ETC) is currently underway to determine the performance of the units both under laboratory and field conditions over the longer term with marginal feed waters. This will allow an assessment of maintenance requirements, membrane life expectancy and the design of appropriate pretreatment systems to enable the units to perform reliably in remote areas.
This paper will describe the findings to date and the areas where further research is indicated.

1 Background

Research into reverse osmosis (RO) desalination has been conducted by the Remote Area Developments Group since 1990 in cooperation with Venco Products Pty Ltd as the industrial partner. The focus has always been on a robust design, capable of providing a dependable freshwater supply from brackish ground or surface waters in remote areas. Initial research examined several renewable energy power supply options and due to portability, low maintenance and an output which matches demand, solar power was selected. The current model, developed in conjunction with Venco Products is the first machine to reach

commercial production and there are now 18 units currently in service in Australia, Indonesia, the Philippines and India.
The unit is available in a 400 litre/day version with two possible recovery ratio options of 16 or 25% (Solarflow 40016 and Solarflow 40025). It has been designed to operate from a two panel photovoltaic array with built in maximiser to keep the solar panels at their optimum voltage of 30 volts. Efficacy can be improved by up to 60 percent with the use of a solar tracker [10]. The solar panels power a DC motor coupled to a high quality industrial gearbox which is capable of providing sufficient torque to run the unit even at low currents. The efficiency of the unit is also greatly enhanced by the novel energy-recovery system which allows the unit to operate with the minimum number of solar panels: the high pressure reject water is returned to the back of the piston to reduce the load on motor and gearbox, rather than going to waste. It was this feature that earned the unit an energy-efficiency award from the Alternative Energy Development Board (AEDB) of Western Australia and it is the AEDB who have provided funding for current research.
The 400 litre/day unit has been designed with small communities of up to 40 people in mind where, in addition, water conservation technologies such as greywater reuse and water efficient appliances are utilised [6]. A 1500 litre/day unit capable of meeting the requirements of larger communities of up to 150 people is currently in the prototype stage and under going performance monitoring before entering commercial production.

2 The Need for Potable Water in Remote Areas of Western Australia

Many communities in rural Australia suffer from scarce and often marginal quality drinking water resources. This is particularly evident in arid areas of Western Australia where rainfall and surface waters are limited and groundwater often contains high levels of salinity (3000 - 6000 ppm) and other contaminants (biological, chemical and aesthetic) [9]. The deleterious health effects associated with prolonged consumption of highly mineralised drinking water are well documented and include kidney and gastric disorders [12]. In particular such health problems due to inadequate quality drinking water in remote Aboriginal communities are prevalent [14]. Significantly over 60% of Aboriginal communities rely on groundwater for their water supply with over an estimated 25% of these bores exceeding the salinity guidelines [13]. Water for human consumption is required to meet the National Health and Medical Research Council Guidelines for Drinking Water Quality [12] and yet this is often not achieved in many remote communities. This has led to the RADG's involvement in developing an appropriate technology for small scale desalination in such communities.

3 Research and Development of the Solarflow Unit

The Solarflow unit has been specifically designed for remote communities and research has focussed on photovoltaics as the most appropriate power supply and reverse osmosis as the desalination technique [8]. The current Solarflow model has been developed through several stages and has culminated in the collaboration with an industry partner for commercial production. Indeed many of the approaches taken were concessions to the range of appropriate technology parameters which were paramount for remote community application [17], [3].
Specifically it was necessary that the unit be simple, easy to service, robust, compatible with energy recovery and of low cost. For example, the initial choice of low speed double acting simplex pumps were ultimately substituted with an integrated single acting pump to further reduce complexity [8]. Similarly there are economies to be had in maximising recovery ratios however this in turn was not deemed to be of greater significance than the need to avoid

pretreatment systems. It was reasoned that the energy recovery system would make this economical. Throughout the research and development to date, many such compromises were made to achieve a balance in the final product.

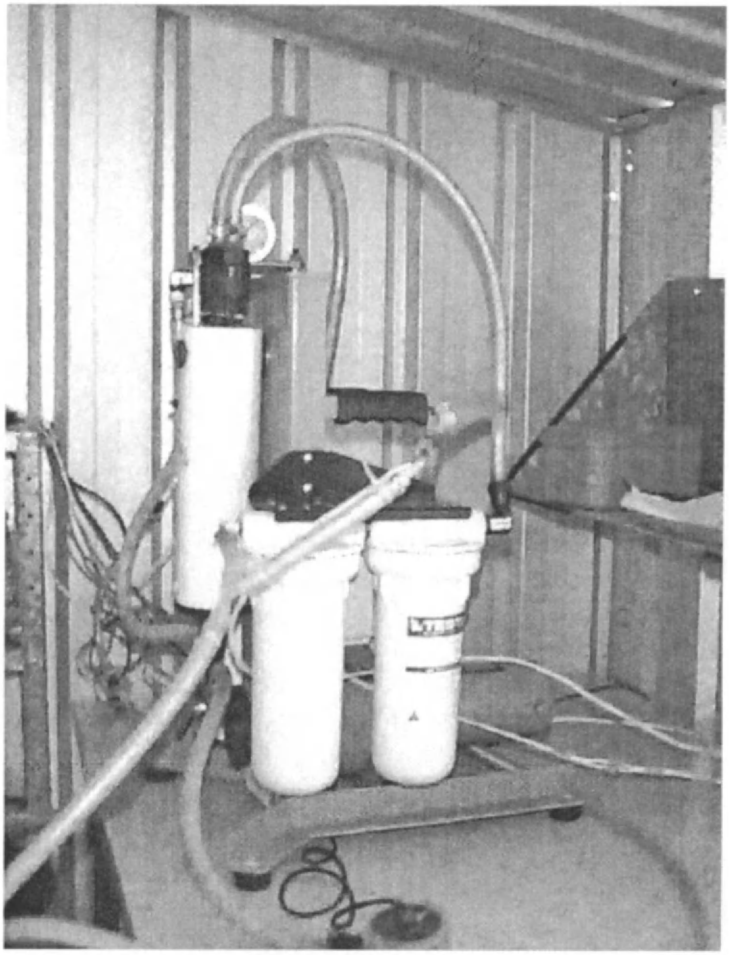

Figure 1: *Photograph Showing Solarflow Unit in Laboratory*

4 Pretreatment in Reverse Osmosis Units

The largest drawback in the application of reverse osmosis technologies is the tendency towards membrane fouling. It occurs as a result of scale build-up, biological growth or clogging and leads to problems in predicting steady-state operating conditions and effective membrane lifespan. The quality of the product water drops dramatically when fouling occurs as membrane characteristics such as permeability and salt rejection constants are affected. The processes by which fouling occurs are highly dependent on feedwater quality, operating parameters, maintenance and hydraulic design of the process [1], [2]. And it must be stressed that with approximately 30% of the price for a complete RO unit spent on replacement membranes alone [4], this is one of the main cost factors in comparison to other water purification technologies.

The main constituents of feed water which are responsible for fouling include hardness, turbidity, total suspended solids (TSS), total dissolved solids (TDS), chemical oxygen demand

(COD) and total organic carbon (TOC). In the Western Australian context, the classical characteristics of groundwater in typical inland semi-arid regions include high levels of iron and manganese, high salinities and hardness [16]. Operating parameters such as recovery ratio, flow regime and configuration are also important for the prediction of fouling in reverse osmosis [11]. The interactions between these parameters and their influence on the fouling process is not yet fully understood and has been described as still involving a degree of 'art' [7].

In any event, small scale, low pressure RO systems are poorly reported in the literature and many potential difficulties have had to be derived from the problems reported by larger plants.

5 Pretreatment Considerations for the Solarflow Unit

As mentioned earlier, all research and development has been committed to low recovery ratios in the 10-25% range from the RO unit to provide flexibility in varying quality feed water whilst minimising the likelihood of membrane fouling. In terms of energy economy this has been offset by the energy recovery system.

With regard to membrane type and performance, membranes of a long and thin design are preferable for their higher crossflow velocities thus increasing the cleansing effect. However, this configuration is difficult to incorporate into a compact design and indeed wider, shorter membrane modules have been selected for cost, compactness and system integration in the current Solarflow unit. Spiral wound membranes of high flux rates but only modest rejection rates are the most suited for the Solarflow unit as the maximum salinity likely to be encountered will of the order of 3000 ppm and where extremely high rejection ratios are not necessary. A range of readily available membranes satisfying these requirements have been trialed by Harrison [8].

The literature also suggests that the single cylinder configuration should accelerate membrane fouling. As described below, no fouling problems have been encountered to date.

All sites which have requested the Solarflow units have been analysed for suitability on technical grounds based on the fouling potential of the feedwater [8]. This has been achieved by determination of the Langelier Saturation Index (LSI) which reflects the tendency of calcium carbonate to precipitate and the use of membrane manufacturer supplied software programs such as 'Desal 96/97' to predict the fouling potential. Thus far only those sites which have not required pretreatment have been considered until further testing under those conditions is carried out. To date, the in-field models have performed without problems for over 12 months with only irregular maintenance, and have maintained production rates and product quality.

In order to remove suspended particles and silt, two in-line prefilters (20 micron and 5 micron) filter feedwater prior to pumping through the membrane. The 20 micron cartridge is washable and can be reused up to four times whereas the 5 micron filter requires replacement after six months or when fouled. The latest models of the unit incorporate a simple membrane cleaning system which operates by flushing the membrane at high flow rates and low pressure. This is achieved by a rotary valve which when operated manually allows some of the energy-recovery pressure to be dumped via the membrane allowing the unit to speed up and flush the membrane at a high flow rate. This system allows for a flushing supply, which can incorporate cleaning agents, to be introduced when the main feedwater supply is closed off [5].

In order to satisfy the demand for these units at sites where the feedwater is marginal in terms of its ability to be treated by the Solarflow, an examination of the likely fouling problems to be encountered was undertaken. Mineral scaling is seen as the most likely condition to occur. The design of the unit itself appears to be providing a certain degree of scaling prevention which is a highly desirable outcome as the inherent maintenance, complexity and cost considerations of additional pretreatment, such as chemical dosing, will greatly detract from the unit's functionality. Nevertheless, research into the following two pretreatment systems is underway:

- **In-line dosing pump for liquid chemicals**
  While proprietary dosing pumps are available, cost, complexity and separate power source requirements are seen as unsuitable. As the Solarflow unit is already equipped with a high pressure pump, a second dosing pump connected to it could provide a constant dosing per liquid volume since the feed water flow is always proportional to the additive flow. Piston and peristaltic pumps are being considered for this purpose.
- **Magnetic feedwater pretreatment**
  Whilst this technology is still not fully proven it has promise in the stabilisation of carbonates and sulfates. Anecdotal evidence of its ability to prevent scaling in Western Australian environments is available.

Initial experimentation is underway and involves the preparation of an LSI positive solution which is used as the feed water supply until performance deteriorates indicated by decreasing recovery and salt rejection ratios.

Earlier RADG work carried out by Robinson [15] in laboratory trials on membranes only indicated the possible reduction in fouling rate with the use of a proprietary antiscalant, in this case 'Flocon 100', at a dosage rate of less than 4 ppm. Similar trials will be run using the Solarflow unit as it operates in the field to determine what water qualities cause scaling and the necessary dosing pump design and dosing rates required.

6 Membrane Fouling in Field Trialing of the Solarflow Unit

At the time of writing four of the installed units had been recently equipped with dataloggers to monitor performance. These include three 25% recovery ratio units operating on groundwater of which one unit is in Indonesia and a 16% unit operating on a surface water supply (a small creek) near Perth. This latter unit has experienced a degree of biofouling of the prefilters however insufficient time has elapsed since the dataloggers were installed to be able to detect any marked deterioration of performance in any of the membranes.

7 Conclusions

Whilst it is possible to report that the instances of membrane fouling in Solarflow units installed in the field has been minimal to date it would be premature to conclude that no fouling is likely to take place. This situation is primarily due to the following:

- limited number of units in the field;
- insufficient time has passed since the units were installed;
- no sites contain feedwater of a large fouling potential.

It would appear however that the unit's design and low recovery ratios are accommodating in terms of membrane fouling avoidance.

In order that more sites may have access to the unit, investigations into pretreatment systems suitable to the Solarflow are underway. This will allow those sites which have feedwater that according to current knowledge should induce fouling, to be serviced. Any additional equipment required, however, to enhance the performance of the Solarflow unit will need to be developed according to the same guidelines that were paramount in the construction of the unit itself: simplicity, low cost, low maintenance and robustness [9].

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THE FEASIBILITY OF SOLAR ENERGY USE IN RURAL AREAS OF MONGOLIA: SOLAR "GER"

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Abstract

Mongolia, despite of its heavy investment in energy sector, still faces difficulties to supply the rural population with electricity. The energy system of Mongolia is strongly dependent on indigenous coal and imported oil, and needs applications of emerging energy efficient technologies.
Rural centers, which are still not connected to the centralized electricity system, supply their inhabitants with the electricity by diesel. However, the use of renewable energies is just being initiated designing solar panels and wind generators for nomads. At present, in rural areas some nomadic families depend on a simple petrol generator or a small wind generator.
To avoid the environmental degradation and to improve life standards in rural areas, it is essential to supply the rural population with an appropriate electricity.
This paper synthesizes the possible application of emerging technologies of photovoltaics and solar panels in nomadic families.

1 Introduction

The rural population of Mongolia still keeps the traditional nomadic life style adjusting to the modern civilization of the technology era.. The nomadic life-style is practical, simple, open, mostly based outdoors, perceived by some as an ideal life", and often exposed to natural hazards. Nomadic Mongols live in their traditional dwelling called "Ger" moving several times a year on the vast steppe.
In order to improve life standards of nomads and prevent them from natural accidents, it is vital to supply them with electricity. However, the population dispersion, requires a particular infrastructure and energy policy for the sustainable development. The country's territory is relatively large in comparison to the population; the land are is 1.56 square kilometers while the total population is only 2.3 millions. The population. density is uneven throughout the whole territory and, in average, is about from 0.8 to 0.9 hectare per person. In the country,

each family or a group of families is located in a distance of about 5 to 10 kilometers from another family, and from 50 to 500 kilometers from a settled city.
Nomads move several times a year to select the best pasture land for their livestock and to avoid overgrazing, one of the main reasons for land erosion. This is positive factor from the point of view of cattle breeding and pasture land management, but, on the other hand, from the point of view of living conditions it makes difficult to supply the nomads with necessary energy for domestic and agricultural use, such as household electricity, water pumping wells.
The principal source of energy for nomadic families is biomass energy, including fuelwood and dung. The forest covers the 10% of the country's territory and also fuelwood is not acceptable in every region. Forests, including *Saxual* forests in the Gobi desert and semi-desert areas, have being cut severely, thus causing environmental degradation, land erosion, and the acceleration of desertification. This is far worse in case of Mongolian forests because overexploitation of the forest leads to environmental degradation and increase of fuelwood price in rural areas.
At present, about 20 % of the country's total population still remains without centralized electricity supply. Some nomadic families depend on simple oil or wind generators of low capacity. Nevertheless, oil generator needs a continuos supply of oil or petrol which are difficult to get. Therefore, solar panels are particularly suitable for the nomadic life in Mongolia as the country receives more direct sunlight than most other countries in the world.

2 Solar Energy as an Alternative Source of Energy

The sun is the main source of light and heat on the Earth. At the outer atmosphere the solar energy constant is equal to 1,373 W/m^2.[7] This energy is transmitted in the form of radiation waves. The energy of radiation is varies depending on waves, from low-energy long radio frequencies to higher energy X-and Gamma-rays. The 46 % of the sun's radiation is in the visible light band, while 49 % is in the infrared band, sensed as heat. The remainder 5 % is in the ultra-violet band.[7]
The type of radiation and how much radiation actually reaches the surface of the earth are strongly affected by the atmosphere. For example, heavy clouds or fog diffuse all the radiation reaching the Earth's surface and consequently, the solar radiation is scattered by particles and molecules in the air. On a clear day, the most part of the solar radiation that reaches the surface is undiffused. Hence, the total radiation that reaches the Earth's surface is constituted from the beam, direct radiation, and insulation or hemispherical insulation, diffuse radiation. The maximum solar radiation available at the Earth's surface on a clear day is normally about 1000 W/m^2.
A part of the solar energy at the outer atmosphere is scattered by air molecules and dust, and adsorbed by water, carbon dioxide and other airborne matters. Thus, only the remaining part reaches the Earth's surface and this part of the total solar radiation is available for conversion into energy.
The amount of solar radiation available for conversion into energy varies at any location depends on key factors as follows:

- location of the sun in the sky (altitude and azimuth), which varies daily and seasonally;
- atmospheric conditions, both general and micro-climate;
- altitude above sea level;
- hours of daylight.

Besides weather conditions, solar radiation may also differ at a site due to air pollution, either from man-made or natural sources, such as volcanoes and intense dust storms. The total ground-level radiation is fairly constant in any one location although it may vary by as mash as 25% or more annually.

2.1 Solar Energy Use in Rural Areas

Application of solar energy technologies in remote and rural areas results in considerable improvement of life conditions and moreover facilitates the energy policy of the country.
Solar energy can be used either for domestic purposes such as cooking and food processing, drying, water and space heating, telecommunications, household electricity, space cooling and refrigeration, sterilization and disinfecting, desalination and distillation of brackish water to improve serous health problem among local villagers or for agricultural uses water pump of wells, irrigation pumps, grinding, threshing and wood cutting.

3 Solar Energy Potential of Mongolia

Mongolia has a sharply continental climate, with long, cold, and dry winters and mild and relatively wet summers. In mid-winter, the temperature drops down 20 to 30 °C below zero when Arctic air masses dominates. By contrast, in summer the temperature is pleasant about 25 °C in central, northern, eastern and western regions, while in the Gobi desert it may reach as high as 35-40°C.
Mongolia has high solar energy potential whereas the most days of the year are sunny. In average, about 345 days of the year are sunny and it differs by regions. Available sunny days and hours of the year are shown in Table 1 and Table 2 by regions of Mongolia. Solar energy resource of Mongolia is approximately equal to, 1400 kW.hour/m^2.

Table1: *Available Sunny Days (by regions)*

Regions	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Year**
Central	30	27	30	29	30	28	29	30	29	30	29	30	**351**
Eastern	30	27	30	28	30	29	30	30	29	29	29	29	**350**
Northern	29	27	29	28	30	29	29	29	28	29	28	27	**342**
Western	28	26	30	29	31	29	30	30	29	31	29	30	**352**
Southern	28	27	30	29	30	30	30	31	29	31	29	30	**354**
Ulaanbaatar	30	27	30	29	30	29	30	30	29	30	28	29	**351**

Source: Ministry of Nature and the Environment, Department of Meteorology and Climate, "Meteorological Data of Mongolia".

Table2: *Available Sunny Hours (by regions)*

Regions	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Year**
Central	210	206	217	270	260	274	250	242	234	236	206	148	**2753**
Eastern	163	181	236	240	280	274	248	259	220	202	158	135	**2596**
Northern	159	175	227	265	290	290	284	280	272	234	176	142	**2794**
Western	195	218	266	256	300	278	276	275	241	232	191	178	**2906**
Southern	230	250	253	257	301	331	341	305	298	277	222	192	**3257**
Ulaanbaatar	184	193	260	254	288	274	258	261	247	232	183	164	**2798**

Source: Ministry of Nature and the Environment, Department of Meteorology and Climate, "Meteorological Data of Mongolia".

4 The proposal "Mongolian Solar Ger"

Nomadic families can have their own independent energy facilities using solar energy. In general, solar systems consist of the following parts:

- Solar energy collectors
- Converter
- Storage or back up system

However, for Mongolian nomads every solar energy technology cannot be appropriate to apply due to the particular life-style. Since the nomads change their locations every few months, solar systems are required to be easy to assemble, to disassemble, to transport and to maintain.

4.1 Particularities of Mongolian Traditional Dwelling - "Ger"

Mongolian traditional dwelling "Ger" has been changed and elaborated to meet the conditions of nature, life-style, the weather, and, as well as, particularities of the cattle husbandry. It is simple and easy to build, to dismantle and to transport when nomads move every few months of the year in order to select the best grazing pasture for their cattle.
Mongolian Ger combines many systems to represent Mongolian lifestyles. It functions as a complete one-room space and its functions are divided into individual sections based on the location and sunlight.
The Mongolian traditional dwelling "Ger" consists of the following elements:

- floor - round shaped made of wood, consists from several separates parts
- honeycomb wall - made of wood. It is placed on the floor around the outer edge of the floor.
- roof - wooden sticks. It connects the wall to the sky-light and support felt covers.
- sky-light called "toono" - placed on the top center of the roof. The sunlight illuminates the interior of the Ger through a sky-light called "toono" which is placed in the center of the Ger. This sky-light, as well as, functions as a natural clock.

4.2 Solar Sky-light

The main concept of the solar sky-light is replacing the covering cloth of "toono" - skylight with solar cell panels.

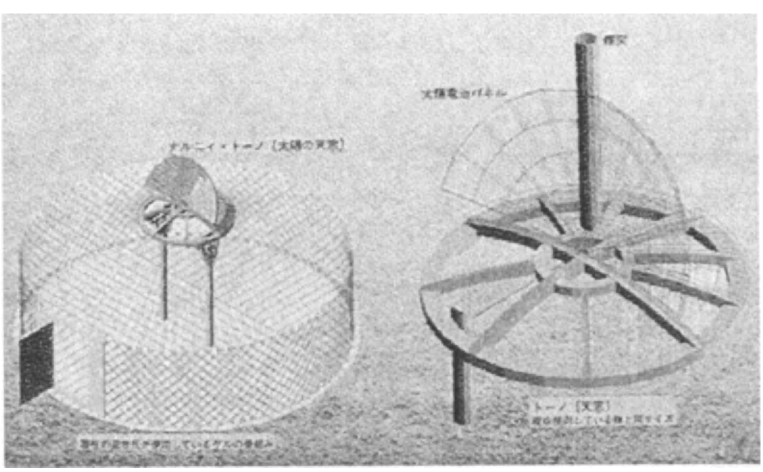

Figure 1: *Solar Sky-light of the "Ger"*

These panels will be designed possible to open and close, and they can be shut at nights or when it rains. Only replacing the present "toono" of the Ger should be sufficient.
Solar collector can be placed on the top of the Ger working as a solar sky-light. Solar sky-light in Mongolian traditional dwelling "Ger" simply adopts solar panels on the "toono" - the sky-light of the Ger, leaving the present materials of the Ger as they are.

4.3 Mongolian Solar Ger

Mongolian Solar Ger optimizes solar panels by evolving the Ger itself, including its materials. The main idea of Solar Ger is using honeycomb panels as its composite material. Solar panels will be placed on the roof section, and the above-mentioned Solar sky-light on the top of the roof. Honeycomb panels will support the increased weight for solar panels installed on the roof. In this case, the resistance against strong wind needs to be enhanced. These solar panels consist of several parts, which are assembled, in order to be for transportation.

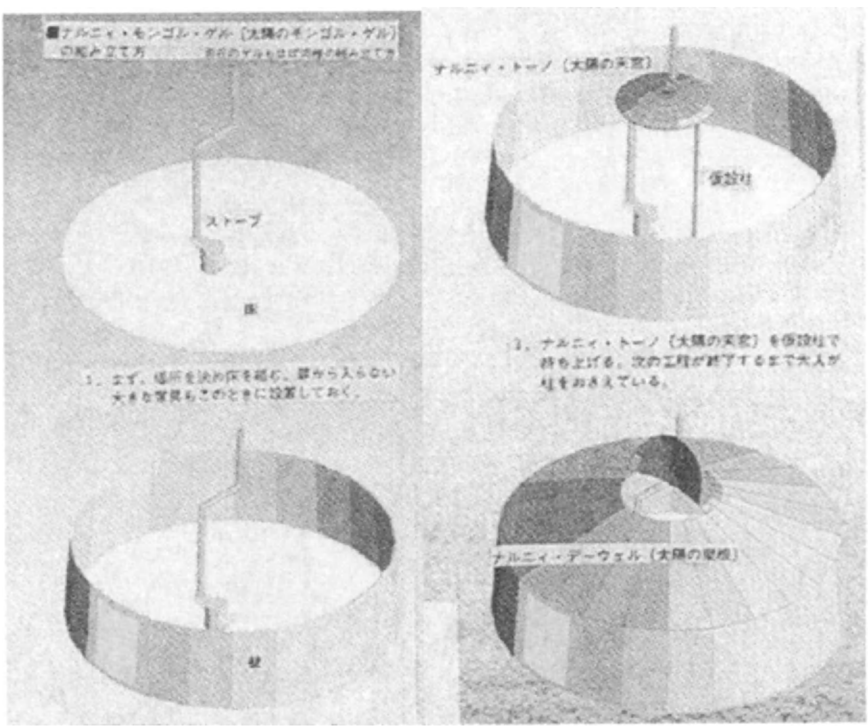

Figure2: *Mongolian Solar Ger - Solar Panels*

5 Conclusions

Solar energy is not only environmentally sound but they also result in comprehensive economic and social gains. An important benefit of solar energy is the secure and independent energy supply in rural and remote areas that can advance the development process more rapidly at lower cost than comparable efforts based on non-renewable conventional energy sources. Of equal importance are the benefits that solar energy use allows rapid improvement in life standards.
In conclusion, the opportunities for using the solar energy in Mongolian Ger of nomadic families are considerable. Taking advantages of the existing elements of Ger it is possible to

design solar system suitable in nomadic life-style. It will not only facilitate the energy system of the country supplying the rural population with energy but also result in improvement of life standards. Furthermore, it also makes it possible to use small devices such as portable computer to connect to the internet services by satellite transmission so that the people in the immense grasslands could make shorter the distance with the civilization and communicate with the world.

Acknowledgement

The proposal "Mongolian Solar Ger" was designed by a Mongolian architect I. Gonchigbat and an Japanese architect Maemura, Yutaka for a design competition "Harmony between the human and the mercy of the sun" organized by Photovoltaic Power Generation Technology Research Association in Japan, in 1996, and won the second prize.

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THE WORLD SOLAR PROGRAMME

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Abstract

The world would clearly be a worse place without the efforts humankind is making to use renewable energy on a larger scale. New employment opportunities, a clean environment, energy independence, peace building and sustainability of development are some of the incentives for the promotion of renewable energy as an important element of the world's energy sources. Know-how on renewable energy technologies is very unevenly distributed. The process of technology transfer and dissemination should be facilitated and promoted based on the principle that selection of the most suitable technologies and their adaptation to local conditions should take priority in technological co-operation. This will lead to a strengthening at the local level of the capacity to select, adapt and eventually develop it further.

1 The World Solar Programme

The High-level Expert Meeting, "*The Sun in the Service of Mankind*", organized in 1993 on UNESCO's initiative, in broad partnership with major relevant organizations, suggested undertaking a three-year campaign 1993 - 1996 entitled "**World Solar Summit Process**" (**WSSP**) leading to the organization of a World Solar Summit. The World Solar Summit Process 1993 - 1996 was a concrete response to the recommendations of the Earth Summit concerning energy and the decisions of the 27th and 28th Sessions of the UNESCO General Conference.

This communication process and highly focused campaign had the following objectives:

- **enhance** understanding of the role that renewable sources of energy could play in the preservation of the environment, in the provision of energy services - particularly in ecologically fragile areas - and in contributing towards a solution to unemployment
- **favour** the access, transfer and sharing of knowledge on renewable energies by establishing a global information networking system using state-of-the-art communications technology

- **promote** and **harmonize** co-operation in education, training and research, as well as in the transfer of research disclosures to industry at the regional, interregional and international levels
- **demonstrate** how wide use of renewable energy is a cost-effective and rapid way for many developing countries to reduce energy costs, save foreign exchange and stretch the energy supply base without heavy investment
- **urge** non-governmental organizations to enter into partnership with, and make their knowledge and experience available to, global and regional intergovernmental bodies, as well as to establish innovative programmes for the promotion of the use of renewable energies
- **reinforce** local industrial capacities
- **identify** and **define** selected strategic projects of universal value and high-priority national projects for inclusion in **the World Solar Programme 1996 - 2005 (WSP)** - a major developmental initiative, which will trigger a wider use of renewable energy sources and create open competitive and sustainable markets for renewable energy technologies, equipment and goods
- **reinforce** the involvement of the international community and, in particular, that of the multilateral and bilateral sponsors, as well as the national commitment towards large-scale use of renewable energy
- **promote** small-scale financing and delivery mechanisms
- **prepare and convene** a World Solar Summit at the highest governmental level
- **launch** the World Solar Programme 1996-2005 during the World Solar Summit.

The European Commission and the International Energy Agency played a decisive role in this major initiative. An Action Plan for Renewable Energy Sources in Europe was prepared in 1994 that provided a most timely and useful framework for the European energy sector, and gave a useful example for development of similar Action Plans in other parts of the world, as foreseen by the World Solar Summit Process.

The creation of National and Regional Solar Councils was recommended. The Mediterranean Solar Council was created in January 1995, and proposed at the ministerial meeting organized in Sousse (Tunisia) a Mediterranean Plan of Action involving five selected regional strategic projects for execution in 1996-2005. The African Solar Council was created in December 1995. The Americas and Caribbean Solar Council was created in May 1996. High-level Expert Meetings were held in Harare (Zimbabwe), Beijing (China), Tel Aviv (Israel), Islamabad (Pakistan), Penang (Malaysia), Muscat (Sultanate of Oman), Valletta (Malta), San José (Costa Rica), Moscow (Russian Federation) and Akita (Japan) to define national and regional high-priority projects for execution during the period 1996-2005.

The Executive Board of UNESCO approved in 1994 the creation of a **World Solar Commission (WSC)** to provide high-level leadership and guidance in the preparation of the World Solar Summit and to achieve the objectives of the WSP. Heads of State and Government from Austria, China, Costa Rica, Georgia, India, Indonesia, Israel, Jamaica, Malaysia, Pakistan, Palestinian Authority, Senegal, Spain, South Africa, Tunisia and Zimbabwe are members of the World Solar Commission, under the chairmanship of H.E. Robert Mugabe, President of Zimbabwe. In 1995, an institution of personal representatives of members of the World Solar Commission was created to facilitate daily administrative and operational matters.

The United Nations Secretary-General welcomed the development and implementation of this UNESCO initiative as a joint effort of the UN system and underlined that the World Solar Summit Process would make a distinct contribution to the work of the United Nations and the system as a whole in support of sustainable development. Two UN inter-agency consultation meetings took place at UNESCO Headquarters prior to the World Solar Summit.

A **WSSP** International Organizing Committee supervised the preparatory activities leading to the World Solar Summit and the launching of the World Solar Programme 1996 - 2005. The

Engineering and Technology Division of UNESCO serves as the **WSSP** and **WSC** General Secretariat.

The World Solar Summit Process culminated in the World Solar Summit which took place in Harare, Zimbabwe on 16 and 17 September 1996. This event was an unqualified success and will undoubtedly be considered in future as an important milestone in the high-scale use of renewable energies as a major contribution to sustainable development. Never before has a meeting on a renewable energy issue brought together participants at such a high level, i.e. ten Heads of State and a Vice-President, seven Prime Ministers, two Deputy Prime Ministers, 34 Ministers, four Vice-Ministers and an important number of high-ranking officials. A total of 104 countries were officially represented at the Summit, as well as 12 organizations of the United Nations system and 10 regional and inter-governmental organizations, including the European Union, the European Commission and the Organization of African Unity. Approximately 1000 participants took part in the Summit, 593 of whom attended as official representatives of their respective countries. Private industry and non-governmental organizations also attended the Summit.

The three main results of the World Solar Summit can be summarized as follows:

- Renewable energies are recognized as being an important component of the energy sector of the 21st century and as being worthy of development and use on a large scale in the coming decade
- The decision was made to launch a World Solar Programme 1996-2005 as a common effort of national Governments, specialized agencies and programmes of the United Nations, inter-governmental and non-governmental organizations, university and research institutions and the private sector
- The outline of the World Solar Programme 1996-2005 was approved and a working decision was made to elaborate a fully-fledged **WSP** document by July 1997.

The World Solar Commission was invited by the Summit to continue to provide high-level leadership and guidance in order to attain the objectives of the Summit. UNESCO was asked to continue to play a leading role in the **WSP** preparation.

Following the meeting of a Task Force on Energy of the relevant institutions of the United Nations system in December 1996, a co-ordination meeting took place on 20 December 1996 at UNESCO Headquarters to review the respective roles of the UN institutions in the development and implementation of the WSP. Personal representatives of members of the World Solar Commission met on 27-28 January 1997 in Vienna on the invitation of the Federal Chancellor of the Republic of Austria, member of the World Solar Commission, and also on 19 March 1997 at UNESCO Headquarters, to discuss the **WSP** structure and contents. A Consultation Workshop of government designated experts on the preparation of the World Solar Programme 1996-2005 was organized at UNESCO Headquarters on 20-21 March 1997. A final consultation on the draft document entitled «World Solar Programme 1996-2005 » was held on 9-10 June 1997 at UNESCO Headquarters in Paris, with the participation of Personal Representatives of Members of the World Solar Commission and other partners involved.

A meeting of Personal Representatives of Members of the World Solar Commission was organized on 11 June 1997 at UNESCO Headquarters, and approved a final draft of the **WSP** document, for submission to the World Solar Commission.

The « Harare Declaration on Solar Energy and Sustainable Development» and the « World Solar Programme 1996-2005: An Outline » have been presented as official documents to the Earth Summit + 5 Special Session of the UN General Assembly, which was held in New York, 23-27 June 1997.

The World Solar Programme 1996-2005 was approved on 23 June 1997 by the World Solar Commission at its second session, held in New York on the occasion of the above Special Session of the UN General Assembly.

An information package has been prepared to provide information on what can be expected from the World Solar Commission Secretariat, the Regional Solar Councils and UNESCO, and what is expected from national competent authorities as far as the implementation of their High Priority National Projects is concerned as well as their participation in WSP global projects.

A reference document is being prepared giving a two-page summary on all High Priority National Projects submitted so far to the World Solar Programme 1996-2005. This document is planned to be submitted to funding sources concerned by the end of 1997.

A detailed outline of the African Solar Programme 1996-2005 is being prepared by the World Solar Commission Secretariat in close co-operation with the African Solar Council.

An Internet Web Site for the World Solar Programme 1996-2005 is being permanently updated (*http://www.unesco.org/general/eng/programmes/science/wssp/index/html*).

A series of meetings on business and investment to enhance the implementation of the World Solar Programme 1996-2005 are being organized by the World Solar Commission.

An awareness and fundraising campaign has been launched jointly by the UNESCO Assistant Director-General for Science and the UNDP Assistant Administrator for a High Priority National Project from Ecuador, « Solar Energy for Development of the Galapagos Islands ».

In parallel with the preparation, negotiation and approval of the World Solar Programme 1996-2005, the Engineering and Technology Division, the Secretariat of the World Solar Commission and major partners of the World Solar Summit Process have implemented some High Priority National Projects (HPNP) and also WSP global projects. For example:

- one of the Zimbabwe HPNP, « Solar Electrification of Rural Institutions », has got a US$10.5 million funding in the form of a grant from the Italian Government;
- a US$20 million soft loan from the World Bank and a grant of US$20 million from GEF were obtained for implementation of one of the nine Indonesian HPNP, « Home Photovoltaic Rural Electrification in Indonesia »;
- a US$97.5 million soft loan is being negotiated with EBRD for one of the five HPNP of the Russian Federation, « Geothermal Electrical Station for Kamchatka »;
- the Onamunhama Demonstration Solar Village has been built in Namibia and inaugurated by the UNESCO Director-General;
- a solar village in Zanzibar has been provided with the necessary equipment;
- a human settlement in Niger in the National Park « W » has been provided with solar power supply;
- a solar school in mountainous areas of the People's Republic of China has been equipped with a solar power system;
- a nine-volume UNESCO/WSP learning package on renewable energy for practising engineers has been printed and largely disseminated;
- a CD Rom « UNESCO/ISEEK Energy Database » has been prepared and largely distributed;
- a prestigious annual summer school « Solar electricity for Rural and Remote Areas » has been held at UNESCO Headquarters since 1990 with technical visits to the best European solar centres.

UTILIZATION OF ELECTRICITY OF HERDSMAN FAMILY AND POSSIBILITY TO SUPPLY IT WITH SOLAR BATTERY

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Abstract

Today supplying herdsman families with an electric generator is one of the important problems in Mongolia.
First of all herdsman need electric equipment in addition TV, communication techniques, electric generator which has the sufficient power to be worked out. Nowadays only 11% of herdsmen families have any generators out of 167200 families in Mongolia.
It's necessary to decide the electric supply of herdsman families on scientific basis depending on the conclusion of research work and it should be carried out without any influence for environment, small sized, easy to carry and equip and has the system to repair.
Also choosing the system of solar battery is very important and it's necessary to produce electron block to adjust and get solar panel, accumulator in homeland and charge it's service and reparation.

1 Situation of Utilization of Solar Electric Generator for Herdsmen Families in Mongolia.

Last years there are many research works on utilization of solar, energy in small enterprises and everyday life over the world. In 2000 America has a purpose to supply 30% of production of electricity with method solar energy is the ecological pure source and it's specific has no bad influence for environment.
Research and experiments solar energy are being carried out much in USA, Germany, Japan, Australia, England, Canada, France, Finland, Russian Federation and China.
Modern scientific possibilities to utilize solar energy were increased considerably.
There is an important task to utilize solar energy, which is independent, the cheapest and easy source to use for herdsmen families in Mongolia. There are many possibilities to utilize solar energy in Mongolia and the research work fixing distribution of solar in detail, dividing it in zone.

As for the result of the research work utilization of solar energy has the economic high efficiency everywhere, each season in Mongolia.
Modern scientific possibilities of solar energy utilization were increased, the frame of usage and economic index of solar battery equipment have been increased 2 or 3 times because of reliable process in long-time and automatic controller of the equipment.
As for the research work 11.8% or 19 670 families out of 167200 have any generators in Mongolia. The generators have no united policy, technical definite choice of research work and they have been imported and used from various countries as technical experiment.
One of the first solar batteries was the generator B.C 500 (about 500) which imported from Russian Federation in 1989 to provide radios.
The equipment were set in Bayan-Onjuul of Tov province.

Table 1: *Technical Index of the Equipment*

	Quantity
Size of solar energy	1000 watt/m^2
Power	0.5 watt
Voltage	9 V
Size	90x160 mm

The radio BEF which produced in Russian Federation could be worked out using the generator in daytime. The disadvantage of the generator is not to provide the all necessity of family because of the poor power.
The generator NEDO which is the solar battery system with 200 wt power of Japan are being set in herdsman family since 1993 in our country.
The system considers the usage of herdsman family is not exceed than 180 Volt/hour in a day, to supply the usage completely and the voltage was calculated with 220 voltage, 50-H frequency.
The system transmitted over 200 generators depending on technical complete set.
The system has a special equipment which gain data base, adjust the load with it's power and time, adjust accumulator voltage level. Data bases like current from solar battery screen, accumulator battery energy, solar ray to be reflected on, solar screen, temperature of environment, could be gained and kept. It can be useful for selecting work rule, other parameters and technical index of solar battery system further. Disadvantage of the system is big sized and heavy to carry for families who engage nomadic animal husbandry. In other side it's useful for families are in permanent place and who move rarely.
The solar energy system its generator's with 30-watt power were produced from the institution of Mongolian regenerated electricity are is being supplied for herdsmen.
The system has been produced with one or 2 solar energy screen depending on the necessity of herdsmen.
The system consists of solar battery, accumulator and solar charge adjuster. Although it was made simply; car accumulators don't provide the health requirement.

2 Usage of Electricity of Herdsman Family in Mongolia

There is a deep change in herdsman life as a result of socialnd economic change in the beginning of 1990
Agricultural units were divided because of the privatization and most cattle were owned.
As of November in 1995 totally 197000 families in 59600 hot ails pasture 28.0 million cattle in country side of Mongolia. It means from 3 to 4 families winter in per hot ail on an average.
Today Mongolians are likely to transfer to the traditional way as hot ail.

As for the research of electric supply of herdsmen 11,8% or 19677 families out of 167200 have any generators.

Table 2: *The Supply Research of Electric Parts of Herdsman*

Province	Number of sums	Number of herdsmen families	Electric lamp		With TV		With radio	
			Family	Percent	Family	Percent	Family	Percent
Arkhangai	19	17894	764	4.2	499	2.8	12046	67.3
Bulgan	16	6787	621	9.2	383	5.6	5297	78
Govi-Altai	18	8799	550	6.3	316	3.6	6787	77.1
Dornod	14	3967	1495	37.6	595	15	2148	54.1
Dundgovi	16	6901	587	8.5	264	3.8	6121	88.7
Zabkhan	24	11757	584	5.0	409	3.5	6892	58.6
Omnogovi	15	5648	664	11.8	52	0.9	4399	77.9
Selenge	17	1871	795	42.5	682	36.5	1387	74.1
Xobusgul	24	15461	609	3.9	59	9.7	9273	60

The number of families with electric generator which is worked with solar and wind energy to switch on the light, work radio and TV which imported and produced by scientific and business departments to electrify herdsman as MON-MAP company, The institution of regenerated electricity, ABE company, Malchin company is not above 4500.
About 1000 if 15000 families use the electricity of Central Electric System, about 14000 use Honda, Yamaha, Kuboto electric motors of Japan.
The research result of electric equipment's of herdsmen is shown in 2 table dividing into aimags.
Electric Utilization of electricity of setflement and families are in outskirts is higher than others. 73,3 % of families with TV is in Ulaanbaatar, 44,9% is in Darkhan, 42,5% is in Selenge, 34,7%is in Orkhon, 37,6% is in Dornod out of families with any generators.
It's necessary to study electric usage of herdsman to implement the task of supplying them with electric generators.
The important part of herdsman electric equipment's are the spare parts to lighten and hour of utilization in a day is various depending on a season.
It's appropriate to calculate the utilization of electricity herdsman using it's hours and normal power of equipment. Utilization hour of electric equipment's of herdsmen families in Mongolia is shown in 3 table.

Table 3: *Utilization Hour of Equipment's of Electricity of Herdsmen Families*

Consumer	Hour of utilization			
	Winter	Summer	Spring	Autumn
Electricity	6	2	3	4
TV	5	5	5	5
Radio (BEF)	8	8	8	8
Electricity of shelter	3	0.5	3	2
Iron	1	1	1	1
Music tape recorder	2	2	2	2

From table 3 it can be found that other usage except the light's of yards and shelters inside of gers is more permanent not depending on a season.
Although time of utilization of electricity is the most (25 hours) in winter, it's very short in summer (18 hours).
We should decide the eight not less than 30 Luxe according to health requirement considering the place of the table which is behind the stove as a part of main work for choosing the light inside the ger by our tradition.
From the research time of equipment's to lighten is 1200 hours in a yard and 3,5 hours in a day on an average. To calculate utilization of electricity of each herdsman family on the basis of electric parts which is used present days.

Table 4: *Utilization of Each Herdsman Family*

Equipment's	Working voltage [V]	Power [Watt]
Record TV (Russian Federation)	220	180
Normal luminescent lamp	220	60
Radio	9	1
Iron	220	1000
Sum		1241

Total sum is 1241 watt .
Electric part's which are sold and haven't been used among herdsmen are shown in 5 table.

Table 5: *Modern Electric Equipment's of Electricity*

Equipment's	Working voltage [B]	Power [Wt]	Price tugric]
Tamir TV	220 12	28 18	3500 3500
Electric lamp	220	9	
Radio BEF	12	1	
Iron	12	600	

From table 5 it can be found that there are modern TV, bulbs and irons with little power. From the research the electric utilization of electricity of herdsmen families can be divided into 3 groups.

1. Families with little usage
- Spare parts to lighten (9-11 watt)
- Radio 1watt
2. Families with average usage
- Spare parts to lighten (9-11 watt)
- Radio 1watt
- TV (28-35 watt)
- Iron 600 watt
3. Families with much usage
- Spare parts to lighten (9-11 watt)
- Radio 1watt
- TV (28-35 watt)
- Iron 600 watt
- Refrigerator
- Lights in outside (9-11 watt)
- Video player

- Equipment of air communication 10 watt

It's very important to adjust the accumulation with solar generators which have appropriate power considering the 3 levels of consumers.

3 Experimental Result of Solar Generators in Families with Little Usage

The experiments of the system consisted of a block to adjust equipment with 11 to light, accumulation with capacity of 50 Ampere, 4 solar panels were done in families between 1996 and 1998. (Tsenkher sum of Arkhangai province, Xarkhorin sum of Ovorkhangai province)

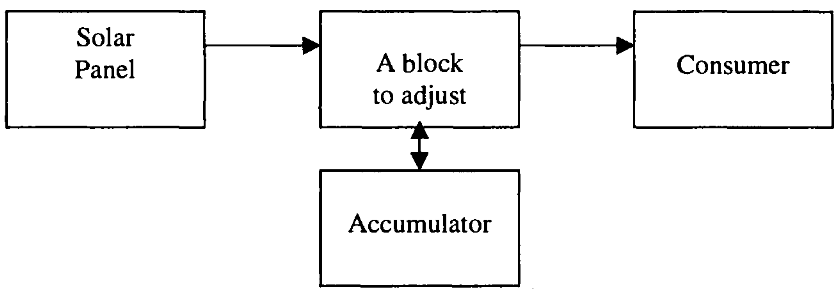

Figure 1. *Solar Battery System*

From the experimental result the system is reliable in winter and summer time solar panel of the system was equipped in Singapore and the car accumulator was used.
The charge adjuster of accumulation, equipment's to lighten luminescent lamp with 12 voltage regular charge were produced at laboratory of Electrical System Automation Research Laboratory.
Charge adjuster Electron block has following duties:

1. To interrupt the consumer if accumulation charge is less than 10,5 voltage.
2. To insulate the accumulation from solar panel when the accumulation voltage is more than 14 voltage.
3. To keep the communication of consumers when the accumulation voltage is between 10,5 and 14 voltage.
4. To interrupt the consumer using high current defense when the consumer voltage is more than 1.2 $*I_N$.
5. To give an electric signal about defense, accumulation voltage level and consumers.

The preparation of producing and improving the system is being carried out active.

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WIND FARMS IN NORTHERN CLIMATE

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Abstract

Wind energy exploitation in cold regions such as Alaska, Canada, Finland and part of Denmark, Russia, Sweden has reached 200 MWe capacity in general with medium sized turbines in wind farm configurations.
Many northern (large latitude) or high altitude (middle latitude) territories are flat and exposed to cold and very strong winds with resulting good wind energy potential; moreover often they have a critical need of electricity for the scattered villages or small towns particularly in winter, when transportation of fossil fuel, for their power plants, is difficult and expensive. Related to the strength of electric grids wind farms of medium sized turbines (600 kW) could be of benefit, relatively economic and environmentally acceptable compared to fossil fuel plants.
The climate of northern and high altitude regions could be very severe for low temperature levels, ice build up on structures, weakness of electric grid connecting users at long distance from power plants, difficult maintenance.
Climate and electricity distribution problems have been experienced now in many applications and solutions have been developed and tested.
A specific review will be presented with the aim to give an incentive for a significant exploitation of wind energy in Mongolia. In the high altitude plains (1000÷1500 m a.s.l.) of this Asian country wind farms of medium sized turbines could be easily connected to electric grids of the few larger towns.

1 Introduction

Northern regions (for example Finland) and high altitude -middle latitude regions (for example Mongolian plateau at 1000m a.s.l.) experience very cold climatic and icing conditions. Wind turbines in both regions face similar operational problems; then wind energy studies in cold climate in general refer to both regions, taking care of some differences.
Really northern climate, related to high latitude up to Arctic Circle, is characterized by very low temperature. In this condition, at sea level, the density of the atmospheric air is higher and winds transfer more power to turbines, due to the direct relation between the two

parameters. On the another side an increase of altitude has two reverse effects: a significant decrease of air density with height and a smaller increase with decreasing temperature. The two effects partially compensate each other and a reduced power is transferred to wind turbines at high altitude compared to sea level.

Extremely low temperatures frequent in northern and high altitude regions are associated to snowfalls, hailstorms and to ice build up on structures with consequent malfunctions, failures and loss of generation of wind turbines.

As a preliminary guess 4% of grid connected wind farms in north European (Denmark, Finland, Norway, Sweden, Russia), and American countries (USA, Canada) might experience cold climate conditions; the result is about 200 MW of wind turbines with icing and other low temperature operational problems;

Moreover often in cold climate countries wind farms supply electricity to very sparse villages in weak MV (Middle Voltage) local grids, fed by far diesel generators or high voltage networks, producing frequency and / or voltage fluctuations; many studies have been carried out in the past and are still continuing on this subject.

In 1992 it was recognized the importance of the above studies and investigations of wind energy in cold climate regions and the WECO (Wind Energy in Cold Climate)project was started by the European Commission, followed by the International Meeting BOREAS, organized by the Finnish Meteorological Institute in four biennial editions in Finland [1].

Due the growing power demand by towns and villages, even in the cold climate regions, the paper covers more specifically the generation of electricity by wind farms connected to local or regional grids.

2 Cold Climate Wind Power Technology

Wind power technology is today well established with preferred commercial turbine size of 600÷750 kW (40÷50 m rotor diameter) and demonstration turbines of 1÷1.5 MW (50÷60 m r. diameter). The most used configurations are up-wind, horizontal axis, three÷two blades, gear box, fixed rotational speed, power stall ÷pitch control, glass fiber/epossidic resin blades.

Advanced configurations use variable rotational speed, direct drive (no gear box), optimized aeroelastic structures compact and low weight, special electric generators, carbon fiber/epoxy blades.

Commercial wind farm installation costs on the average start from US$ 1000 / MW in standard sites with fair climate.

In cold climate regions wind farms and turbines have to be adapted to local harsh environment, that influences transportation of components, installation costs, repair and maintenance, lifetime of turbines, reliability of electric supply, amount and kWh costs.

The main effects of cold climate on turbines performance are due to ice build up (icing) on structures and control anemometer, and on meteo anemometers; the extremely low temperature effects are on lubricants, operational fluids and on electronic equipment.

The main effects from wind farms on weak MV grids could be unacceptable electric perturbation level to users (voltage and power fluctuations, flickers)

2.1 Icing

There are different types of icing, depending on the environment, with different effects on wind turbine components.

The main types are : a) cloud based icing, which takes place at windy, foggy sites with water droplets impinging and immediately freezing on a surface at given wind speed, resulting in a dry growth process and rime ice; b) icing (supercooled) rain, that occurs in coastal areas with a wet growth process, resulting in a dense glaze ice layer all around blades and structures.

Icing in general can occur: in the temperature range of 0° down to –30°C with the maximum rate around –10°C; with relative humidity over 97% at temperature below zero; is favored by lower than average barometric pressure.
Ice build up can affect wind turbines blades (leading edge) changing their aerodynamic profiles with drag and lift characteristics and can even block the control anemometer (see Figure 1) [2].

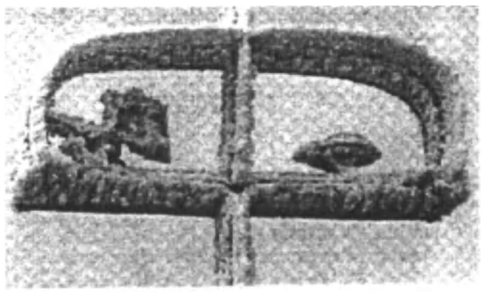

Figure 1 :*Non Heated Control Anemometer and Wind Vane*

The icing of the blades has then following effects:
- reduction of aerodynamic performances up to 30÷50 % - Increase of static and particularly dynamic loads on structural components (blades, rotor, power shaft, nacelle) - risk of ice shedding up to 100 m with danger of people in that area.

The icing of turbine control anemometers and vanes has following effects:
- reduction of energy production ; damage of the turbine (the blocked anemometer does not allow to stop the turbine even when wind is over cut out values, with particular risk for stall controlled turbines); high overload if the vane is blocked and the turbine yaw control is not rightly working.

The icing of meteo anemometers and vanes produce inaccurate wind speed and direction data.
To evaluate the above effects and to give solutions to most critical problems the following activities are under way in many countries with cold climate regions:
- monitoring, reporting of icing event with turbine failures and production of maps
- development of ice free anemometers: for accurate wind measurements (direction, speed) and for reliable wind turbines control
- adaptation of wind technology to cold climate (blades, ice detectors, de-icing systems, corrosion, material, lubricants)
- understanding and modelling of ice build up on blades and of the induced aerodynamic and load variations.
- effects of icing on blade performance and on turbine output
- safety aspect of ice shedding from rotating turbine blades

A preliminary map of the European location with reported icing events is shown in Figure 2 [2]. Many solutions have been envisaged and are still studied and tested. For blades intelligent heating systems (de-icing) driven by ice detectors, free-ice anemometers and vanes (heated) for turbine control and meteo measurements.
Extra costs of ice protection systems (order of magnitude 5%) are considered worth for the improved wind farm performance, depending of course by the frequency and duration (see figure 3) of icing events in the chosen site in Germany [2b].

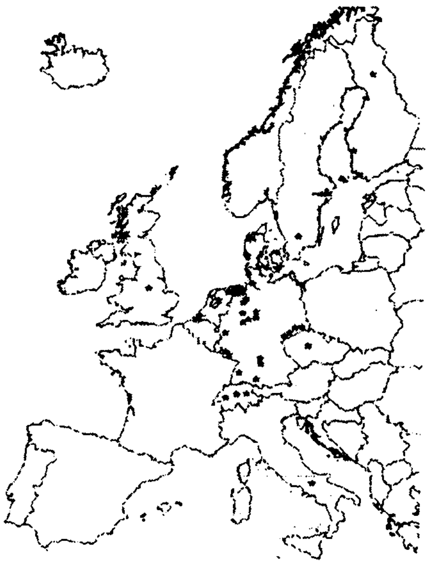

Figure 2: *European Locations with Reported Icing Events*

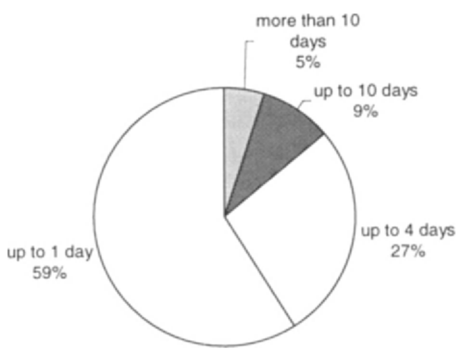

Figure 3: *Duration of Operation Disruption for Icing (Germany)*

2.2 Low temperature

Very low temperature down to –30°C and more can cause the following effects:
- brittleness of welded structural materials -reduced lubrication of bearings and gear box-malfunctions of oleodynamic systems-malfunctions of the electronic control equipment.

Research and development activities are providing following design solutions:
- use of special steel for welded structure - special synthetic lubricants for bearing and gear box -low temperature oil for oleodynamic circuits - pre-heating of gear box and control electronic equipment.

2.3 Wind farms in weak electric grids

In general Middle Voltage (MV) networks in cold regions are extended over long distance to reach dispersed users and can be far away from the main rigid High Voltage (HV of 110 kV or more) network ; a specific evaluation of loads and network configuration should be carried out to optimize the connection of wind farms to reduce voltage level change, fluctuations or dips at start up. In similar way extended weak local grids with diesel generators can experience voltage and frequency variations; many studies and pc programs have been developed to evaluate the effect of wind power penetration on grid behavior in steady state and transient conditions. Solutions to reduce electric perturbations induced by wind farms on weak grids are found on a case by case base.

3 Wind energy in some northern regions

Characteristic high latitude-sea level regions with cold climate are in Canada (Northwest Territories, Labrador), Russia (Peninsula of Kola, Siberia), Scandinavia (Finland, part of Norway, Sweden), USA (Alaska). A very good wind energy potential exists in many areas of this regions and interest for wind energy is growing. Information on wind energy resources and applications are given below.

3.1 Canada

Canada has a good wind energy potential in the northern territories and very low population density. Wind energy installations in 1995, and even today amount to 22.6 MW [3]. Operational experience of wind turbines in cold climate is under way: at the Cambridge Bay (NWT) from 1994 on a 80 kW Lagerway, plus two additional in Coppermine; at a site close to Kincardine (Ontario) from 1995 on a 600 kW Tacke Windpower; at a site close to Whitehorse (Yukon) from 1996 on a 150 kW Bonus.
In May 1998 a three-day conference on "Renewable Energies Technologies in Cold Climates" was held in Montreal with emphasis on wind energy in the remote communities of Canada included in a government development program.

3.2 Russia

The most of North coastal region of Russia, from Europe to Siberia, is flat, cold (air temperature from +5 to –30°C), with good wind regimes, but very few human settlements. The preliminary World Wind map of PNL 1981 [4] gives indication of mean annual wind speed 6 to 7 m/s in coastal areas. The recent wind map of North European Russian (figure 4) confirms high wind regime in Barents coast of Kola Peninsula up to Ural Montains with 6 to 8 m/s at 10 m a.g.l.

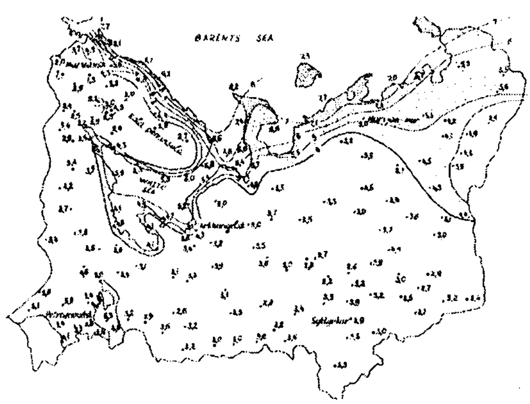

Figure 4: *Wind Map of European Russia*

Wind energy development (up to 1000 MW) is seriously considered in Kola Peninsula in connection with hydro power systems in the area of Murmansk [5].
Kola Peninsula is located entirely above Artic Circle to North-West of Russia, bordering on Finland, Norway and facing Barent Sea to the North and White Sea to the South.It is a quite flat taiga or tundra with inland mountains up to 1200 m.

Total generating capacity is 3.6 GW with 1.6 MW hydropower. The 350 kV and 150 kV transmission lines cover the most populated part of the Peninsula. A wind turbine coastal Test Site for artic conditions is in Danie Zelezny (Murmansk). Wind energy installations in Russia at present amount to 5 MW.
Under the US Agency for International Development cooperation program in 1996 Bergey Windpower has obtained a contract to ship 40 wind systems of 1.5 and 10 kW for off-grid villages in Kola Peninsula [6].

3.3 Scandinavia

Finland
Wind energy potential is 14 TWh/year with medium term prospects of installation of 250 MW. Starting in 1991 wind energy installations in Finland were 21 turbines in 1995 with 6.3 MW capacity (6 wind farms of 2 o 3 turbines of 200÷500 kW - Figure 5); production rate has reached 11 GWh/year with availability factor of 90% [7], compared to 95% in other land siting in mild climate. In 1997 wind capacity was 12 MW.

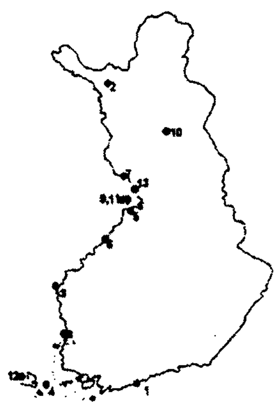

Figure 5: *Location of Wind Turbines in Finland*

Norway
Wind energy installations in Norway at present amount to 4 MW. The utility Nord Trondelags Elverk is planning a 15 MW wind farm of ten Vestas in Vikna after the good performance of a 2.2 MW wind farm on a mountainous site. Particular feature is the lightning protection system.
Utility Varanger Kraft plans to test two wind turbines in artic conditions in a far North site; in case of positive results 75 turbines will be installed for the electricity needs of the area with 26 000 people [8].
Sweden
Wind energy potential is high with 56 TWh/year (36 onshore, 20 offshore) compared to the today annual consumption of electricity of 140 TWh; wind capacity at present amount to 108 MW [3]. Large size wind turbines (3 MW capacity) have been tested since 1982 in Sweden (Marglarp and Nasudden) studying icing on blades and lightning protection. Cold climate conditions are severe during winter in the country area at 60° latitude.

3.4 United State of America (USA) - Alaska

Alaska latitude is from 50° to 70° crossing the Artic Circle with air temperature down to –40°C. The wind map of USA indicates high wind regimes in the Aleutinan islands and in South west coastal areas and on the inland mountains.

Mean annual wind speed is 6.2 m/s in the area of Kotzebue town, west cost of Alaska, 30 miles north of Artic Circle. Under the new Distributed Wind Turbine Verification Program (TVP), managed by EPRI and funded by DOE, K. Electric Association (KEA) has installed a wind farm of three AOC15/50, of 66 kW each, in July 97 in the tundra area with special foundation piles (filled with refrigerant liquid to prevent heat conduction to ground permafrost). In 1998 7 AOC 15/50 will be installed (0.46 MW) in the tundra area. KEA estimates that 70 coastal villages could reduce oil consumption of diesel using wind farms. KEA is collaborating with NREL and other agencies to install 1÷2 MW wind farms [9].

4 Wind Energy in high altitude regions

High altitude areas with cold climatic conditions are frequent in middle latitude regions as the Alps, Appenines, Pyrenes, Carpates in Europe, Rocky Mountains in America, Hymalaya, Mongolian Plateu in Asia, to say some of them.
As general trend wind regime is higher in altitude even though some power reduction is expected from density reduction. No many wind data are known from the technical literature. Cold climate in this regions can even be of artic intensity. In the paper only the Mongolian plateau is considered to center the theme of the ENREN conference.
The high altitude of Mongolian plateau (1000÷1500 m a.s.l.) and the continental regime of climate make the territories very cold in winter (min. temperature down to –31°C) and rather milde in summer (max +23°C) with low annual precipitation values (100÷350 mm) for rain and snow. Sunny days are very frequent, 220÷250/year.
Griffith [10] gives a preliminary wind map (see figure 6). More accurate wind data are given in the wind map of China (see figure 7) for Inner Mongolia, where the application of wind farms is more ahead [11].

Figure 6: *Outer Mongolia with Three Wind Energy Regions*

The Mongolian plateau, with Gobi desert, is included in two bordering countries: Outer Mongolia in the North and Inner Mongolia in the South. In the following some wind energy information are given for both countries.

4.1 Wind Energy in Outer Mongolia

Mongolia is a large inland country (1.6 million square Km) with North boundaries to Russia and the other ones to China; it lays in a North latitude range of 42¡ to 51°, about at same values for Europe, from central Italy up to central Germany. The country, far from the Pacific ocean, is bounded from South-West by Altai Mountains (up to 4200 m), from North by Northern Mountains, and in the South East by Gobi desert.

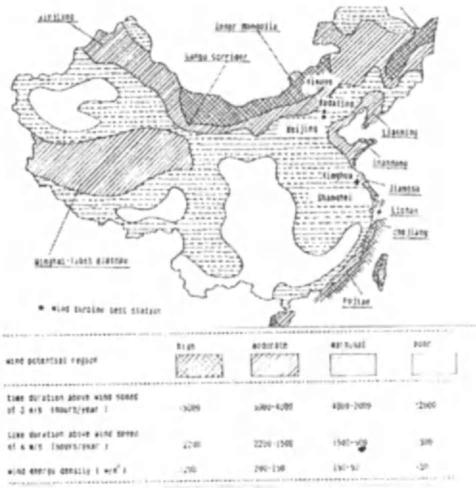

Figure 7: *Wind Map of China*

Griffith [10] in Figure 6: indicates three areas of wind regimes (10 m a.s.l.):
- Altai mountains, 60% of surface with mean annual wind speed of 4.5 to 5.1 m/s
- Nothern mountains, 60% of surface with mean an. wind speed of 5.1 to 5.6 m/s
- Plains, 15 % of surface with mean annual wind speed of 5.1 to 6 m/s

Wind regime is considered significant in the plains where the most of population (2.5 million) lives with 50% concentrated in few towns (Ulaan Baatar, Dharan, Karakorum, Tariat,..) and the rest living sparse on land farming or as nomads.
Electricity is generated from domestic (coal) or imported (oil) fuels. The energy consumption per capita in 1978 was 1240 Kg of coal, equivalent about 60 % of China value; the demand of electricity should be quite high today. Surely due to the large size of the country and to the low population density (1.6 person per square Km) in the plains the electric grid is probably extended only to single large towns with some weak connections to close villages
Moreover small communities or villages could have diesel electro-generators and weak grids. Where possible, out of dry territories, of close Gobi desert, wind water pumping for irrigation or for livestock watering might be used.
Similar energy situations with about the same environment conditions and wind regimes, are present in Inner Mongolia, for which more information are available. Wind energy has been implemented in the years 1986-1990 for nomads with small size, low weight, easy assembly (200 W) wind turbines.
At present an English company, Proven, is ready to market a larger 2.5 kW wind charger of electric batteries for new villages of about 50 families of nomads, who start now to settle down under government incentives.
A large number of this electricity generators have been and are still used for TV, radio, illumination in the nomadic villages of other Asian areas [12].
From technical literature of Outer Mongolia information lack on wind farms and on single wind turbine installations connected to diesel or to electric grids.
No land limitations, no particularly environment barriers and a significant wind regime in the plains would benefit wind electricity generation in the grids. A preliminary evaluation of above electricity potential of wind farms will be presented starting from the few available information.
Due to altitude (1000 m a.s.l.) the air density is reduced, in reference to sea level, by about 12 % in summer, but partially compensated by low temperature in winter; the results is as small reduction of the mean annual electricity generation compared to sea level areas.

For the region where mean annual wind speed is 6 m/s, that could be for about 2% of the plains (40% of 1.6 million square Km, total country area), it results 12 800 square km. Assuming an installation pattern of 600 kW wind turbines with 10 rotor diameters distance and then with 6 MW/square Km, an usable surface for wind farms of only 1/10, the resulting wind power potential is of the order of magnitude of 7.7 GW with electricity generation in the grid, for 1600 hours/year and a loss factor 0.9, of about 11 TWh/year. Of course the above values are theoretical, because do not consider many other technical and economic limitations.
However developing only 10% of the above wind power potential, about 770 MW in 15 years at mean rate of 50 MW/year, the resulting grid electricity per capita of the present urban population is of the order of 850 kWh/year.
The power of 770 MW could be produced by the installation of 32 to 64 wind farms of 24 to 12 MW (40 -20 turbines of present size, 600 kW) or of 20 wind farms of 40 MW (40 turbines of coming size 1MW) connected to an extended electric grid, to be developed in coming years. A project could start with a small wind farm of five turbines (3 MW) for demonstration and formation of technical man power. This pattern, on a smaller scale, is under development in Inner Mongolia.
The cold climatic problems for wind turbines in Mongolia should be something less compared to northern countries, because even though the winter temperature can be very low, there are less frequent events for snow, hailstones and conditions for ice build up on structures (Blades, electric lines) and components (anemometers). Due to presence of the desert of Gobi in the Mongolian plateau the abrasion effect of sandy winds should be considered and evaluated particularly for the roughing of the blade surface and the resulting decrease of turbine power.
A complete collection of wind and meteo data and a extended wind measurement campaign, with icing and sanding events monitoring, should be carried out to improve the evaluation of wind energy potential and climate conditions.
Moreover it is necessary to evaluate the configuration of the electric grid chosen for the connection of the first wind farm and to carry out a study of the complete grid for the integration of many hundred of MW in coming 15 years.
Wind turbines can be partially imported from Europe or from other areas of the world; local factories can supply towers, civil works, and service equipment.
Truss type tower could be appropriate for local manufacturing and easy transportation from the shop to wind sites. Manpower during construction and operation will be from local utility with support of turbine manufactures. Financing of wind farm projects could be promoted under by-lateral or international agreements, to be based even on environment protection rules.

4.2 Wind Energy in Inner Mongolia

The southern part of the Mongolian plateau is included in the Inner Mongolia (1.18 million square Km), independent region of China, with Gobi desert as nothern boundary to Outer Mongolia. The territory morphology, and the wind regime are similar in both countries. However population density is higher up to 18 persons per square km with main towns: Hohhot (capital), Guyang, Baotou, Hailar. Centralized electricity generation for those towns is mostly by coal, and by diesel in far villages; moreover these local electric grids are becoming more interconnected to the strong national network, allowing in this way more penetration of wind energy.
In recent years more than 58 turbines have been installed, totaling 14 MW, with 4 wind farms (Zhurihe, Shangdu, Baoligen, Huitengxile) connected to the grid of Chinese, American (Wind Power), European (Husumer, Nordtank, Bonus, Micon) technologies. The size of wind turbines has been growing from the 55KW of previous units up to the 600 kW of today turbines[13].

Wind energy utilization started in 1980 in stand alone applications for scattered rural families. Wind turbines of 50 to 500 W, bactery charging, developed and mass produced by Chinese industries, are used for lighting and other household appliances.

5 Conclusion

An high wind energy potential is available in many cold climate regions of nothern latitudes areas as Alaska, Canada, part of Scandinavia and Russia, and of high altitudes as many mountains or plateaus of America, Europe, Asia. The most part of cold climate regions are not densely populated. Many wind farms are in operations in northern areas for about 200 MW.
Wind technology is in a commercial exploitation phase for moderate climate regions, but many problems are to be faced for the wind farms in cold climates.
In the nineties WEPO project of the European Commission, and projects of other international organizations are promoting R and D activities for adapting wind turbines to cold climate conditions. Results of studies and evaluation are reported in the biennal specialized International Seminar BOREAS in Finland.
Application of wind farms in high altitude plateaus of Asia with cold climate and still uncontaminated nature conditions, as in the Mongolian plateau, should be feasible for the electricity supply to local grids of urban areas.
In particular Outer Mongolia with very low demographic density and few towns and villages, where 50% of population lives, could exploit wind energy to reduce polluting and greenhouse gas emissions by coal power plants.
There wind energy potential is good and technical cold climate problems can be overcome. Few barriers are foreseen for the installations of wind farms.
Financing of wind farm projects could be promoted under by-lateral or international agreement, based even on environment protection rules (GEF,..)
Wind turbines can be partially imported from Europe or other area of the world; local factories can supply towers, civil works, and service equipment. A small wind farm could be installed within 2000 close, if possible, to a town for demonstration and formation of manpower during construction and operation.

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CO_2 LASER BASED MOBILE DIAL SYSTEM FOR ATMOSPHERIC POLLUTANTS MONITORING

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Abstract

There are different techniques of remote sensing, with the dial has been obtaining good results to achieve concentration profiles of several pollutants. In fact, it allows to evaluate the remote concentration of atmospheric constituents. In particular a good tools for this purpose are the dial systems based on CO_2 laser which can be used routinely having an high degrees of eye safety. At the Department of Physics of the University of Calabria a lidar-dial land system has been developed and on the basic of that we have realised a prototype of a mobile station. In the system there are mounted two home-made twin TEA CO_2 lasers in SFUR configurations. The receiving system is based of a cassegrain telescope with 40 cm of diameter that acquire the backscattered signal and on the focal plane is located a cooled HgCdTe detector. The signal is acquired by VXI system and stored in a memory of a personal computer. The laser pulse is transmitted and received by a scanner module The system is mounted in a container which can be transported. At the aim to test the fixed station was done measurements on an horizontal path to span with the laser beam over both a large urban area and a rural one. Work is in progress to improve the mobile dial system in order to have better performances and to achieve atmospheric profiles of compounds of environmental interest.

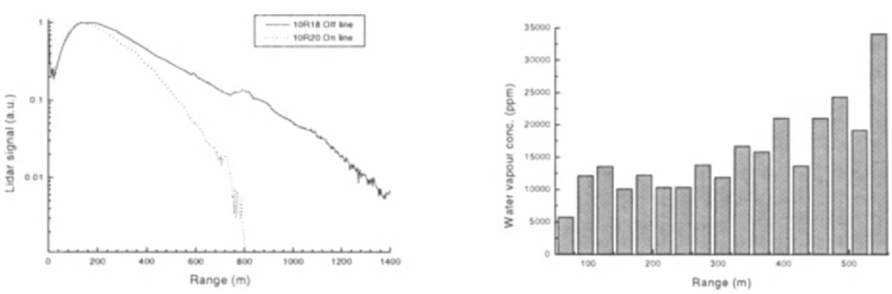
1 Introduction

Today the pollution due to many gaseous toxic species is a great problem for many countries and a lot of environmental control systems are used to defend the atmosphere.
The utilisation of DIAL (differential absorption lidar) technique in controlling the atmospheric pollution has been widely established by several authors [1,2,3] At the Department of Physics of the University of Calabria a prototype of a dial system has been set up [4,5] and now , starting from this one, we are engaged in developing a mobile unit. Water vapour and ozone have been selected to tests the lidar system. After a careful study of experimental

results of the fixed station we have decided to change the sending and receiving optical systems[6], the mirrors of telescope and to improve the range resolution using a pulse clipper system for cut the nitrogen tail of our laser pulse. Moreover with the mobile station it will be possible make measurements around all the territory. Actually work is in progress and in this paper we describe preliminary experimental results with the land station and the main characteristic of our mobile lidar station.

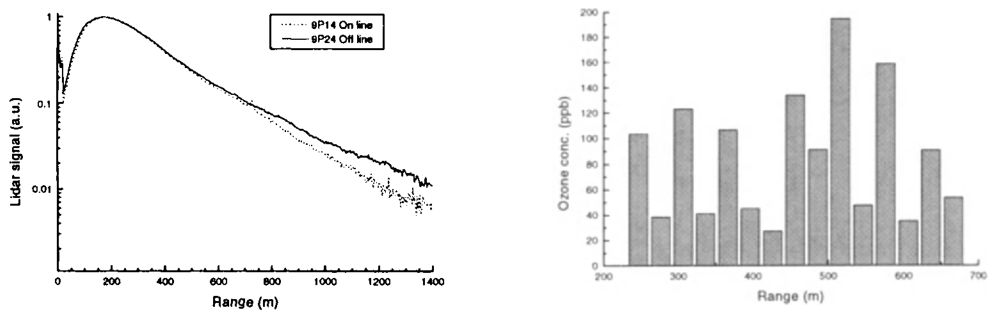
2 Experimental Results with a Fixed Dial Station.

Generally we use to monitoring ozone and vapour water. Water vapour is the most variable of the principal molecular constituents of the atmosphere, it plays a primary role in many aspects of atmospheric physics controlling several chemical reaction of many compounds which interest the environmental aspects. Measurements of troposheric water vapour content and its profile are a basic requirement for meteorological application such as global and local weather predictions. Ozone in the low altitude is a secondary pollutant but it is very toxic and its oxidant power is very high. Its time of permanency in atmosphere is connected to the pollution, so it is possible to consider ozone such as primary pollutants indicator (e.g. NO, CO and formaldehyde).
The idea is to test mobile lidar system with these substances and after to go near a thermal power plant and make preliminary measurements on SO_2 and NO_2. In fact we have already worked to test fixed station with water vapour using alternatively the lines R18 (λ_{off}) and R20 (λ_{on}) around branch 10 μm and with ozone using the lines P14 (λ_{on}) and P24 (λ_{off}) around branch 9 μm. At the moment the pulse repetition rate *f* is 1 Hz and about the spatial resolution we are involved to reduce it until to 15 m.
We have used two different methods to make these measurements, the first one allows to obtain average values of concentration long the path between dial system and a topographical target, this is known as integrated technique. Typical horizontal backscattered signals are shown in figs. 1a and 2a respectively for water vapour and ozone. The second method allows to achieve concentration of a particular molecular specie as a function of the distance, these measurements are known as range resolved, this kind of measurement is based on molecular or particulate scattering but it is less sensitive then the first one. In figs 1b and 2b are reported range resolved profiles for water vapour and ozone respectively.



a) b)

Fig. 1:*Dial Horizontal Water Vapour Measurement: a) Average Backscattered Signals; b) Range Resolved Water Vapour Profile*



a) b)

Figure 2: *Dial Horizontal Ozone Measurement: a) Average Backscattered Signals; b) Range Resolved Ozone Profile*

3 Description of Mobile Lidar Station

3.1 Mobile Laboratory Equipment

To implement the mobile laboratory we have preferred to choose a container in spite of a truck. The full size container is: 20 x 8 x 8 foot (length x width x height). It is more versatile and easily transportable whether on road or on ship and moreover during its utilisation it is fixed on the ground to achieve high stability during measurements. Inside of it we have designed our mobile laboratory. It is quite similar to the fixed one with the same optical parameters. An overview of the of the laboratory is given in Figure 3.

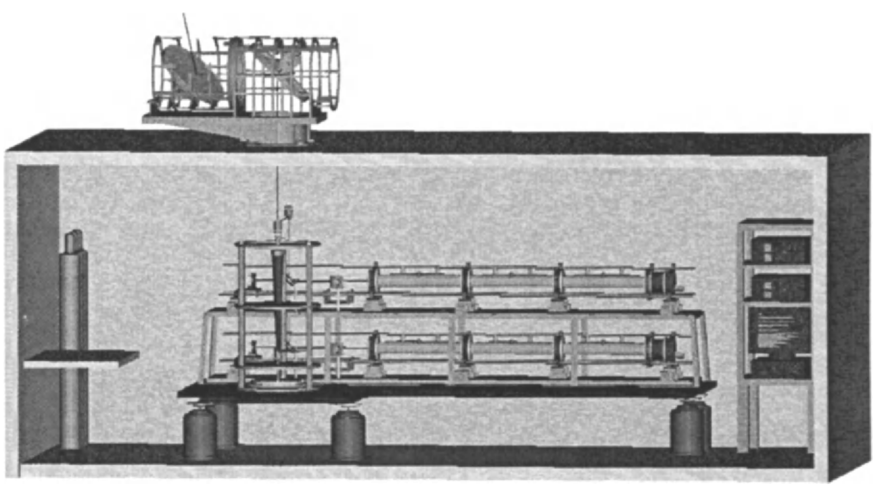


Figure 3 *Equipment Overview*

The transmitting and receiving optics (including laser sources) are placed on a optical table. This is on 5 stabilizer vibration isolators to improve isolation by mechanical vibrations. It is very important for correct alignment among two laser IR beams and the telescope. These stabilizer vibration isolators are acquired from Newport; they have overload capacity of 720 Kg, vertical resonance frequency < 1.1 Hz at 80 psi and horizontal resonace frequency < 1.5 Hz. Inside the container there is also a rack where there are two regulated power supplies to feed lasers, two pulse generators and a controller for the timing and the handling of all the apparatus. In the figure it is shown also the scanner module on the roof of the container.

3.2 Optical System

The schematic diagram of optical arrangements of DIAL system is shown in Figure 4.

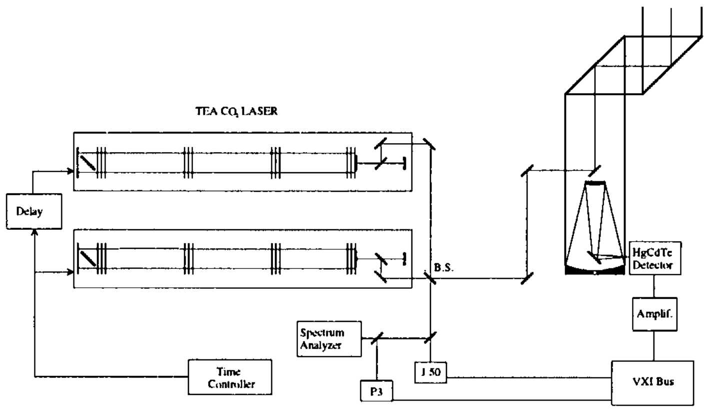


Figure 4: *Optical Arrangement of DIAL System*

The transmitter consists of two home made twin TEA CO_2 lasers in SFUR (self filtering unstable resonator) configuration which are tuneable over more than 60 different lines in the spectral range between 9 ÷ 11 μm using a diffraction grating (λ blazed around 10 μm) mounted inside the cavity. Our cavity uses only one concave mirror, one mirror fully reflecting (focal length = 0.625 m), the second one being replaced with a lens of ZnSe followed by a plane grating (equivalent focal length = 2.50 m). Lasers can achieve maximum pulse energy of 2 Joule. You can see a single laser in Figure 5.

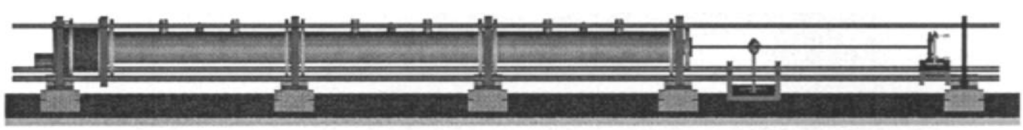


Figure 5: *Laser TEA CO_2*

The adoption of the SFUR laser cavity [7] has allowed us to operate with reduced beam divergence (1.54 mrad.) and to work with a single mode TEM_{00}. The laser chamber was filled with a standard (CO_2:N_2: He - 8%:12%: 80%) gas mixture at atmospheric pressure.
It is possible to selected different laser lines using a DC motor controller that move the grating located at the end of laser cavity on a precision rotation stage. It is shown in Figure 6.
As you can see in the Figure 3, one laser is placed directly on the optical table and the second one is on a scaffold over the first laser to optimise the space. On the same optical table there are mounted some mirrors to transport the beam. They serves to send the radiation on the folding plane mirror mounted at the top of the secondary mirror of the telescope. On the vertical path there is a beam splitter 50% that is used to overlapping the two beams.

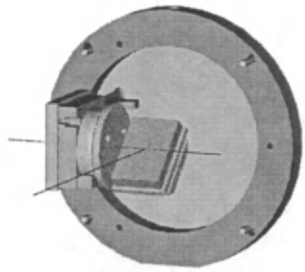


Figure 6: *Diffraction Grating*

The scanner module mounted on the roof of the container is used both for transmission and for optical reception. It consists in two elliptical mirrors (with axes of 40 cm and 60 cm) made in aluminium, gold coated. The scanner module can to rotate of 360 degrees on a vertical axes and of 90 degrees on horizontal axes, it directs the laser beam in the atmosphere and in the same time it directs backscattered light down into the telescope. Figure 7 shown the scanner module.

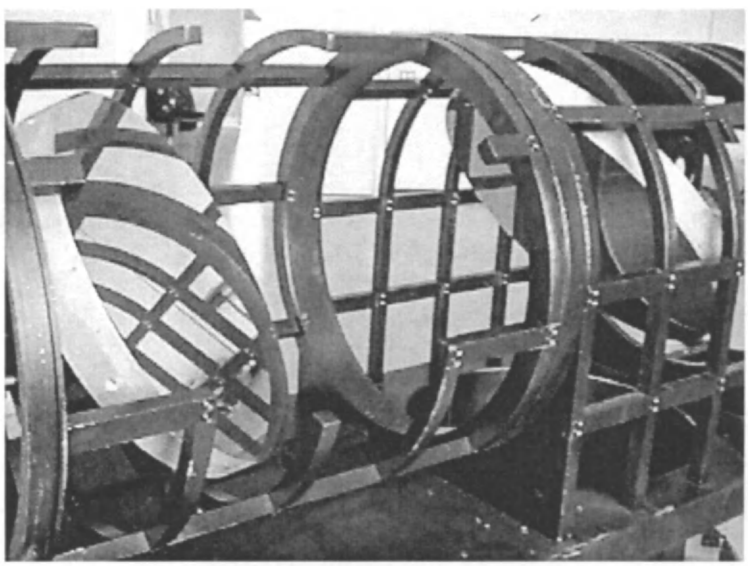


Figure 7: *Scanner Module*

3.3 Detection System

The receiver consists of a vertically mounted telescope in cassegrain configuration with 40 cm diameter primary mirror and a focal length of 1,2 m (it is shown in Figure 8). The secondary is an hiperbolic mirror having 100 mm of diameter. A photovoltaic HgCdTe infrared detector with 1 mm diameter is used to convert the received optical signal. It is cooled with liquid nitrogen and it is placed on the focal plane. The electrical signal is acquired by a standard VXI station digitized by a module ADC Tek 4250 with two channels, 8 bit vertical resolution sampling time 500 MS/sec and stored in a PC. Later they are analised by a special software developed in labview.

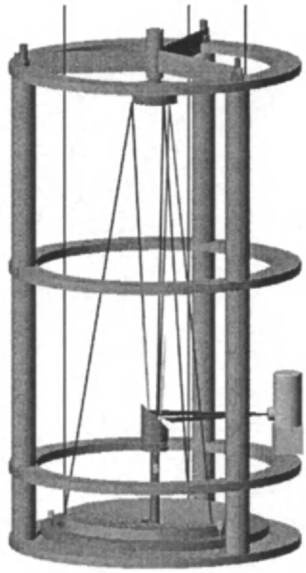


Figure 8: *Telescope*

4 Conclusion

The preliminary measurements made with the fixed station have proved the capability of our lidar /dial apparatus to perform range resolved monitoring with a useful investigated field around 1000 m. Work is in progress to improve the system and to calibrate it in comparison with standard device.

Acknowledgements

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MANAGING AIR QUALITY IN EUROPEAN UNION

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Abstract

The main problems related to air pollution, currently facing the European Union (EU), can be identified in urban air quality, climate change, tropospheric ozone and acidification (atmospheric deposition). The policies and measures to control the emissions have been frequently offset by an contemporaneous increase of the activities producing the pollutants, particularly in the transport sector. But some important improvements have emerged in recent years, particularly in those aspects of the problem which have been recognized on time, where the policy of the interventions is very specifically targeted and the control thecnologies readily available. However further substantial reductions of all atmospheric emissions are needed to reach the current and new target levels for air quality and for exceedances of critical loads on ecosystems.

1 Introduction

The public perception and scientific evidence identify in urban air quality, climate change, tropospheric ozone and acidification (atmospheric deposition) the main problems related to air pollution in the European countries. The activities principally involved in the pollutants emission are related to industrial productions and waste disposal, power generation, road transport, domestic heating and agriculture.

EU is making progress in reducing some air pollution and its impact on human health and ecosystems, but generally the policies and measures to control emissions have been largely offset by an increase in the driving forces behind the pressures, particularly in the transport sector. However some improvements have emerged in recent years, particularly in those environmental problems which have been recognized on time, where remedial measures are readily available, and where abatement measures and policy can be very specifically targeted, such as urban CO (carbon monoxide), NO_x (nitrogen oxides NO+ NO_2), methane and non methane carbon organic volatile ($NMVOC_s$) concentration from vehicles without catalytic converter, urban lead concentrations from leaded petrol, urban SO_2 concentration from sulfur in fuel used for domestic heating or acidification due to sulfur emissions from large point sources, such as power plants.

But in spite of this, new policies allowing further substantial reductions of all atmospheric emissions are needed, to reach the current and new target levels for air quality and for exceedances of critical loads on ecosystems.

2 New UE Limit Values for Air Quality

In the 1996 the EU, in order to maintain and improve air quality within the Community, adopted a Council Directive[1] on the assessment and management of ambient-air quality. This Directive defines basic principles which make it possible and announces in advance a new set of air quality standard to be laid down by the Council at the latest for 1999. The limits concern SO_2, NO_2 and NO, fine particulate (PM_{10}), lead (Pb), benzene , CO, polycyclic aromatic hydrocarbons(PAH), cadmium(Cd), arsenic(As), nickel(Ni) and mercury(Hg). Currently the European Commission (EC) presented a Directive proposal [2] containing for the first 5 pollutants listed(Tab.1).

Table 1: *Air Quality Limit Values*

Pollutant	**Averaging time**	**Limit value($\mu g\ m^{-3}$)** (% compliance allowed per year)	**Year of the compliance**
SO_2			
Health protection	1 h	350(99.7)	2005
Health protection	24 h	125 (99)	2005
Ecosystem protection	year	20	within 2 year
NO_2			
Health protection	1 h	200(99.9)	2010
Health protection	year	40	2010
$NO+NO_2$			
Crops protection	year	30	within 2 year
PM_{10}			
Stage 1			
Health protection	24 h	50(96)	2005
Health protection	year	30	2005
Stage 2			
Health protection	24 h	50(98)	2010
Health protection	year	20	2010
Pb			
Health protection	year	0.5	2005

Ambient-air quality is monitored throughout the Member States. Different methods are used for this: either measuring or mathematical modeling, or a combination of the two, or by means of estimates. An assessment of this type is mandatory in built up areas having more than 250 000 inhabitants, or in areas where the concentrations are close to the limit values.

If the limit values are exceeded Member States must devise a program enabling the limit values to be reached within a set deadline. The program which is open to the public at large, will, in particular, contain the following information: the point where the pollution is excessive, the type of pollution and its assessment, and the origin of the pollution. The

Member States are required to draw up a list of the areas and conurbation where pollution levels are higher than the limit values.

3 UE Sources of Air Pollution [3]

3.1 Power Generation

Total European emissions of SO_2, NO_x, N_2O, NH_3, $NMVOC_s$, CH_4 , CO and CO_2, related to 1995 for 15 UE members plus 14 other European countries, are reported in Tab.2. In Fig.1 the contribute in percentage of sector power generation is reported. Stricter operating practices and the use of up-to-date abatement techniques have resulted in a considerable reduction in the amount of pollutants emitted from power stations: high concentrations however occur in many eastern European countries, particularly from older power stations and from the use of high sulfur lignite or brown coal.

Table 2 *Total Emissions(Mt y^{-1}) of 29 European Countries(data related to 1995).*

SO_2	NO_x	N_2O	NH_3	$NMVOC_s$	CH_4	CO	CO_2
28	18	2	12	22	46	70	479

The countries of the European Union and those which are a party to the Convention on the Long Range Transport of Air Pollution (CRTP-Second Sulfur Protocol), are committed to major reductions in sulfur dioxide emissions. Power generation is, however, likely to remain an important source of pollution for some time to come, particularly as some countries are reconsidering their programs of nuclear power generation.

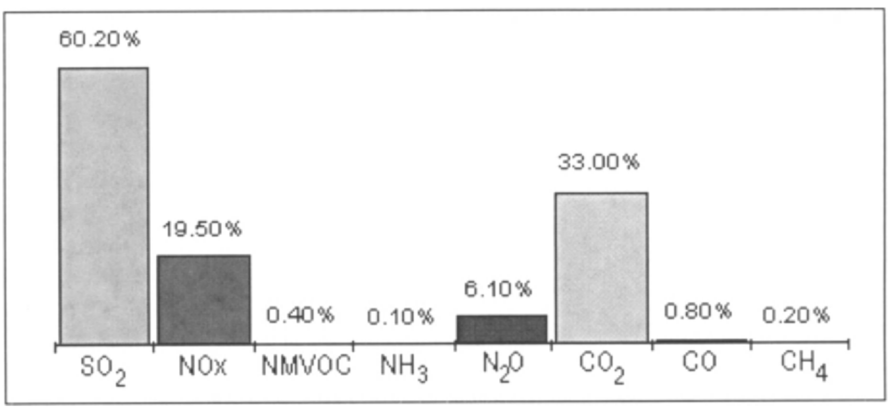

Figure 1: *The Contribute of the Power Generation to Total European Emissions*

3.2 Industry and Waste Disposal

Although fossil fuel power plants are the stationary major source of air pollution in many countries, all industry and many businesses, large and small, can be significant local sources of a wide range of air pollutants.The contribute of this activity is reported in Fig. 2. The use of both regulatory and planning controls, adopting the best available thecnology not entailing excessive costs (BATNEEC) are the principal tools to minimize the industrial emissions and their effect.. Concerning the waste disposal, landfilling and incineration are the two most common methods . If not properly managed landfill sites can cause a number of problems, including the production of potentially explosive levels of methane gas and trace concentrations of toxic substances in the biogas. Uncontrolled or poorly managed the waste incineration can produce toxic pollutants such as hydrochloric acid, dioxins, furans and heavy metals. Modern, properly operated incinerators produce emission which respect the very strict limit existing in EU regulatory .

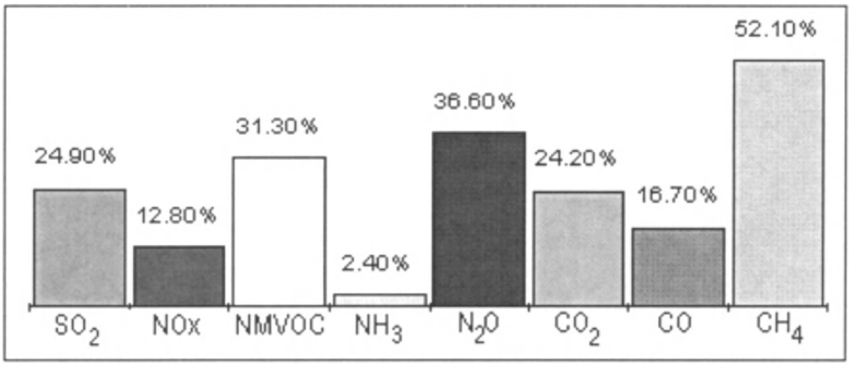

Figure 2: *The Contribute of the Industry and Waste Disposal to Total European Emissions*

3.3 Road Transport

Air pollution from motor vehicles, whose the contribute is reported in Fig.3, has in many countries replaced coal smoke and heavy fuel in fixed sources, as the major cause for concern. The continuing growth in vehicle use means that efforts to reduce emissions from individual vehicles are in danger of being overtaken by increases in the volume of traffic. In much of eastern Europe the continued use of rather old cars, which are unable to meet modern pollution control requirements, means that efforts to control pollution from this source are going to be increasingly difficult.

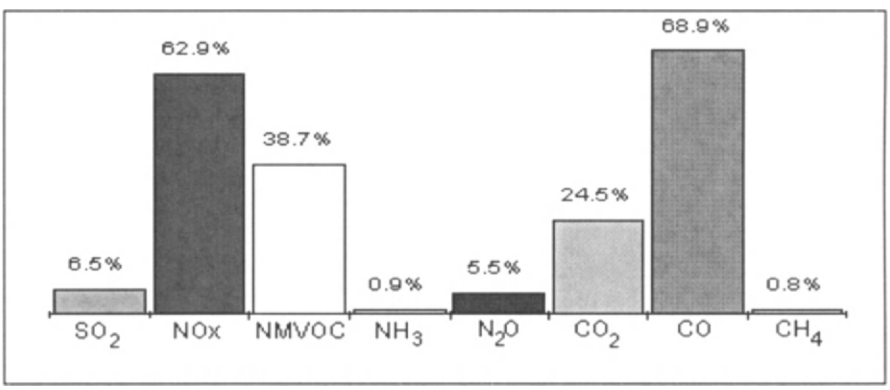

Figure 3 :*The Contribute of the Road Transport to Total European Emissions*

3.4 Domestic Sources

Before about 1960, the domestic use of coal and heavy oil were the major sources of particles in urban areas. Concentrations of airborne particles in many European cities frequently exceeded 1000 $\mu g\ m^{-3}$ and annual average concentrations of several hundred $\mu g\ m^{-3}$ were commonplace. Current emission, due principally to use of gas, allow annual average concentrations in most European cities lower than 30 $\mu g\ m^{-3}$. In eastern Europe much higher concentrations still occur as, to a lesser extent, they do in southern European cities such as Athens. The use of more suitable fuel, as gas and light oil, the adoption of burners, ensuring complete combustion and low NO_x production and the practice of district heating schemes with co-generation plants, provide largely controlled emissions.

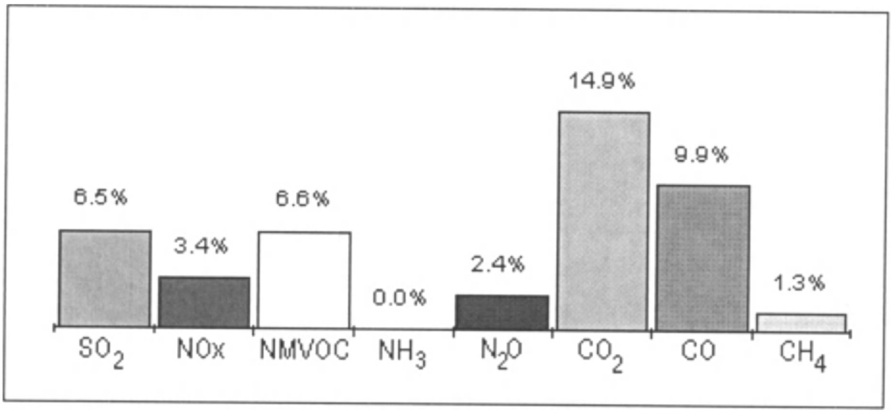

Figure 4: *The Contribute of the Domestic Sources to Total European Emissions*

3.5 Agriculture

Agricultural practices can also be a significant source of nuisance, contributing both to local levels of air pollution and causing odor problems. The main sources of pollution are the burning of agricultural waste, or of crops in the field and large intensive livestock units. Depending on soil type and fertilization, the nitrogen in the dung and urine of grazing cattle contributes 20-40% of nitrous oxide emissions from agricultural land; methane is also emitted by cattle and other ruminants; nitrous oxide and methane are of course both greenhouse gases.

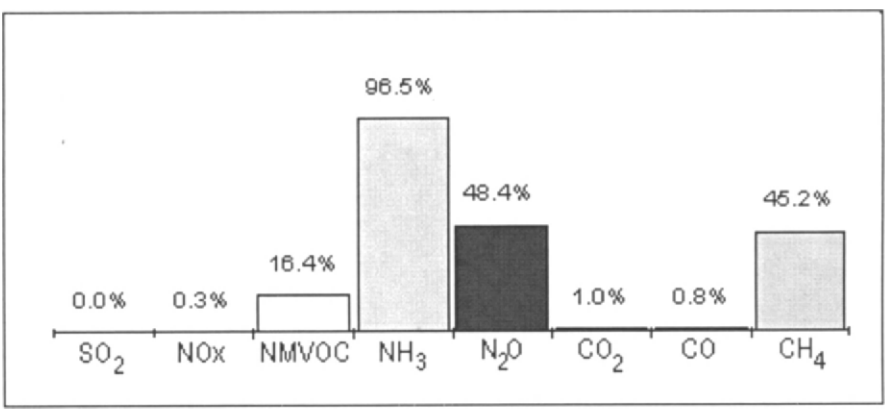

Figure 5: *The Contribute of the Agriculture to Total European Emissions*

4 Current status of Air Quality and Policies in EU[4]

4.1 Climate Change

The Second Assessment Report of IPCC (1995)[5] concluded, inter alia, that "the balance of evidence suggests a discernible human influence on global climate", "the atmospheric concentrations of GHGs(green house gases), inter alia CO_2, CH_4 and N_2O have grown significantly since pre-industrial times: by about 30 %, 145 % and 15 % respectively (values for 1992)", "global mean surface air temperature has increased by between about 0.3 and

0.6 °C since the late 19th century". From 1990 to 1994, CO_2 emissions of several EU Member States (Germany, United Kingdom, Italy) decreased, resulting for the EU15 (15 Member State) in an emission reduction of approximately 2-3 %, mainly due to short-term factors like the temporary decrease of industrial and economic growth rates, the restructuring of industry in Germany, the closing of coal mines in the UK and the conversion of power plants to natural gas. The target of stabilization of EU CO_2 emissions at 1990 levels by 2000 is being monitored by the European Commission but there is uncertainty whether the EU will achieve this target .There is also uncertainty regarding the implementation of measures by Member States and probably many measures will only have an impact after 2000. In the meeting held in Kyoto from 1 to 10 December 1997, which brought together more than 150 nations with the European Union as a major driving force, most industrialized countries gave binding commitments to cut emissions of greenhouse gases by 2010 (reductions by 8 % compared to 1990 levels in the European Union and most central European countries, by 7 % in the USA and 6 % in Japan and Canada; stabilization in New Zealand, Russia and Ukraine; and increases limited to 1 % in Norway, 8 % in Australia and 10 % in Iceland), subject to certain measures allowing a degree of flexibility (the possibility of exchanging emission quotas). The estimated total reduction in emissions of the six greenhouse gases (carbon dioxide, methane, nitrous oxide and three substitutes for CFAs - HCFs, PFCs and SF6) will be 5.2 % compared with 1990 levels. The target is based on the combined reduction of the main GHGs, taking into account their global warming potential. Some EU Member States would be allowed to increase their emissions because this would be offset by decreases in other Member States.

4.2 Acidification

For the whole of Europe a first target for 30 % reduction of SO_2 emissions (from 1980 levels) has been largely reached in 1994, because the emission reduction between 1980 and 1994 was nearly 50 %.

The reduction of SO2 emissions in Europe between 1980 and 1994 was due to a number of reasons, including the possibility to target abatement measures on large point sources (low-sulfur coal and flue-gas desulfurisation) and emission reductions from indirect effects such as fuel switching with an increasing share of natural gas and a decreasing share of coal, renewal of power plants and the restructuring of the economies in Central and Eastern European countries.

For EU and the rest of Europe achieving the aim of the second target , based on United nations - Economic Commission for Europe(UNECE) Sulfur Protocol by 2000 is uncertain. For EU as a whole the target is an emission reduction of 62 % (from the 1980 emission level). New and more strict emission reduction targets for EU15 are currently being developed in connection with the two new EU strategies on acidification and ozone. The provisional EU emission ceiling by 2010 for SO_2 is 2.7 million tonnes, or an 84 % reduction (from the 1990 level). These figures are provisional and they will be reviewed in the light of e.g. the forthcoming ozone strategy and further refinements to the scientific analysis.

The target of the first NO_X Protocol of the Long-Range Transboundary Air Pollution (CLRTAP) Convention of stabilizing the emissions at the 1987 level by 1994, has been achieved on an overall European level, although not by all signatories to that Protocol. The European emissions of NO_X were reduced by about 13% between 1987 and 1994.

The target for EU is a 30% reduction in NO_X emissions between 1990 and 2000, but although NO_X emissions have been reduced in recent years, it does not appear likely that this target will be met. There are several reasons for this, including the expected large growth in road traffic. Furthermore, the results of several measures taken to reduce emissions from motor vehicles, such as strengthened car emission standards, will not take full effect until after the year 2000, due to the rate of turnover of the vehicle fleet. Regarding stationary sources, emission reductions by 2000 are dependent on a number of factors, such as the level of energy use, the type of fuels used, and on how and how fast the provisions of relevant EU Directives are implemented by the Member States.

The relative importance of nitrogen as compared to sulfur in contributing to potentially acidifying depositions is currently increasing. The main reason for this is that over the last 10-15 years emissions of SO_2 have been reduced much more than those of NO_x and NH_3. The provisional emission reduction target for NO_X, as given in the EU acidification strategy, is 6 million tonnes by 2010, which means a reduction of 55% as compared to 1990. Currently there are no international reduction targets for ammonia emissions in the EU.

4.3 Tropospheric Ozone

Concerning the $NMVOC_s$, which are important precursors of tropospheric ozone not strictly involved in acidification phenomena, their emission , for the EU15 and the whole Europe has been reduced respectively by 9 % and 14 % , between 1990 and 1994. The lower reductions in non Member EU States is partly due to the economic restructuring process involving these countries. Due to the fact that the several important Directives for EU Member States, specific for the $NMVOC_s$ control, will not have full effect before 2000, the target of 30 % emission reduction (from 1990 levels) in 2000, remains uncertain.

The EU ozone threshold value for the protection of human health (110 $\mu g\ m^{-3}$, 8h average) is exceeded substantially. Based on measurements at urban stations it can be concluded that 80 % of the EU urban population is exposed to these exceedances at least one day per year during summer smog episodes. On average the EU urban population is exposed to concentrations above the threshold during 1-2 consecutive days per year. Maximum episode lengths of 5-8 days were reported in 1995. Based on model calculations, it can be concluded that 66% of the non-EU-Europeans may be exposed, at least once per year, to exceedances of the WHO and EU thresholds for the protection of human health. Exceedance of the threshold value for warning the public (360 $\mu g\ m^{-3}$) has been reported from one site in 1995 and three stations during 1996.

In 1995 the threshold value for daily average concentrations set for the protection of vegetation (65 $\mu g\ m^{-3}$) was exceeded substantially (by up to a factor of 3), in all reporting EU15 countries and frequently. Exceedances during more than 150 days are estimated for more than 27% of the area.

4.4 Air Quality in Urban Area

For SO_2 about 70% of the total population of all the European cities with monitoring stations (population of about 37 million) is exposed to levels above the lower EU Guide value (100 $\mu g\ m^{-3}$, 24-h average). Maximum 24-hour concentrations regionally may reach 100-150 $\mu g\ m^{-3}$ in several areas in Europe (central/east Europe and UK).

For NO_2 a number of cities with about 40% of the population (population of about 27 million) have an average level above the EU Guide values (50 $\mu g\ m^{-3}$, P50). Maximum 24-hour concentrations regionally may reach 60-70 $\mu g\ m^{-3}$ in most of central Europe, well below the WHO Guideline of 150 $\mu g\ m^{-3}$. Thus, episodes of regionally high NO_2 concentrations do not pose a health risk to the population outside urban areas.

Trend data for SO_2 and NO_2 levels in recent years is only available on a consistent reporting basis for a limited number of cities in Europe. Over the period 1988-1993 a rather consistent downward trend in SO_2 concentrations occurs with an average reduction in SO2 (annual mean) in these cities of 30%. There is a similar trend in NO_2 concentrations, with an average reduction in annual mean of 16%. These trends are the result of several factors, including past and current abatement policies like the sulfur protocol and introduction of 3-way catalysts for passenger cars, but also indirect effects like the restructuring of economies . For particulate matter measurement data is not complete enough to present a representative map on the European scale. The total suspended particulate exceeds EU Limit values to some extent at a few places, and EU Guide and World Health Organization Guideline values at several places. The small-sized particulate matter (PM_{10}, 98-percentile) exceeds the UK recommended guideline of 50 $\mu g\ m^{-3}$ extensively in most of the cities for which data are available. Regional PM_{10} concentrations can reach 25 $\mu g\ m^{-3}$ as annual average in certain parts of Central/North-western Europe. The additional urban contribution is most often smaller than this regional component. To control long-term average PM_{10}, abatement of the regional scale contributions is thus very important. For maximum short-term (24 hour) episodes, the urban contribution is more important. Although lead concentrations have been decreasing in recent years, lead still may a pollution problem near roads with intense traffic in the countries which still have a relatively high lead content in gasoline.

The EU has not yet established Guide values for benzene. UK, the Netherlands, Italy and Germany have recommended guidelines within the range of 3-16 $\mu g\ m^{-3}$, as annual average. City background levels are presently in the same range as the range of these recommended guidelines the current ongoing introduction of three-way catalysts on gasoline-powered vehicles, current legislation for diesel-powered vehicles, and further vehicle technology and fuel improvements will have a further significant effect on urban air quality as regards NO_2, CO, benzene and, to a smaller extent, PM_{10}.

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REMOVAL OF NITROGEN OXIDES PRODUCED DURING WASTE INCINERATION: OPERATION OF A FULL-SCALE DENO$_X$ SYSTEM

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Abstract

All the conventional combustion processes produce nitrogen oxides (NO_X). In the present paper the main installation commonly used for NO_X removal are reviewed and the experience carried out in the $DeNO_X$ unit of a full-scale waste incineration plant is synthesized.

1 Introduction

All the conventional combustion processes produce nitrogen oxides (NO_X). The main compounds referred to as nitrogen oxides are the monoxide (NO) and the dioxide (NO_2) of nitrogen; in fact, only the monoxide and the dioxide are dangerous as regards to the atmospheric pollution. Generally, the NO_2/NO volume ratio is between 0,05 and 0,1. The NO_2 is one of the most dangerous atmospheric pollutant; in fact it is one of the major contributors to the acid rain and the precursor of the so called photochemical smog. Although the NO has a certain level of the toxicity (about 1/4 of the dioxide toxicity), it is quickly transformed, even at low concentration value, into the nitrogen dioxide at the presence of some atmospheric oxidant compounds, such as O_3, O_2H, RO_2, etc. (for instance, the 50% of the 0.1 ppm of NO is converted in NO_2 reacting with 0.1 ppm of O_3 in less than a minute).

During the combustion process, two kinds of mechanisms basically contribute to NO_X formation: thermal oxidation of the nitrogen coming from combustion air, that determines the formation of the so-called "*thermal NO_X*"; and conversion of the nitrogen coming from the combustible, that determines the formation of the so-called "*fuel NO_X*".

Thermal NO_X is formed from nitrogen in the combustion air, when combustion gas remains for enough time at the temperature higher than 1,600°C. The reaction kinetics of the thermal NO_X is:

$$[NO] = A \times e^{\left(\frac{-E}{RT}\right)} \times [N_2] \times [O_2]^{\frac{1}{2}} \times t \qquad (1)$$

where the chemical compounds are expressed in molar concentration; "A", "E" and "R" are constants, "T" is the flame temperature expressed as °K and "t" is the detention time.
Therefore when increasing the flame temperature, the detention time and the excess of air, ($[O_2]$) in flue gas, the thermal formation of NO_X grow up.
The concentration of nitrogen compounds in the waste contributes to the formation of *Fuel NO_X*. Fuel NO_X is formed at the temperature lower than what is necessary to the fixation of nitrogen in thermal NO_X [1]. It is due to the low tightened forces in organic compounds in the waste. Nitrogen contained in the Municipal Solid Waste (MSW) is only about 0,5% by weight, so the contribution of fuel NO_X in the flue gas is negligible. The main parameters that influence fuel NO_X formation are the nitrogen compound content in the waste and the excess of burning air, from which depends oxygen concentration in the flue gas.

2 Method Control

The methods to control the emission of nitrogen oxides are generally divided into two groups. The first group includes the primary actions that allow the reduction of NO_X while they are produced, i.e. during the combustion process; the second one includes all the secondary actions, represented by the techniques for NO_X removal once formed.

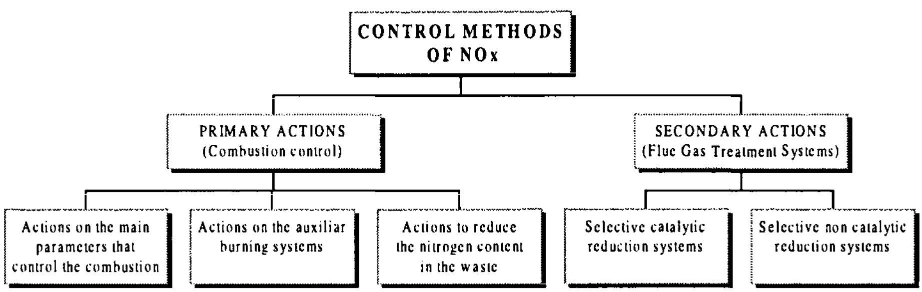

Figure 1: *Methods to Control the Emission of Nitrogen Oxides*

<u>Primary actions</u> in incineration plants determine the control of the operative conditions of the combustion, using one or more of the following methods:

- limitation of the maximum temperature in the combustion zone and reduction of the detention time in the high temperature zone (limitation in thermal NO_X formation)
- reduction of the oxygen content acting on primary and/or secondary air (limitation in thermal and fuel NO_X formation)

The more commonly used primary actions in waste incineration plants are the *Two Stage Combustion* and the *Flue Gas Recirculation* methods.
The *Two Stage Combustion* (TSC) method uses two sequential combustion stages; the first stage is in depletion of oxygen, the second one is in excess of oxygen. This allows to reduce flame temperature and to produce "reducing condition" where nitrogen oxides (thermal and fuel NO_X) are removed. The TSC method can be applied using two technique:

- burning waste in two separate combustion chambers, the first chamber operates the chemical reduction, the second the chemical oxidation;
- injecting different amount of air into two distinguished zones of the same combustion chamber. In this way the first zone, placed in the beginning, operates the chemical

reduction, while the second, which is at the end of the combustion chamber, operates the chemical oxidation.

TSC technique allows the NO_X removal with efficiency of about 30%, but it may result an incomplete combustion, which means increased amount of unburned substances in the slags. TSC method, if used as single method, often causes a lower endurance of materials due to the high temperature reached in the combustion chamber. In fact, the low amount of primary air reduces the amount of oxygen but, at the same time, reduces its cooling effect in the combustion zone. For this reason TSC method is generally used together with the Flue Gas Recirculation technique.

The *Flue Gas Recirculation* (FGR) is based on oxygen content reduction by recirculating a part of the flue gas from the boiler's outlet into the combustion chamber. This technique reduces the nitrogen oxides formation by means of two mechanisms:

- to decrease total and local temperature of the flue gas in combustion chamber so that the thermal NO_X formation is reduced;
- to reduce the oxygen content in combustion chamber, and consequently limit thermal and fuel NO_X formation.

Flue gas can be injected into the combustion chamber directly or after mixing with the primary air so to obtain an enough oxygen concentration in the mixture and assure a good combustion. In incineration plants, it is possible to apply this method as the oxygen concentration in the flue gas is in the range of 7,5 to 11% by volume and the temperature of the flue gas is in the range of 150 to 300 °C, while in the combustion chamber they have to be at least 6% and at the best 950 °C respectively. Furthermore, considering that the amount of oxygen in the air is 20,94% by volume, it is necessary to have an appropriate mix ratio between the flue gas and the external air to obtain an available primary air so that have a good combustion with a limited amount of unburned substances in the slags. The mix ratio value depends on the main characteristics of the plant and of the burning waste. The FGR NO_X removal efficiency is quite variable, it increases with versus temperature.

Secondary actions consist of the nitrogen oxides removal in flue gas after forming. This method may be used as single or combined with primary actions control method. The most used secondary actions techniques are the "Selective Catalytic Reduction" and the "Selective Non Catalytic Reduction".

In *Selective Catalytic Reduction* (SCR) process ammonia, concentrate or in solution, is used to react selectively with NO_X forming nitrogen (N_2) and water, at the presence of a catalyst. At the presence of oxygen, ammonia is also oxidized to nitrogen, so that it is necessary an excess during its injection to allow the desired goal. In the catalytic reactor the following chemical reactions occur:

$$4NO + 4NH_3 + O_2 \longrightarrow 4N_2 + 6H_2O \qquad (2)$$

$$2NO_2 + 4NH_3 + O_2 \longrightarrow 3N_2 + 6H_2O \qquad (3)$$

The quantity of injected ammonia is higher than stoichiometric requirement. Its excess depends on the concentration of nitrogen oxides in flue gas and on the value that have to be respected to the emission. The NH_3 fraction oxidized by oxygen is not effective in NO_X chemical reduction. Chemical reactions (2) and (3) are catalyzed by metal oxides, the so-called "active compounds", that are present in honeycomb or plate structures in order to limit the head loss and to have an extended contact area. In SCR technique, the flue gas temperature must be in the range of 300 and 400°C depending on the type of catalyst used; temperature higher the admissible value may damage catalyst (syntherization), while at the lower temperature ammonia sulphate and bisulphate can be formed and poison the catalyst. Many factors influence the SCR removal efficiency:

- the chemical reactions temperature (variable by nominal value);
- the catalyst (type, chemical composition, etc.);

- the NH_3/NO molar ratio (in MSW incineration plants this ratio is generally equal or little bit more than 1, with efficiency of about 80%). The higher is this ratio, the higher is the removal efficiency, and the higher may be the amount of unreacted ammonia (ammonia slip) that follows the gas out of the stack;
- the ratio between the gas flow rate in catalyst and the catalyst volume (in the range of 2.000 - 10.000 h^{-1}; the higher is this ratio, the lower is flue gas detention time in the catalyst, and the efficiency of the system).

The catalysts, generally, are metal oxides such as V_2O_5 and/or WO_3 on TiO_2. These oxides are usual combined with these other constituents: FeO_3, MoO_3 and CrO_3. Catalysts are in dust or granulate form. The dusts, SO_X and/or heavy metals in the flue gases to be treated can damage the catalyst. The dusts determine dirt and erosion, while SO_X and/or heavy metals poison the catalyst. Moreover the catalyst have effect on the kinetic to form SO_3 by SO_2. The SO_3 react with ammonia (4) (5) reducing the removal efficiency of the system. The formed products may condense on cool surface starting up corrosion process.

$$2NH_3 + SO_3 + H_2O \longrightarrow (NH_4)_2SO_4 \qquad (4)$$

$$NH_3 + SO_3 + H_2O \longrightarrow NH_4HSO_4 \qquad (5)$$

MSW incineration plants, which have installed a spray dryer followed by a filtering section, are not directly suitable for SCR system. In fact, after filtering, even if the flue gas is enough clean to go into the catalyst bed, it is too much cold (flue gas temperature in the outlet of the spray dryer is about 90°C). So it is necessary to heat the flue gas by means of an heat exchanger,.

The *Selective Non Catalytic Reduction* (SNCR) method allows the limitation of nitrogen oxides by means of injection of ammoniacal compounds (ammonia or urea) in the flue gas at well defined temperature, so that NO_X is reduced to N_2, while ammonia is oxidized to N_2.

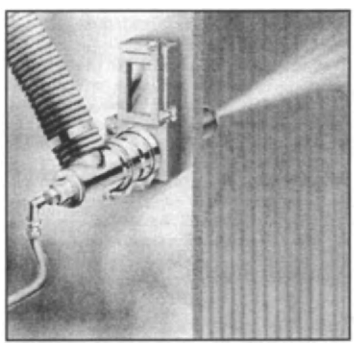

Figure 2: *Ammonia Injector in a SNCR DeNO$_X$ System [2]*

The following chemical reactions occur with respect of nitrogen monoxide:

$$6NO + 4NH_3 \longrightarrow 5N_2 + 6H_2O \qquad (6)$$

$$2NO + 4NH_3 + 2O_2 \longrightarrow 3N_2 + 6H_2O \qquad (7)$$

$$2NH_3 + 2{,}5O_2 \longrightarrow 2NO + 3H_2O \qquad (8)$$

The reactions (7) and (8) occur when oxygen is present in the flue gas; oxygen, versus its concentration, determines the partial oxidation of NH_3 while, at the same time, the NH_3 reacts with NO forming N_2 and H_2O (7). The NH_3 reacting with oxygen, is not effective for NO_X removal. Therefore, the real ammonia consumption is in the range of 0,66 - 2 moles of NH_3

for each mole of reduced NO_X ((6) and (7) respectively). Temperature has a strong influence on SNCR system, because the reaction (7) occurs, with a reasonable kinetic, only if the flue gas temperature is in the range of 870 and 1095°C. At the temperature higher than 1095°C reaction (8) becomes predominant so that nitrogen oxides are formed rather than removed. At temperature lower than 870°C, reaction (7) doesn't occur and ammonia doesn't react causing the "ammonia slip" in the flue gas. For this reason, $DeNO_X$ SNCR plants are usually provided with several injectors actionable at different zones, in this way the best field of temperature (870 - 1095°C) to inject ammoniacal compound into combustion or boiler zone can be chosen during the real managing of the plant. The ammonia amount injected has to be higher than the stoichiometric need depending on the NO_X concentration out of the combustion zone and the removal efficiency to reach. This may produce ammonia slip in the flue gas. So a right solution between NO_X removal efficiency and cost of system management, that depends on the quantity of ammonia used, must be found.
The advantages of SNCR method are the following:

- the technique is very simple;
- catalysts or other reagents are not necessary;
- pre-heating of the flue gases is not required because the reaction occurs in an available high temperature zone;
- the building area of the plant is reduced as space for catalytic bed is not necessary;
- it is applicable in a high range of initial NO_X concentration in flue gas.

The SNCR removal efficiency may reach up to 80% [3].

3 Real Application of a SNCR System on a Full Scale Incineration Plant

In the present paper the real experience coming from the incineration plant of Rome is presented.
The plant is situated in the south-west of Rome and it burns the hospital waste produced by hospitals, nursing homes, surgeries, pharmaceutical producers and health structure in general coming from the Lazio District. This incinerator is the biggest incineration plant in Italy and one of the biggest in Europe that treat hospital wastes solely. Its capacity is about 15.000 Mg/year of hospital waste with a Low Calorific Value (LCV) of about 860 kJ/kg (its nominal thermal capacity is about 1.500.000 kJ/h). It is substantially composed of the following systems:

1. an automated system (dynamic storehouse) for the storage and the movement of the waste
2. a storage and movement system for expired pharmaceutical
3. two lines of thermodistruction, one at a back up for the other, composed of the following systems:
   - hopper charge
   - combustion section, constituted by a rotating kiln, a post-combustion chamber and a system for the extraction of the slags
   - steam generator
   - ammonia injector for the control of NO_X from flue gas
4. two lines for the treatment of the gas, composed of the following systems:
   - conditioning tower, where the temperature of the gas is lowered with water injection
   - adsorbing reactor for the dry control of the acid compounds
   - fabric filter, for the particulate control
   - wet scrubbing, for the final gas control
5. double flue stack for the treated gas

The plant has, in addition, some systems auxiliary for the processes, such as

1. a scrubbing and disinfecting system for vehicles,
2. a section for the storage and the disinfection of the pallets.

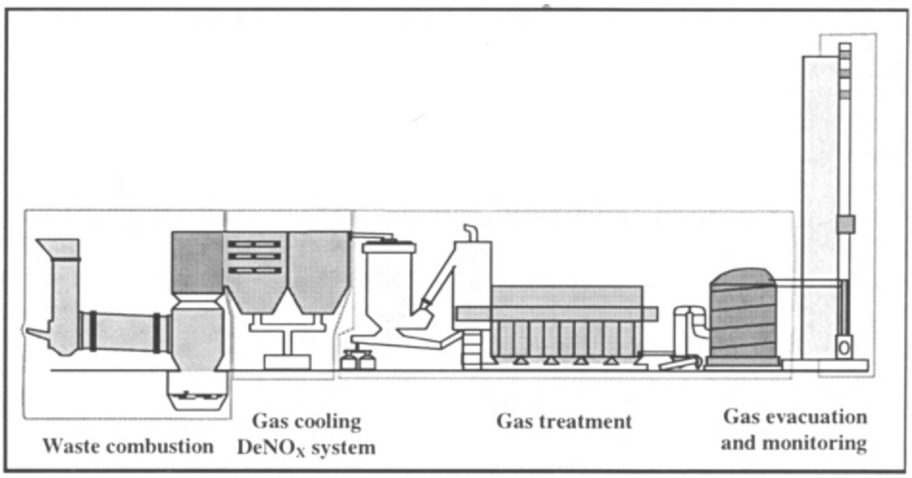

Figure 3: *Incineration Plant of Rome*

The DeNOx SNCR system has been installed in the incineration plant of Rome. The system consists of the following elements:

1. ammonia loading and storage,
2. ammonia line,
3. carrier steam line,
4. ammonia/steam injection manifold.

Figure 4 shows the process diagram of the DeNOx system.

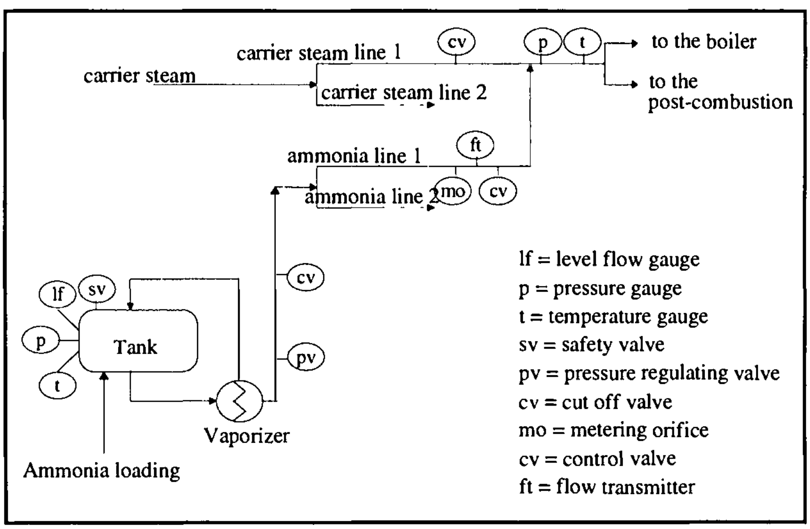

Figure 4: *DeNOx SNCR System in the Incineration Plant of Rome*

Anhydrous liquid ammonia is stored in a tank of a volume of approximately 8,000 liters. Storage tanks is filled with anhydrous ammonia to a capacity of 85% and operates at the pressure of approximately 4.0 barg. A metering orifice and a control valve are specified to control the flow of ammonia vapor from the storage tank to the injectors. Moreover, a relative large amount of carrier steam is added to the ammonia to provide optimum mixing of the ammonia vapor with the flue gas. The flow rate of steam is controlled using a pressure regulating valve connected to the plant steam line. Before the line splits to supply the injection manifolds, a 20 pipe diameters should be allowed for the ammonia to mix with the steam. Each injection manifold supplies three injection nozzles in the post combustion chamber and each manifold supplies four nozzles in each of the three zones in the heat recovery boiler. The injection nozzles increase the velocity of the ammonia/steam mixture in order to achieve proper mixing with the flue gas.

On the plant, during the initial starting period, were carried out different tests aimed to set the best control parameters to optimize the management of the plant. Among these tests, with regard to SNCR DeNO$_X$ system, were analyzed:

1. the optimal injection zone of ammonia;
2. the best ratio ammonia/carrier steam;
3. the optimal ammonia flow at different amount of burned waste;
4. the definition of removal efficiency of the optimized system.

In practice, we tried to optimize the values of these parameters to obtain, for each different operative condition, a fixed NO$_X$ value in treated flue gas and the minimization of the used ammonia and carrier steam flow. In order to control the process, it was necessary to choose one parameter as the combustion representative parameter of the incinerator. The steam flow from boiler has been chosen as the combustion control parameter for the following reasons:

a) Steam flow from boiler directly depends from waste flow and waste Low Calorific Value;
b) Hospital Solid Waste treated in Rome plant are very heterogeneous. Moreover, the waste is packed and transported in small cardboard boxes, the so-called "standardized loading units", and are stored in a dynamic storehouse. This is a reason that no homogenization can be made during the hopper charge. Therefore, incineration plant of Rome usually runs with a variable waste charge to maintain the steam flow from boiler roughly constant.

Ammonia may be injected in four different zones of the plant.

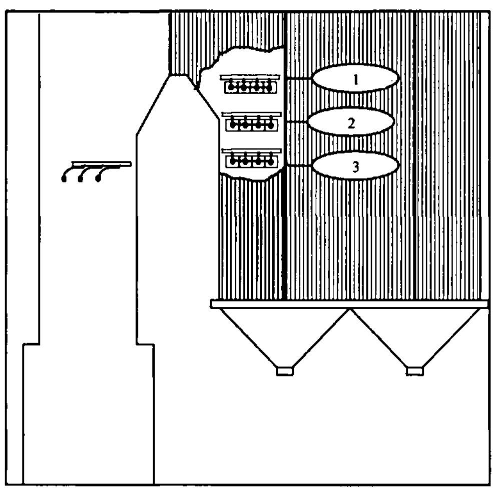

Figure 5: *Injection Nozzles of Ammonia in the Post-combustion Chamber and in the Boiler; Conventional Adopted Notation*

A preliminary study was carried out to measure the temperature in these zones in the different running conditions. The results showed that the zone of the outlet to the post-combustion chamber can never be the "best point" for ammonia injection, due to the high temperature.

Experimental tests carried out to determine the optimal injection zone of ammonia and the optimal ammonia flow, for each injection nozzles, at the following conditions: 1) steam from boiler flow equal to 6.000 kg/h; 2) carrier steam flow equal to 265 kg/h.

The results are shown in figure 6.

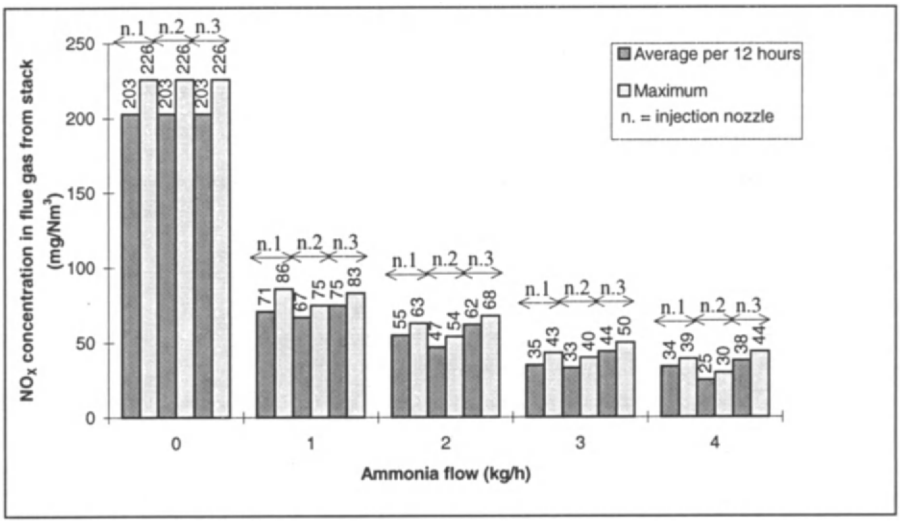

Figure 6: *Maximum and Average per 12 Hours Values of NO_X Concentration in Flue Gas from Stack as Regards to Ammonia Flow*

The figure shows the average per 12 hours and the maximum values of NO_X concentrations as regards to ammonia flow. The graphic shows that higher is the injected ammonia flow, lower is the NO_X concentration in flue gas from the stack. The fixed NO_X emission limit for the Rome incineration plant is equal to the $DeNO_X$ system technological limit (about 80 mg/Nm^3, referred to O_2 equal to 11% in volume in dry gas). Prudently, to define the best operative condition for the $DeNO_X$ system, we fixed the following limits:

- the average per 12 hours NO_X concentration must be lower than 80 mg/Nm^3;
- all the 12 averages per hour NO_X concentration must be lower than 104 mg/Nm^3 (limit value + 30%).

Figure shows that an ammonia flow of to 1 kg/h is enough to keep NO_X concentration values in respect to the limits at the injection nozzle number 2.
All the above-mentioned tests were done at the carrier steam flow of 265 kg/h. Once ammonia flow and point of discharge best values are known, some other tests were carried out to check if the used carrier steam flow was the lowest, to avoid energy waste.

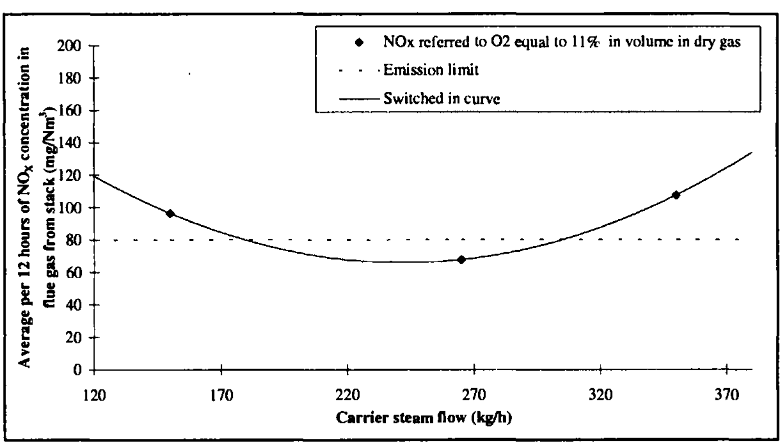

Figure 7: *Average per 12 Hours Values of NO_X Concentration in Flue Gas from Stack as Regards to Carrier steam Flow*

These tests have showed that, if the carrier steam flow increases, NO_X concentration in emissions decrease as far as a minimum value and then increases again. We can explain this phenomenon noting that the chemical reaction to NO_X reduction (7) is limited by the water content in flue gas. In the figure 7 we used a 2nd order switched in curve; you can notice that the optimal carrier steam flow is equal to 265 kg/h.
The tests to determine the best parameter values at the steam flow from boiler of 7.000 and 8.000 kg/h are carried out using the same principles used for the 6.000 kg/h tests. All tests had the same results, so only the final results are described in the table below.

Table 1: *Maximum and Average per 12 Hours Values of NO_X Concentration in Flue Gas from Stack as Regards to Ammonia Flow and Injection Nozzles*

Steam from boiler	**6 000 kg/h**															
Ammonia		**0 kg/h**			**1 kg/h**			**2 kg/h**			**3 kg/h**			**4 kg/h**		
Injection		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
NO_X concentration in gas from stack	maximum	226	226	226	86	75	83	63	54	68	43	40	50	39	30	44
	average	203	203	203	71	67	75	55	47	62	35	33	44	34	25	38
Steam from boiler	**7 000 kg/h**															
Ammonia		**0 kg/h**			**1 kg/h**			**2 kg/h**			**3 kg/h**			**4 kg/h**		
Injection		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
NO_X concentration in gas from stack	maximum	237	237	237	95	87	94	75	60	68	55	42	47	45	37	40
	average	223	223	223	87	74	83	65	51	61	47	36	40	42	32	36
Steam from boiler	**8 000 kg/h**															
Ammonia		**0 kg/h**			**1 kg/h**			**2 kg/h**			**3 kg/h**			**4 kg/h**		
Injection		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
NO_X concentration in gas from stack	maximum	251	251	251	121	116	119	72	67	66	56	52	50	41	36	43
	average	238	238	238	110	107	108	62	59	60	50	45	46	40	33	38

The evidential values are those which correspond to the best operative conditions for the $DeNO_X$ system.
From the table, you can notice that when the steam flow from boiler increases, NO_X formation increases too. This is obvious, especially, if you see the tests without ammonia injection, in which NO_X concentration in flue gas from stack is as same as NO_X concentration in the inlet. This agrees to what we mentioned before that main parameters that influence NO_X formation during waste combustion are the flame temperature and the excess of the combustion air, from which the oxygen concentration in the flue gas depends.
Tests carried out to determine the optimal carrier steam flow showed that 265 kg/h is the optimal value for each steam flows from boiler.

4 Conclusion

In order to determine the $DeNO_X$ system removal efficiency in incineration plant of Rome, it was necessary to define a variability range for nitrogen oxides concentration in emission, due to the higher average per hour variability with respect to average per 12 hours. To do this, we adopted two different methodologies:

1. to consider the maximum difference found during the experimental tests as the variability range,
2. to consider the hourly average standard deviation as the variability range. The standard deviation was calculated using the following expression:

$$Dev = \sqrt{\frac{n\left(\sum x^2\right) - \left(\sum x\right)^2}{n(n-1)}} \tag{9}$$

where "x" is the average per hour value and "n" is the number of "x" obtained from each test ("n" is equal to 12).
Removal efficiency variability range calculated by both methods are shown in table 2. The evidential values are those which correspond to the best operative conditions for the $DeNO_X$ system.

Table 2: *Removal Efficiency of Rome $DeNO_X$ System*

		Maximum difference			Dev		
		Steam flow from boiler (kg/h)			Steam from boiler flow (kg/h)		
Ammonia flow (kg/h)	Removal efficiency	6 000	7 000	8 000	6 000	7 000	8 000
0							
1	min	57 %	58 %	48 %	61 %	62 %	50 %
	max	75 %	74 %	61 %	71 %	71 %	60 %
2	min	70 %	71 %	70 %	73 %	74 %	73 %
	max	82 %	82 %	80 %	80 %	80 %	78 %
3	min	78 %	80 %	77 %	81 %	82 %	79 %
	max	89 %	88 %	84 %	87 %	86 %	83 %
4	min	83 %	81 %	83 %	85 %	83 %	84 %
	max	91 %	89 %	89 %	90 %	88 %	88 %

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TE - CO_2 INJECTION LASER FOR WIND MEASUREMENTS DOPPLER APPLICATION

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Abstract

Within the framework of our LIDAR activity [1] devoted to air pollution measurements, we realised the injection of a continuos carbon dioxide laser into a high power TE CO_2 laser, to get the possibility of better analyse return signal responses and to realise a Doppler wind velocimeter [2], [3]. Apart from the need of temporally smooth pulse to examine measurements results, in remote sensing it is desirable to use narrow band laser sources. The request of high spectral performances is mainly based on the possibility to use heterodyne detection, on one hand, to improve the signal to noise ratio, and, on the other, to observe and analyse Doppler frequency shit in the return signal.
We are engaged in to implement a TE CO_2 laser source by injection of a cw pulse from a low pressure CO_2 into a TE.
Preliminary results we obtained show a smoothing of the output pulse shape and a consequent reduction in spectral band-width, revealing a single longitudinal mode operation.

1 Introduction

Due to beats between cavity modes, pulses generated by a TE CO_2 laser show a spikes structure. Competition between modes is not only due to the amplification at almost equal gain, but also to the fact that spontaneous emission excite them at nearly equal rate. It is well known that single mode pulses can be generated essentially in two ways: a) increasing the gain of the desired mode, or b) forcing the excitation of the desired mode to higher values than those provided by spontaneous emission. The first choice is realised by means of the so called "hybrid configuration" [4], while the second is obtained injecting of a cw pulse from a low pressure CO_2 into a TE [5]. To get a better inside about the importance of single longitudinal mode laser pulse, let us first spend few words in describing the two main methods mentioned above.
As it is well known, the output pulse of A CO_2 laser shows strong modulation dues to beats between different modes inside the cavity, In many applications, such a modulation is highly undesirable. It must be remind that it is observed because the modes making up the output

pulse grow at essentially at the same rate from spontaneous emission, with almost the same power. In fact the gain width in a high pressure discharge is very large in comparison with modes spacing. Contemporary laser gain is almost constant over a wide number of modes.
To reduce the number of transverse modes to the lowest order an aperture is generally introduced into the laser cavity; in this way we take advantage of losses suffered by higher order modes.
To get longitudinal modes selection similar attempts have been made to cause cavity losses to vary rapidly with frequency so that one mode will grow faster then any other during the pulse development [4],[5].
Hybrid configuration [6] essentially consists in incorporating a low pressure gain section in the same laser cavity of the high pressure section. In this way it is possible to ensure a good increase in gain for the longitudinal mode lying inside the narrow gain profile of the pressure section.
In the injection method [7] radiation is injected, into the TE (or TEA) CO_2 laser from an external low power continuous wave (cw) CO_2 laser. Also in this way one obtains a single longitudinal mode emission along with high output energies in pulsed CO_2 lasers. In addition the use of a tuneable cw laser, operating as an injection oscillator allows to match the frequency of an absorbing specie or to detune it out from CO_2 absorption fine centre. Such a choice is of great importance in lidar applications to remote sensing measurements.

2 Injected TE-$C0_2$ Laser

A schematic diagram of injected TE CO_2 laser is given in Fig. 1.

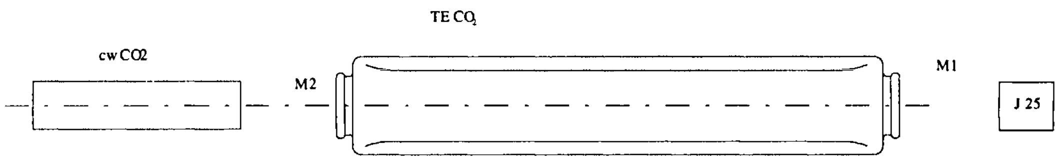

Figure 1: *Set up of Apparatus*

To realise this experiment we have used off shelf components, for this reason we have remounted an old XeFl laser Lunonichs model and after some modifications we have adapted it to work as a TE CO_2 laser. The last is an U.V. preionized device with two sliding spark arrays as preionizers and Rogowski profiled electrodes, 80 cm long, which define 2cm x 2cm discharge cross section. At the end of the TE laser we have mounted a cw CO_2 laser as injection. One side of TE laser cavity is closed by concave mirror (M1) with a centre hole for inject cw laser and the second side by germanium (M2) window for the output part of the beam. The CO_2 laser works with a gas mixtures of CO_2 N_2 and He. We have optimised the energy pulse of TE CO_2 laser for several gas mixtures obtaining the maximum value of the energy pulse when the mixture ratio was 1:1:3 (CO_2:N_2:He). This is shown in fig.2. Moreover, using mixture ratio 1:1:3, we have done other measurements to know the output energy and the power vs pressure. As shown in fig. 3 and 4 better working pressure of job is 450 torr. In summary we have measured the laser pulse profiles of cw CO_2 laser module, it is shown in fig. 5, and maximum power (it results 4 watt).

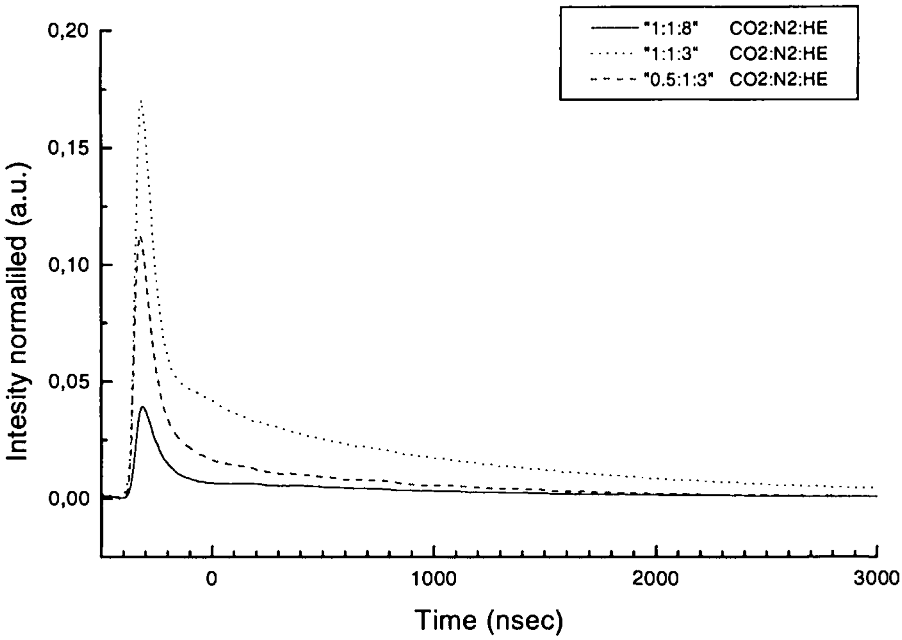

Figure 2: *Laser Pulse for Several Gas Mixtures*

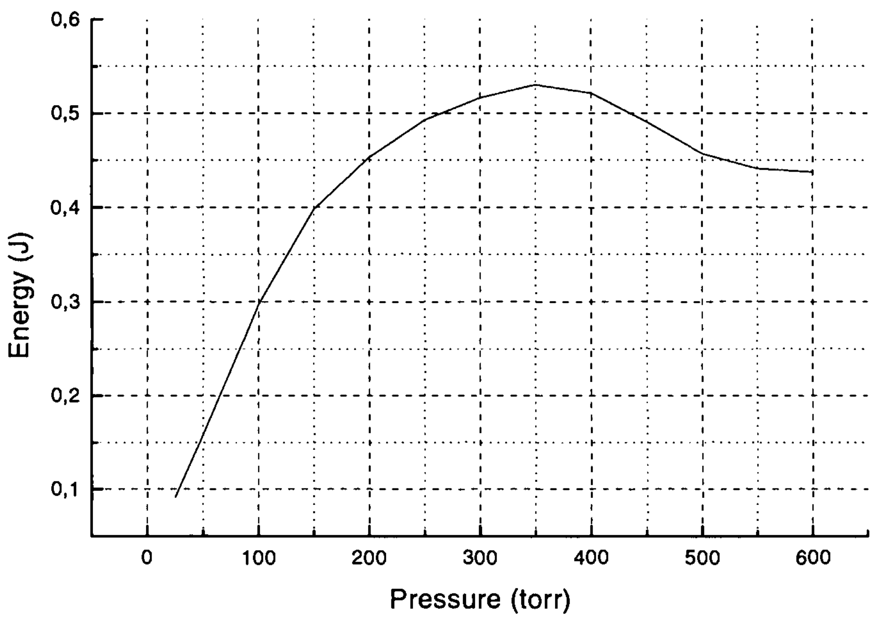

Figure 3: *Energy vs Pressure*

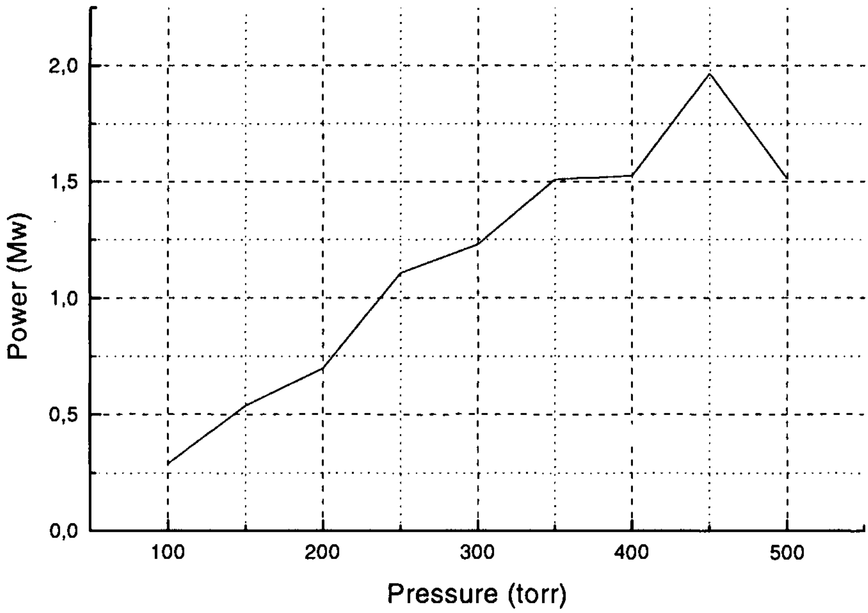

Figure 4: *Power vs Pressure*

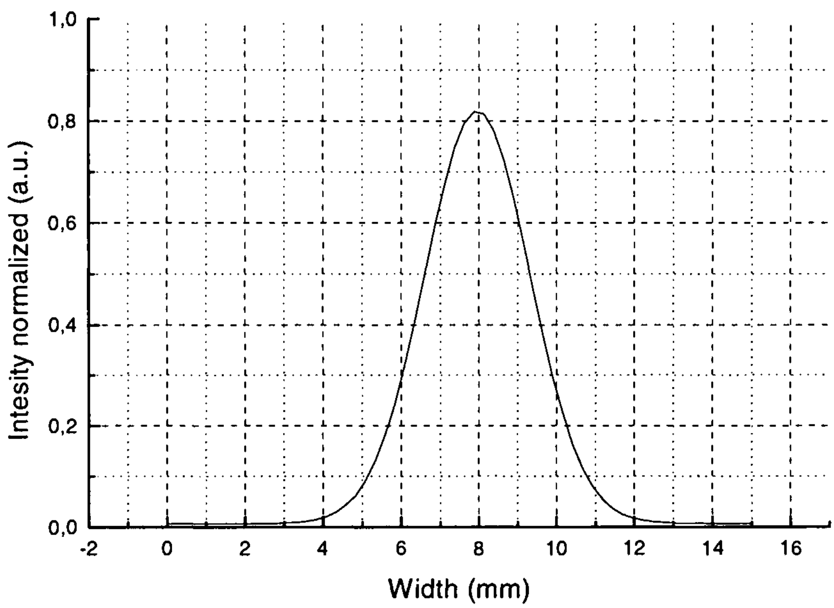

Figure 5: *Cw CO_2 Laser Pulse Profile*

3 Experimental Results

With the above described set up we realised a set of preliminary measurements devoted to demonstrate the possibility of obtaining a good single mode pulse. Comparing from Fig. 7 and Fig 7, in which are reported, respectively, the TE pulse profile without injection (single transverse mode, longitudinal multimode) and the profile of the resulting pulse after injection, we can observe a smoothing of the pulse shape with a contemporary band-width reduction, that in the second case we are operating with a single longitudinal mode, with the attended disadvantage of corresponding reduced power.

On the injected signal we also perform a transverse scanning to test the injection efficiency over the whole pulse (Fig 8).

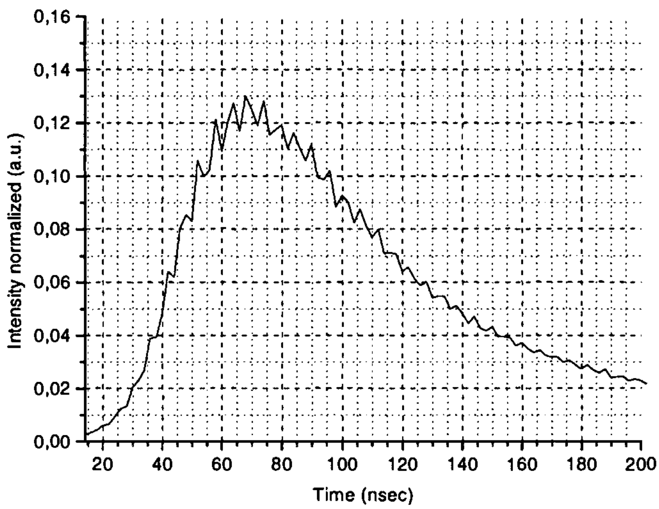

Figure 6: *TE CO_2 Giant Pulse*

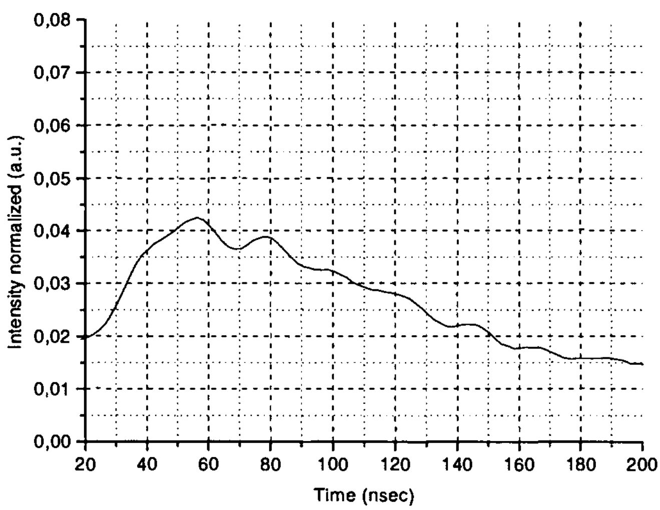

Figure 7: *TE CO_2 Giant Pulse Injected*

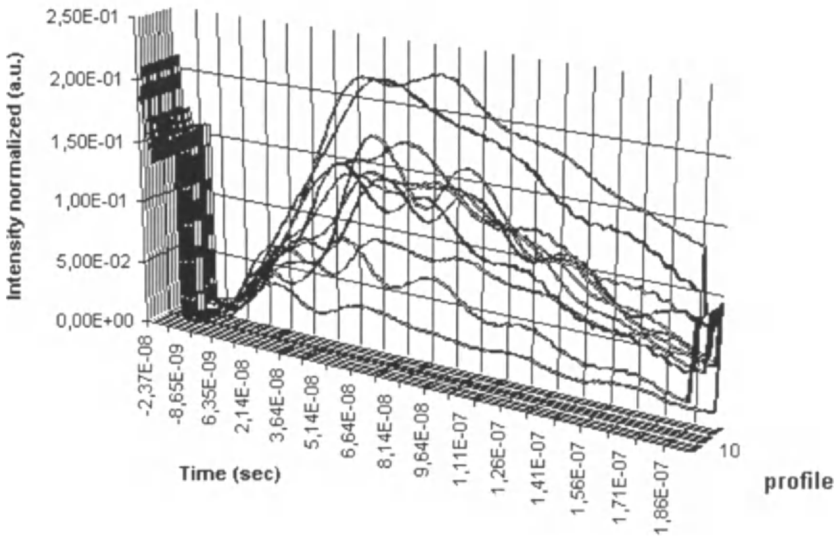

Figure 8: *Horizontal Scanning of the Laser Pulse Injected*

4 Conclusion

The measurements made with this preliminary system have given good results. In fact the FFT of the signals of the TE laser pulse injected (fig. 10) have shown a line width lower than TE laser pulse (fig. 9). The last was about 6 GHz and now with the injection we have a line width equal to 400 KHz.

Now the work is progress and the idea is to work with TEA CO_2 lasers more powerful.

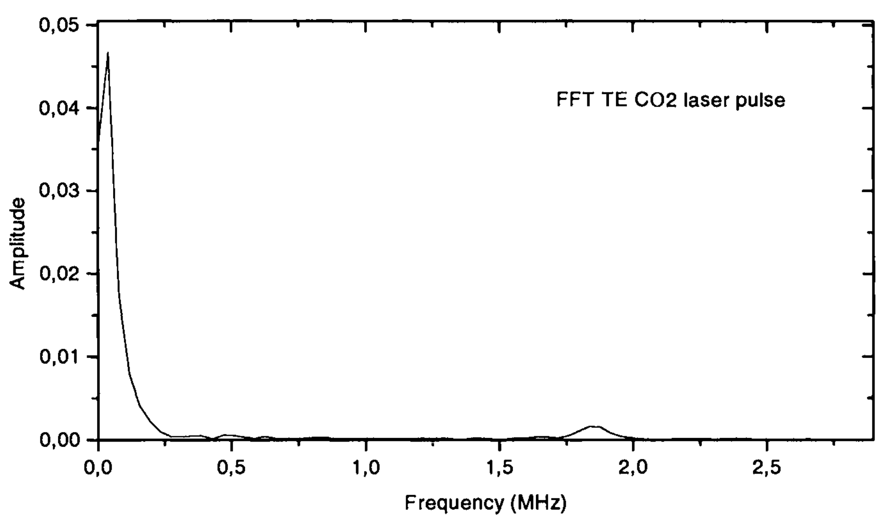

Figure 9: *FFT TE CO_2 Pulse*

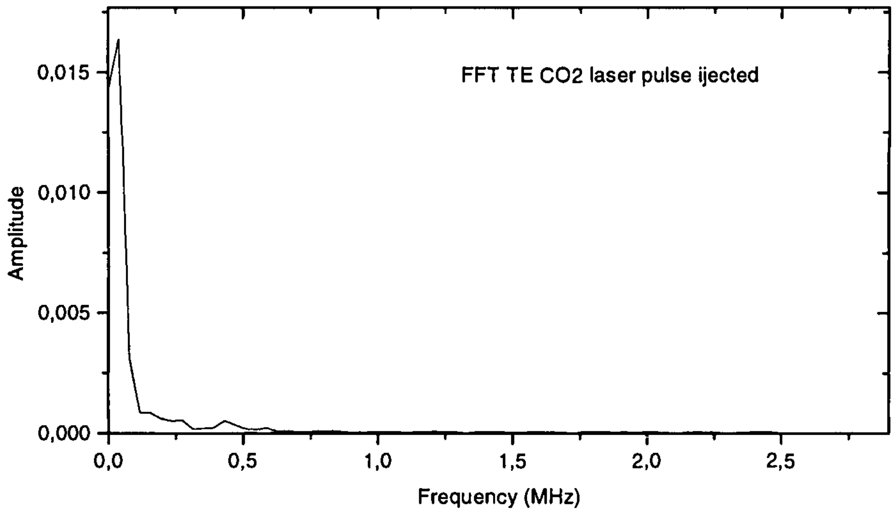

Figure 10: *FFT TE CO_2 Pulse Injected*

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A MONITORING SYSTEM FOR TORRENTIAL REGIME RIVERS: FIRST RESULTS OF THE ACTION TAKEN ON BASENTO RIVER

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Abstract

The aquatic environmental protection from degradation due to human activities must be based on a monitoring program that allows for water quality assessment as a function of basin pollution sources and river self-cleaning capacity.
The objectives of the research are: firstly, to set up a basin scale water quality monitoring program, secondly, obtain a baseline water quality evaluation and thirdly, identify and analyse the relations between water quality and pollution discharges from the basin.
The design of the technical monitoring program on a local scale requires the determining of the location of sampling stations, sampling procedure for water, control parameters and the selection of temporal frequencies.
A preliminary campaign was carried out to validate the water sampling methodology by exploring the transversal and vertical changes of dissolved oxygen concentration in the river cross section. A dissolved oxygen profile along the river put the emphasis on the minimum oxygen values, representative of organic load pollution peaks, and on the river' s capacity for recovering. A monthly monitoring program has been going on since April 1997, focusing on water quality assessment.

1 Introduction

At present in Italy, as well as in many European countries, there is a change from resources utilisation, without forecasting the future needs of environment and population, to sustainable development of resources. The consideration that the development of this country cannot be obtained by increasing the resource extraction without any limits and protection led to a new strategy which relates the resource utilisation to the real needs of the community. Therefore, in order to provide supporting information for the decision-makers, there is great interest in environmental monitoring [9]. Figure 1 illustrates the change from resource utilisation to sustainable development

Figure 1: *Change from Resource Utilisation to Sustainable Development*

In particular, river monitoring proves to be a useful tool for elaborating a correct strategy in water resource management and allow sustainable development [7]. A river water quality is an essential indicator in determining water availability with respect to the specific utilisation (urban supply, irrigation etc.) of water resources. By collecting information on receiving water quality it becomes possible to evaluate human activity impacts, from the overall basin, on water availability [3]. Figure 2 shows the central role of river monitoring for the elaboration of a correct water resource management strategy

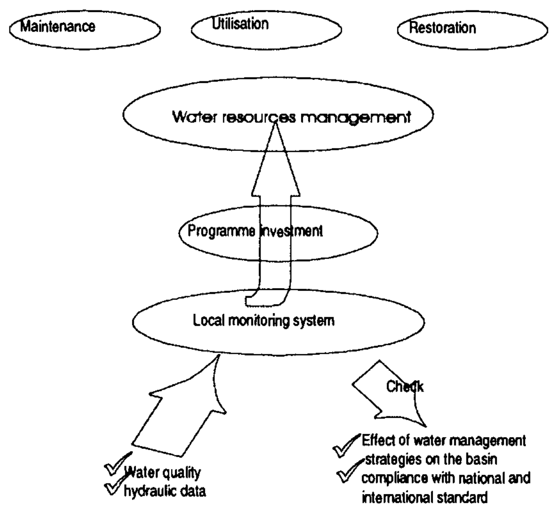

Figure 2: *The Central Role of River Monitoring to Elaborate a Correct Water Resource Management Strategy*

A local river-monitoring program should make the following possible [8]:

- to identify cause and effect relations between water quality and the catchment system;
- to check compliance with national and international standards;
- to identify and prioritise policies in order to keep, improve or restore the aquatic ecosystem;
- to evaluate the impact of the policies on the basin.

2 Research description

The research is being carried out by the Università degli Studi della Basilicata and the Joint Research Centre in the project "Laboratorio di Tecnologie Informative per la Pianificazione dei Bacini Idrografici", with the financial support of the European Union.

The main objectives of the research are three. Firstly, the setting up of a basin scale water quality monitoring program (site selection of the sampling stations' location, control parameters and selection of temporal frequencies). Secondly, to obtain a baseline water quality evaluation, in order to single out the most sensitive problems in the area under study. Thirdly, to identify and analyse relations between water quality and pollution discharges from the basin. In particular, for the identification of these relations it is necessary to schedule a measurement campaign at different temporary frequencies: daily variation to study the urban wastewater impact, weekly for the effect of industrial wastewater.
To analyse the impact of changes in the urban, industrial and agricultural polluting loads on varying discharge rates and also to evaluate the river self-cleaning capacity, a simulation software can be used. Moreover, by using a model it will be possible to find out which are the most sensitive parameters and exactly where the fluvial ecosystem is more sensitive to the organic polluting load.

3 Description of the Study Area

As a pilot basin for the research the Basento river was chosen since it presented the typical characteristics of the Mediterranean river with a torrential regime flow [6]. The climate is temperate, the precipitation regime is Mediterranean with the total rainfall amount concentrated in the winter. Landslides are widely diffused along the overall river course. Figure 3 shows its position in Southern Italy. Moreover, the particular shape (long and narrow), without any important lateral inflow in the lower part, makes drawing a mass balance easier.

Figure 3: *The Study Area of the Basento River*

The Basento river is an example of very high environmental sensitivity, since it is used for irrigation, domestic and industrial water supply and also for recreation, but at the same time, this river receives a number of streams transporting a variety of pollutants from both point and distributed sources. Figure 4 shows water utilisation and pollution sources of the Basento river.
As can be seen, the river can be divided in to three parts: in the upper part the most relevant pollution source consists of both treated and untreated urban and industrial discharges and therefore, must be studied as an impact area.
The middle part of the river is characterised by the absence of any relevant pollution sources therefore, this area can be very useful to evaluate the load degradation from the upper part. The complex hydraulic scheme of this river with two important water uptakes from the basin, must be emphasised. Indeed, since 1971, on its most important tributary, the Camastra, there

is an artificial lake with a capacity of 35 million m^3 used as a drinking water supply, and the river water is brought in to an artificial lake in another basin to be used for irrigation.
The lower part is characterised by the distributed sources, mainly agricultural runoff and industrial discharges so that in this part it is possible to evaluate the effects of the non point pollution sources.

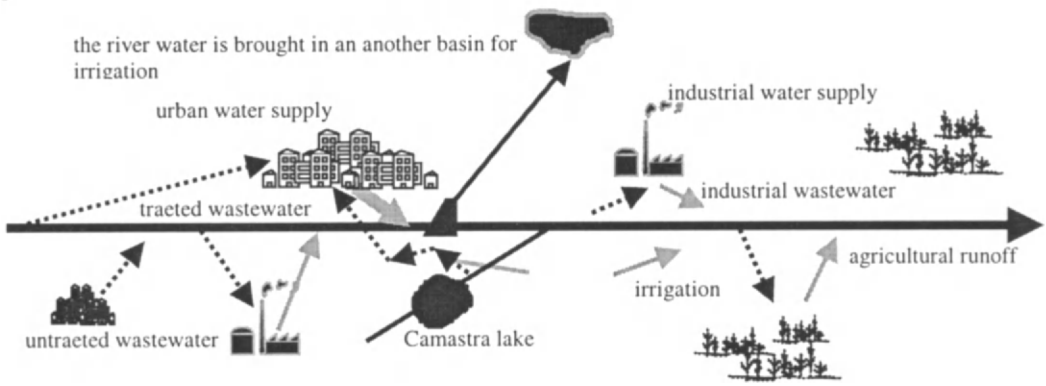

Figure 4: *Water Utilisation and Pollution Sources on Basento River*

4 Methods

The research methodology followed can be divided into three steps:

- an analysis of: basin morphology; environmental standards and legislation; existing information on river water quality and pollution loads from the overall basin;
- a monitoring system design, definition of sampling stations, control parameters and selection of temporal frequencies;
- field and lab work to get variable values and parameters to implement the MIKE 11 software.

4.1 Monitoring System Design

The design of the technical monitoring program on a local scale requires the determining of the sampling stations' location, the sampling procedure for water, the control parameters and the selection of temporal frequencies [1], [2], [3].

4.1.1 Definition of sampling stations

The sampling stations have been chosen according to previous experience and by considering the following main points. Firstly, sampling stations should be locations of interest for pollution effect evaluation, like downstream to industrial and urban point pollution sources, in areas of intensive land use, etc. Secondly, sampling stations should allow a sharp definition of river reaches with a particular condition, e.g.: without any point and non-point inflow, in order to obtain information on the self-cleaning river capacity; river reaches characterised by a single distributed pollution source, etc. Thirdly, in the sampling stations should be possible to get information on the flow. Moreover, the local effect of hydraulic devices in each station should be avoided. Figure 5 shows the basin area with the indication of the sampling station and the photo of the most typical sections along the river

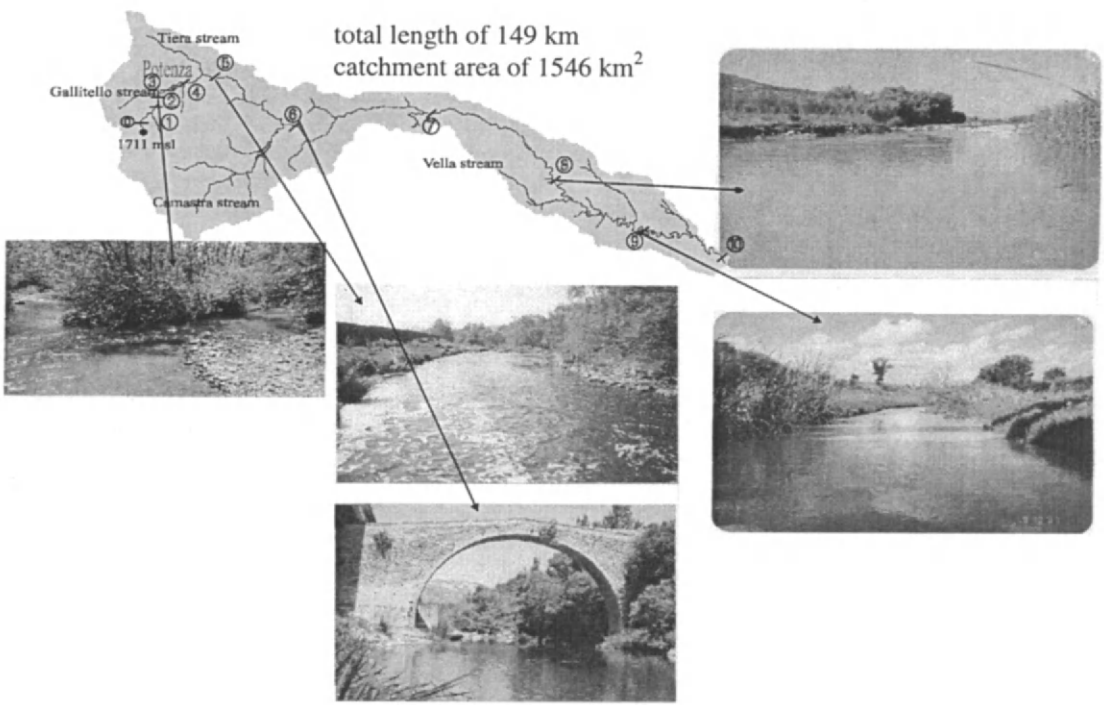

Figure 5: *The River Basin Area with the Sampling Stations*

4.1.2 Control Parameters

Table 1 lists the control parameters chosen for the monitoring system according to present legislation (CEE 75/440 CEE 78/659). Since there is no particular effluent to be monitored the parameters are the typical gross parameters.

Table 1 *Control Parameters Chosen for the Monitoring System*

Physical	Chemical	Heavy Metal	Microbiological	Biochemical and Biotic
TDS	COD	Cd	total coliforms	chlorophyll
turbidity	BOD	Cr	faecal coliforms	algae
temperature	DO	Zn	streptococci	Extended Biotic Index
conductivity	Cl^-	Fe		
pH	NO_3^- NH_4^+	Cu		
	PO_4^{3-}	Pb		

Temporal frequencies have been defined by considering the two research goals. Therefore, a monthly campaign for the measurements of all parameters has been carried out to evaluate the water quality. In order to allow an explanation for seasonal changes, the river discharge has been measured. In addition, short term campaigns are scheduled to check the polluting load fluctuation effects in the river.
The results of these preliminary campaigns will make the discovery of the relations between the control parameters possible and therefore, reduce the number of parameters to be measured for each section. The water quality model implementation can also be a very useful

tool for evaluating and verifying the relative influence between parameters even, in conditions beyond those experienced on the river.

5 Results

The field work on the river consisted of an initial campaign to validate the sampling procedure and a second one, daily and monthly, to obtain the baseline knowledge of the water quality.

The first campaign was carried out to explore, at a fixed time, the transversal and vertical changes in the ten cross sections of the river. This experiment was seen to be useful to validate water sampling methodology. It showed that a single water sample is representative of the overall cross-section concentrations, and it confirmed the assumption that the river flow can be considered as completely mixed both laterally and vertically. As an example, Figure 6 gives the transversal and vertical changes in the river cross section number 9.

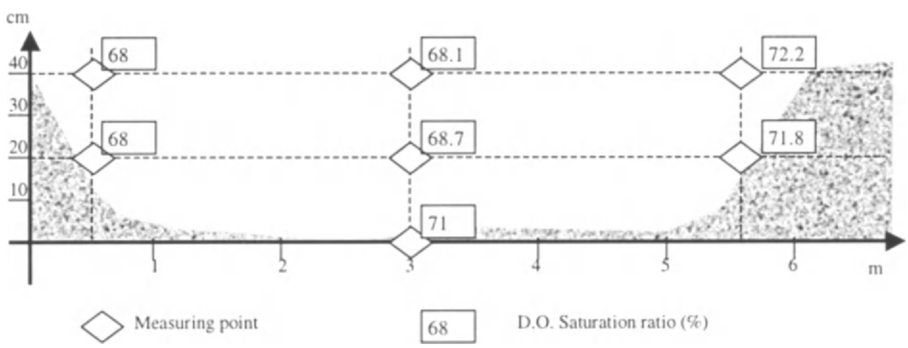

Figure 6: *Transversal and Vertical Changes in the River Cross Section Number 9.*

By using a probe, a daily campaign was possible, to get a Dissolved Oxygen (DO) profiles along the river. This measurement has been carried out in different flow condition. Figure 7 describes the different DO profile during high flow conditions (HFC) and low flow conditions (LFC).

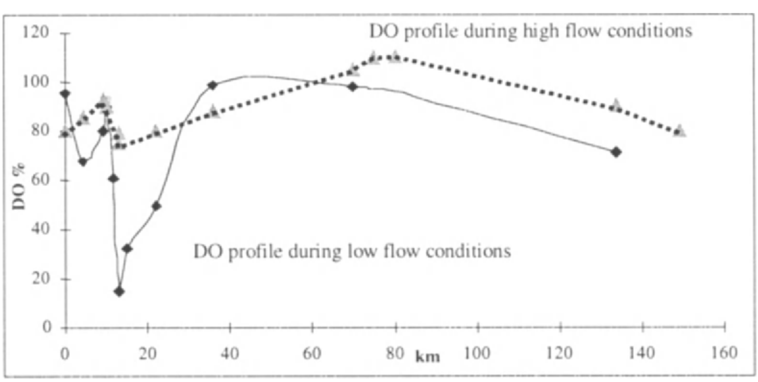

Figure 7: *Different DO Profile During High and Low Flow Conditions.*

As can be seen the DO profile during LFC represents the typical sag curve as quite closely, therefore, it was possible to find each single environmental problem and all pollution sources. However, a successive characterisation of particular local conditions is always necessary. Using the DO profile, in HFC, is not possible.
The monthly monitoring program, focusing on water quality assessment, has been carried out since March 1997. During this time, samples were collected along the river in all the stations. Field measurements of DO, pH, temperature and conductivity were made by using probes, in laboratory COD, BOD, NO_3^-, PO_4^{3-}, SO_4^{2-}, Cl^-, metal concentrations (Cu, Fe, Cr, Pb, Cd, Zn) and coliforms were evaluated. Table 2 sums up the average value of some parameters measured in some stations in low and HFC. Table 3 gives the value of the discharge measured during LFC (July) and HFC (March).

Table 2: *Some Measured Parameters in Low and High Flow Conditions*

sez	BOD_5 mg/l		Heavy metal Cr µg/l		NO_3^- mg/l		PO_4^{3-} mg/l	
	High flow	Low flow	High flow	Low flow	High flow	Low flow	High flow	Low flow
2	3.3	6.5	0.73	2.25	2.8	4.9	0.14	0.52
3	2.3	6.22	0.77	0.14	1.9	2	Abs	0.77
4	8.4	10.2	41.04	0.51	Abs.	2	6.37	1.53
5	4.95	8.7	1.24	0.48	10.25	12.2	0.6	1.85
6	11.4	10	1.28	0.5	7.46	7	0.11	0.73
7	4.6	4.5	2.05	2.15	3.36	1	2.37	0.01

Table3: *Discharges Measured During Low (July) and High (March) Flow Conditions*

Sezioni	Q (m^3/s)	
	high flow	Low flow
2	0.96	0.3
3	1	0.32
4	1.72	0.65
5	2.12	0.68
6	3.82	0.96
7	4.4	1.05

As can be seen, the values in LFC and HFC are quite close to each other and sometimes higher in HFC. This can be explained if we considering that the basin is very small, and therefore the water quality can vary according to some local discharges. Moreover, it must be taken into consideration the fact that two phenomena i.e. the agricultural runoff and the sediment resuspension are always present in storm weather conditions and make the river water more polluted than in LFC.

6 Conclusions

The results of this preliminary part of the local monitoring program showed that the transversal and vertical changes of DO concentrations in the river cross sections are always minor. Therefore, the water sampling procedure is correct.
Since the DO concentration is the most sensitive parameter, a DO profile along the river in LFC can be a very sensitive method to evaluate organic load pollution peaks.
The monitoring system designed is good enough regarding the site selection of the sampling stations' location, control parameters and the selection of temporal frequencies. However, the

results show the necessity for making some changes in the monitoring system regarding the control parameters and the selection of temporal frequencies. For instance, the ammonia must be measured and chemical parameters must be analysed together with biotic parameters. Chemical parameters facilitate the understanding of the causes of river pollution but, biotic parameters make it possible to evaluate the effects on the river environment and explain more complex situations.

Further more thorough campaigns are to be carried out to explore the daily variations of all parameters set in the cross section due to the urban wastewater and the short term (weekly) variation of most relevant parameters in the cross section, in order to evaluate the effects of industrial wastewater.

Finally, the research will consent the exploration of the river self-cleaning capacity and its resilience. In other words, the capacity for receiving discharges from each single human activity will be analysed in order to define different effluent requirements related to the seasonal changes in the river regime.

The idea of having an effluent standard of a wastewater treatment plant which varies according to river flow conditions is expressed also in the most recent legislation which demands that effluent standard should be a direct consequence of river water utilisation

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ALTERATION PHENOMENA OF DRINKING WATER QUALITY WITHIN WATER SYSTEMS

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Abstract

Water quality of tanks and pipelines of drinking-water treatment works and of distribution networks may be altered by: release of reactant impurities; chemical or electrochemical reactions of water compounds with reactants and pipe materials; infiltration of contaminants; mixing with poor-quality water; microbiological contamination. This last phenomenon may occur even without infiltration from the external environment; in fact, some microorganisms adhere to the pipe surfaces, causing biofilm formation, which, besides representing itself an health hazard, may yield significant functional problems, as biofouling and possibility of pipe corrosion.
In the paper the phenomena which are responsible for water-quality alteration in treatment works and distribution systems are examined. In particular, the alteration phenomena determined by microorganism re-growth and disinfection by-products are described, considering the effects of both the water composition and the disinfectant adopted.

1 Introduction

The composition of drinking water in a water system may be significantly altered in different locations from the derivation site to the utilization site. For instance, correction processes utilized within water treatment plants, in which chemical compounds are frequently added to the water, determine the formation of new substances formed by reactions between reactants and compounds originally contained into the water. Corrosion and aggression phenomena within water pipelines not only causes the deterioration of metallic and concrete structures, but also results in the formation of substances which modify the water composition. Alteration of water-quality parameters may also result from mixing water with poor-quality water or with fluids of different origin flowing in a connected hydraulic system or from infiltration of contaminants through pipeline joints or damages in case of inadequate operation of the water system. It has been more recently assessed the possibility of microbiological re-

growth within water pipes and the formation of hazardous disinfection by-products formed by reactions among disinfectants and organic compounds originally contained into the water.
In this work, water-quality alteration phenomena are examined, describing their causes, analyzing their consequences and assessing the effects of environmental conditions. Particular attention is given to the analysis of both the contamination determined by the chemical reactions among substances contained into the water and disinfectants and the re-growth of several species of microorganisms within water systems. These phenomena are strongly correlated and may constrain the choice and the dosage of the disinfectant.

2 Causes and Alteration Phenomena

2.1 Reactants

Reactants used in water treatment plants may contain small fractions of impurities playing no rule in the correction process. However, these substances may modify the water-quality parameters to an extent which depends on the reactant composition and dosage and on the efficiency of following treatment processes. The consequences of the reactions between chemical reactants and water compounds may be by far more hazardous, because in some cases the formation of carcinogenic compounds has been observed.
In particular, the chlorine used for water disinfection determines the formation of halogenated compounds, among which trihalomethanes (chloroform, bromoform, bromodichloromethane, dibromochloromethane), which are known to be carcinogenic.
First studies (Symons et al., 1975), have shown that chloroform is a reaction by-product of chlorine and organic matter naturally occurring in the water. Later, other trihalomethanes have been identified as reaction by-products of bromine compounds with chlorine and organic matter. In any case, it has been shown that trihalomethane precursors are organic substances, mostly fulvic and humic acids. Recent studies (Reckhow and Singer, 1984) have revealed that the addition of chlorine to water yields the formation of many other halogenated substances, as haloacetic acids, haloketones, haloacetonitriles, etc.), which, although occurring usually at very low concentration, are even more hazardous than chloroform. Since the halogenated compounds so far identified represent a small fraction of the halogenated organic matter (TOX) usually occurring in natural water (Singer, 1994) more research is needed to establish whether other halogenated compounds are formed.
Factors affecting the formation of halogenated compounds in drinking water are numerous (Singer, 1994) and include: pH, temperature, disinfection contact time, concentration of chlorine and bromine, nature and concentration of organic matter. With regard to the pH, a decrease of concentration of halogenated compounds has been observed increasing pH above neutrality, since many of them hydrolize for pH larger than about 8. Higher concentration of halogenated compounds are usually observed increasing temperature, since all chemical reactions are accelerated and thus may proceed to completion. An exception is represented by some compounds (as haloketones and haloacetonitriles,) which, after being formed, may be further transformed or hydrolized; since this decay occurs in a relatively long time, it is usually observed within pipelines and tanks of the distribution system.
In order to keep down the formation of halogenated compounds in drinking water treated with chlorine three different approaches may be adopted (Singer, 1994): (i) control of water composition in the supply water body; (ii) use of appropriate water treatment processes; (iii) use of disinfectants alternative to chlorine.
The purpose of the control of composition of the water supply is mainly to limit the growth of algae which may represent the most relevant fraction of organic substance responsible for the formation of halogenated compounds. Algae growth may be limited by keeping nutrients down in the water body.

Water treatment may be accomplished ahead or following chlorine addition; in the first case organic matter is removed through chemical/physical processes as coagulation, adsorption on granular activated carbon and membrane filtration; in the second case halogenic compounds are removed using activated carbon or air stripping. The latter method allows only the removal of volatile compounds (as trihalomethanes), without removing non-volatile compounds.

Disinfection methods alternative to chlorine are chloroamines, chlorine dioxide (ClO_2), ozone (O_3) and UV radiation. It has to be pointed out that results presently available on formation of halogenated compounds when using chlorine-based disinfectant other than chlorine are not conclusive and thus they need to be further verified. In any case chloroamines seem to determine low concentration of halogenated compounds. However, their disinfection efficiency is slight, thus making them not suitable as primary disinfectant; on the other hand, due to their strong persistence and, as discussed later, their high molecular diffusivity, they are more and more used as secondary disinfectant, in order to guarantee sufficient level of chlorine residual in water distribution systems. Likewise, chlorine dioxide yields low concentrations of halogenated compounds, but, in alkaline solutions, it may determine the formation of chlorites and chlorate ions, which are toxic at relatively high concentration. Furthermore, chlorine dioxide oxides high-molecular-weight organic compounds, which are thus transformed in readily biodegradable organic compounds (as, aldehydes), which, as discussed later in detail, support microorganism re-growth within water pipes. The latter phenomenon has been observed even with the use of ozone, which seems to yield the formation of trihalomethanes when bromine is contained in the water. Finally, UV radiation determines, compared to the alternative disinfection methods, the lowest concentration of hazardous compounds. However, it yields a slight disinfection efficiency for several species of microorganisms, particularly protozoa.

Also the use of aluminium salts is very common for drinking water treatment, to destabilise the colloidal and quasi-colloidal dispersion, and facilitate solid separation. The ability of Al and Fe salts to destabilise the colloidal and quasi-colloidal dispersion arises from one of the following processes, depending on pH values and buffering capacities:

a) The Al or Fe ions added to the water are adsorbed on the surface of particles which carry a high negative electric charge. This alters the electric charge of the solids and lowers their Zeta-potential to zero;
b) owing to the partial hydrolysis of the Al or Fe ions, water soluble Al or Fe complexes are formed, which contain a few Al or Fe atoms and which carry a positive charge. These complexes enter into durable bonds with the negatively charged particles changing thus their originally high surface charge. The particles aggregate thereafter;
c) hydrolysis of the Al or Fe ions produces within a brief period of time Al, or Fe hydroxide salts which contain substantial quantities of water and carry a positive charge. These salts consist of particles whose initial dimension is smaller than that of the colloidal particles to be removed. The salts are therefore adsorbed on the solid particles present in surface waters, changing the high negative electric charge of the latter. The ensuing metal-hydroxide solid particle complex has a very small electric charge, and is thus suited to effective, rapid aggregation;
d) the hydrolysis products of the Al or Fe ions aggregate at high rates into large Al or Fe hydroxide flocs which, owing to their large size, sweep the colloidal particles to be removed.

The coagulation process give rise to residual aluminium in the water, which consists of dissolved and particulate species. These componds can be harmful to human, since also the normative standard of Al residue levels overlap with the levels being associated with definite health effect both in clinical and in experimental reports. However, it remains unclear to what extent health effects can be modulated by exposures to different Al species (as a function of e.g. pH) and/or according to silicate or fluoride levels (and hence complexation status).

More studies are needed to evaluate the toxicity of aluminium componds (Golub and Domingo, 1996) and the optimal conditions for the preparation of coagulant aluminium salts. Finally, conditions will be established which limit aluminium residues.

2.2 Chemical and Electrochemical Reactions

Chemical and electrochemical reactions among substances dissolved in the water and pipe materials represent the most known cause of alteration of water quality. The product of these reactions remain in the water producing a modification of the physical and chemical water-quality parameters and damaging the hydraulic system. Examples of these reactions are: (i) corrosion of water pipes yielding dissolution of iron, manganese or copper compounds, which in turn impart color to the water; (ii) aggressive water determines the dissolution of calcium of concrete walls of pipes and tanks, resulting in deterioration of structures and increase of water hardness.

2.3 External Inlet

Modification of water-quality parameter may occur as a result of inlet of contaminants through pipe joints and damages in case of pressure decrease in the pipeline network. Such pressure decrease may be caused by: (i) wrong regulation when operating the system; (ii) extraordinary water demand; (iii) restart of the system after interruption. Contamination may also be caused by hydraulic connection with a system in which flows poor-quality water in case of high pressure in the system; with regard to this phenomenon, examples are utilities pipeline, treated wastewater for agricultural or industrial reuse, building internal water distribution conduits. Finally, good quality water may be altered by mixing with poor-quality water as that of superficial water bodies or shallow aquifers.

2.4 Microbiological Re-growth

The presence of several species of microorganisms in drinking water, although observed for many years, has been studied systematically only recently in order to determine dominant species, environmental conditions supporting the growth and the correlation among pipeline material and geometry and disinfection method. Microorganisms are originally contained in the water or may enter accidentally the water system through pipeline joints and damages. The complete removal of microorganisms is usually not achieved by disinfection because some microorganisms may resist to disinfection sheltering either in the suspended solids or, above all, on the surfaces of pipeline and tanks where they develop a jelly biofilm composed also by other organic and inorganic substances.

Microorganisms growth is affected by several factors including: (i) environmental conditions within the water system, particularly the temperature; (ii) availability of nutrients (above all nitrogen and phosphorous) and organic matter; (iii) hydraulic regime; (iv) pipeline state; (v) operation mode; (vi) residual concentration of disinfectant. Temperature, in fact, not only influences directly the rate of microorganisms growth, but also affect many other factors as efficiency of water treatment processes, corrosion rate and hydraulic regime (water demand depends on climatic conditions). The availability of nitrogen, phosphorous and organic matter is essential for microorganisms and the lack of only one of these substances prevents microorganism growth. In particular, several studies have shown that microorganism growth is possible only for concentration of the available organic carbon above 50 $\mu g/l$. The source of organic carbon is represented by both biodegradable substances originally contained in the water and substances produced by oxidation of complex organic molecules during chlorine or ozone disinfection. Carbon and nutrient supply also depends on the hydraulic regime of the water system, because hydrodynamic stresses act on the biofilm and may determine its detachment from pipe walls. Biofilm formation is more developed in old and deteriorated elements of the distribution systems and in pipelines where either particle sedimentation or corrosion occur. In fact, in these regions great substrate availability and high roughness of pipe walls occur, constituting an optimum habitat for microorganism adhesion and shield from disinfectant action. With regard to operation mode, adverse conditions include: (i) irregular feed of tanks; (ii) interruption of main pipelines; (iii) long detention time in the water distribution system. Finally, it must be pointed out that although a residual concentration of disinfectant keep microbiological growth down, it does not guarantee complete sterilization: in fact, it has been demonstrated that even in presence of significant concentration of free chlorine (up to 10 mg/l), microorganisms staying in the inner part of the biofilm are not affected by disinfectant because of the low molecular diffusivity through the membrane; better results have been achieved using chloroamines, which are more and more used as secondary disinfectant. The choice of the disinfection method should also take into account that disinfection efficiency depends on microorganism species as well. For example, chlorine-based disinfectants are very efficient for bacteria removal in drinking water and work poorly with viruses, whereas ozone exhibits an opposite response. In Table I (Pianese et al., 1995) efficiency of several disinfectant is showed with regard to the most common drinking-water microorganisms: the table confirms that no method can guarantee the complete sterilization, which may be achieved only through synergic action of different disinfectants.

Table 1: *Efficiency of Several Disinfection Methods with Respect To Microorganism Usually Found in Drinking Water*

MICRORGANISM	CHLORINE	OZONE	U.V.
Fecal Coliforms	E	M	S
Clostridium	M	M	S
Streptococci Fecal	E	M	S
Salmonella	M	E	E
Pseudomonas Aeruginosa	S	E	E
Viruses	S	E	E
Protozoa	S	M	S
Algae	M	M	S
E = Efficient;	M = Moderately efficient;		S = Scarcely efficient

Biofilm growth on pipeline walls not only raises health-hazard problems, but also may determine significant functional problems: for some environmental conditions (specified pH, hardness, oxygen and phosphorous concentration), biofilm contributes to hardness precipitation and scaling on pipe walls (biofouling); in the case of metallic pipe biofilm increases the probability of corrosion phenomena, which may be determined by the following mechanisms. First, biofilm represents a discontinuity on the pipe wall, representing a cathodic area to which electrons may migrate from anodic areas and be neutralized. Second, the high oxygen gradients occurring within the biofilm – determined both by low diffusivity and by microorganism utilization – yield the phenomenon of differential aeration. In this condition, metallic elements in low-oxygen regions work as anode and thus are consumed, whereas metal elements in high-oxygen regions work as cathode. Finally, within biological membrane it has been often found both species of microorganisms (usually anaerobic, as Desulfovibrio) producing acid katabolites with high corrosion strength, and species able to consume directly metals as Sphaerotilus, Leptothrix, Crenothrix, Gallionella, which metabolize iron determining its deposition as ferric hydroxide, Coccoidi of the Siderocapsa species and Porfirine producers (i.e. Arthrobacter).

3 Conclusions

In this work the major causes of water-quality alteration are discussed, considering possible modifications both during water treatment processes and in pipelines and tanks of distribution systems. Both conventional causes are considered, due to corrosion, aggression and contaminant infiltration from the external environment, and alteration determined by disinfection by-products and microbiological re-growth. These phenomena are seemingly affected by the choice of the disinfection method, whose aim is to satisfy two objectives: hygienic safety of the water and guaranty that users are protected from health hazard of toxic nature. In order to reduce the inconveniences of the two above phenomena more research has to be carried out on mechanisms of biofilm formation and development. In any case, it is absolutely necessary to control the organic content of the drinking water in the distribution system, because of the fundamental role it plays in the formation of halogenic compounds and biofilm. Furthermore, it is highly desirable to adopt, in the design step, a number of actions aiming to keep the re-growth rate down. In particular, in critical locations of a distribution system, it would be appropriate to provide measurement devices of significant water-quality parameters (residual chlorine, suspended solids, etc.), to reveal problems and, where is the case, to adopt appropriate operations (increase disinfectant dosage, interruption of one or more water-supply sources, etc.) in order to guarantee optimal drinking-water quality.

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GROUNDWATER QUALITY MONITORING IN A RURAL AREA

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Abstract

The paper describes results of monitoring activities of groundwater in a rural area carried out to verify the impact on water quality in an uncontaminated area resulting from the initiation of an atmospheric pollution source. Significant emissions of nitrogen oxides from the pollution source resulted in particular attention to verify increase of nitrate concentrations in monitored water. Over 10,000 analytical tests including several chemical parameters were conducted in the full monitoring period.
In the paper, a first reading of data, graphical trends and nonparametric statistical analysis of resultant water quality, are presented.
Measured values for nitrates, nitrites, hardness, alcalinity and pH showed poor variability during the entire period. Checked parameters were in the usual ranges of uncontaminated rural areas and comparisons between meaningful values of the periods ante operam and post operam do not show any degradation of water quality following the atmospheric pollution source activity. Nitrites are occasionally found in some spring water due to organic pollution, confirmed by randomness of presences detected.

1 Introduction

Great concern is the growing in scientifical and technical community regarding the progressive decrease in drinking water resources due to groundwater pollution from nitrate. Nitrate contamination is diffused in all the world and its extension is particularly serious where intensive agricultural activity is practiced [1, 2].
Nitrate toxicity to humans is due to the reduction of nitrate to nitrite that takes place in the human body and is related to cardiovascular effects at high dose exposure and to methemoglobinemia in blood at low dose exposure. Increase of methemoglobinemia in blood causes reduction of oxygen level in blood and is particularly dangerous for infants up to three months for whom about 10% of ingested nitrate is transformed to nitrite [3]. Concentrations in excess of 44 mg/L of NO_3^- are considered hazardous [4].
In table 1 guideline and maximum concentration from different organizations are presented:

Table 1: *Nitrates Guidelines and Maximum Allowable Concentration from Different Organizations.*

	suggested concentration (mg/L NO_3^-)	maximum allowable concentration (mg/L NO_3^-)
World Health Organization (1984)	11,3	22,6
USEPA (1977)	-	10,2
EEC (1980)	5,6	11,3
Italian Government (1988)	5	50

Natural sources of nitrate in groundwater are due to geologic nitrogen, which can be mobilized and leached to groundwater because of irrigation practices, or nitrogen losses from forests, which can start after man disturbances.

More important sources of groundwater nitrates pollution related to human activity are usually considered: the expanded use of nitrogen fertilizers and waste materials such as animal manures or land application of sludge or wastewater. Many factors and practices strongly influence the concentrations of nitrates in groundwater for example precipitation, irrigation, soil type and depth, geological features, denitrification phenomena, fertilizing intensity, crop types and land usage [3]. Indeed, the complexity of nitrogen cycle renders very difficult the identification of nitrogen sources in groundwater and the increasing use of natural fuels in industrial facilities brings the need to control atmospheric emissions of nitrogen oxides which, in particular situations, could become an important cause of presence of nitrates in groundwater.

In the following, after a brief explication of how atmospheric pollution could adversely affect groundwater nitrates increase, the groundwater monitoring in a rural area is described, carried out to verify the impact on water quality resulting from the initiation of an atmospheric pollution source in an uncontaminated area.

2 2. Nitrates from Atmospheric Pollution

Removal of nitrogen compounds from the atmosphere can occurr by wet or dry deposition, but prevailing phenomena from a quantitative point of view is due to atmospheric wash-out, related to rain.

When nitrogen oxides are in contact with water, we have the absorption equilibria [5] :

$$NO_{(g)} \leftrightarrow NO_{(aq)} \quad \text{and} \quad NO_{2(g)} \leftrightarrow NO_{2(aq)}$$

and dissolved NO and NO_2 give:

$$2NO_{2(aq)} \leftrightarrow N_2O_{4(aq)} \quad \text{and} \quad NO_{(aq)} + NO_{2(aq)} \leftrightarrow N_2O_{3(aq)}$$

Nitrite and nitrate are produced by:

$$N_2O_{4(aq)} \leftrightarrow 2H^+ + NO_2^- + NO_3^-$$

$$N_2O_{3(aq)} \leftrightarrow 2H^+ + 2NO_2^-$$

Former equilibria can be simplified to:

$$2NO_{2(aq)} \leftrightarrow 2H^{+} + NO_2^- + NO_3^-$$

$$NO_{(aq)} + NO_{2(aq)} \leftrightarrow 2H^{+} + 2NO_2^-$$

In gas phase:

$$NO_2 + OH \rightarrow HNO_3$$

Nitrate concentrations in rain increase with wash-out of HNO_3 and aerosol with nitrates. Production rate of HNO_3 depends on atmospheric photochemistry and nitrate concentrations may be not linear dependent to NO_x emissions.

3 Monitoring Activities

The area where water monitoring activity was performed is located about 50 km from the town of Salerno (southern Italy). Limited zootechnics with low density animals activity and agriculture, with manuring usually obtained with natural fertilizers, are the anthropic activities in the area. Use of reclaimed wastewater is not permitted and effluents from septic and Imhoff tanks can be considered neglectable for the very low population density.
Monitoring activities occurred over a 30 month period differentiated between two distinct phases, respectively a period *ante operam* for a duration of about 6 months, prior to the activation of the new atmospheric pollution source, and a period *post operam*, of about 24 months, subsequent to the starting day of emissions. Monitoring activities were carried out with a sampling frequency of 15 days in the period *ante operam* and with a sampling frequency of 7 days in the period *post operam.*
A total of 20 sampling points (a deep well, a small lake and 18 spring water points) were chosen after an investigation about hydrogeological characteristics of the area. Nitrates, nitrites nitrites, hardness, alcalinity and pH were determined in each sample.
Average emission rates of nitrogen oxides from the new pollution source were about 9 kg/h and air quality monitoring, undertaken by the Italian National Research Council using an automatic monitoring station, showed nitrogen oxides concentrations in the area insignificant but related to the source emissions.

4 Data Analysis Methodology

Exploratory data analysis, obtained with box and whisker graphs in figure 1 - 4, where average value, maximum and minimum value and 25 and 75 percentiles of pH, alcalinity, hardness and nitrates are showed for all the sampling points, was followed by comparison beetwen average values before and after the initiation of the activity of the pollution source and by the statistical characterization of data performed using a nonparametric statistical test for trend detection.
Nonparametric tests are usually suggested for environmental data analysis because they don't require data to conform to any particular distribution and can be used also where data are uncorrelated. Nonparametric tests ignore the magnitude of observations in favour of the relative values of data. In other words, results from non parametric test can individualise the trend of a data series but do not afford any indication on the magnitude of the trend [6].

The Mann Kendall Test was used on monitored parameters for each sampling point because of its utility in determining if a series contains a trend over time. The test verifies the null hypothesis H_0, that the data are independent and identically distribuited. The alternative hypothesis H_1 is that data follow a monotonic trend over time [6].
Letting $x_1, x_2,...,x_n$ the measurements performed over time and:

$$\operatorname{sgn}(x_{j+l} - x_j) = \begin{cases} 1 \text{ if } (x_{j+l} - x_j) > 0 \\ 0 \text{ if } (x_{j+l} - x_j) = 0 \\ -1 \text{ if } (x_{j+l} - x_j) < 0 \end{cases}$$

The Mann-Kendall statistic, function of the data set, is:

$$S = \sum_{i=1}^{n-1} \sum_{l=k+1} \operatorname{sgn}(x_j - x_k)$$

A positive value of S indicates an upward trend with time and so it's possible to refuse hypothesis H_0 and accept the hypothesis H_1, a negative value of S indicates a downward trend. The statistic S with more than 10 data can be considered with a normal distribution. If data are less than 10 it's possible to introduce Z, supposed normally distributed, as:

$$Z = \frac{S-1}{[Var(S)]^{\frac{1}{2}}} \text{ if } S > 0$$

$$Z = 0 \text{ if } S = 0$$

$$Z = \frac{S+1}{[Var(S)]^{\frac{1}{2}}} \text{ if } S < 0$$

The maximum possible value of S occurs when $x_1<x_2<...<x_n$ and it is called D. A statistic closely related to S is Kendall's τ:

$$\tau = \frac{S}{D}$$

If data are influenced by season, to keep account of seasonal effects, it is possible to use a trend estimator adjustable for seasonal variation with seasonal Mann Kendall test, description of which is particularised on adduced references [6, 7, 8].
In the following paragragraph Kendall's τ is used to verify parameters trends. Tests were accepted if significance level α referred to Z is lower than 0,05, which means that the probability of committing a type 1 error, fixed as the probability to reject hypothesis H_0 when H_0 is true, is of 5%.

5 Results and Discussion

In figures 1 - 4 box and whisker graphs of results of the analysis are showed.

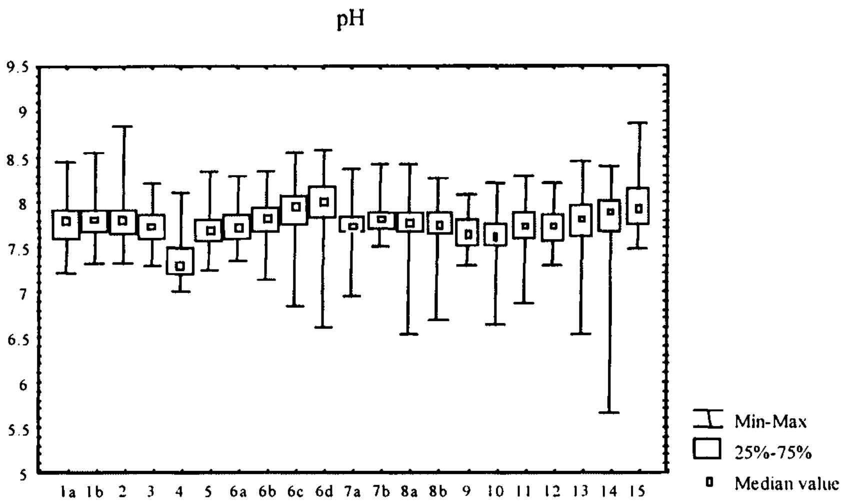

Figure 1: *Determined Values of pH in all the Sampling Points.*

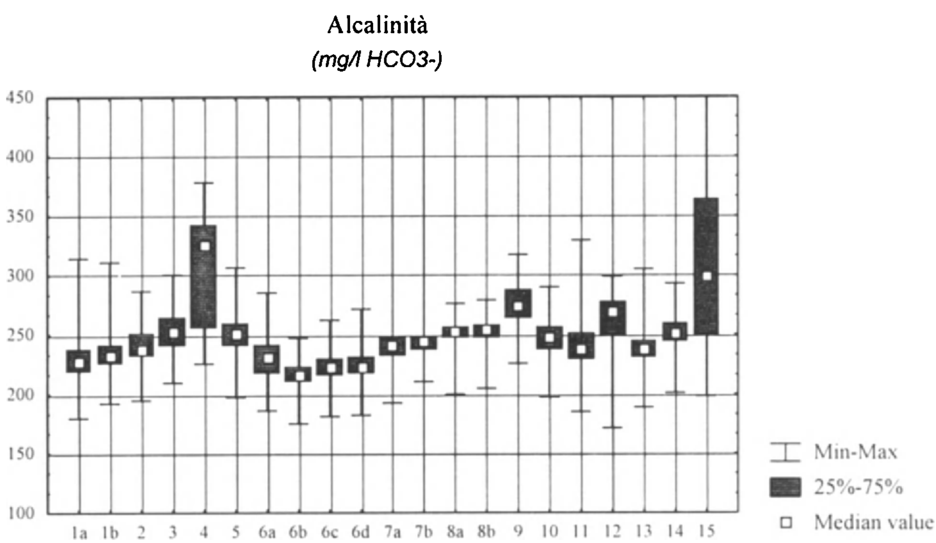

Figure 2: *Determined Values of Alcalinity in all the Sampling Points.*

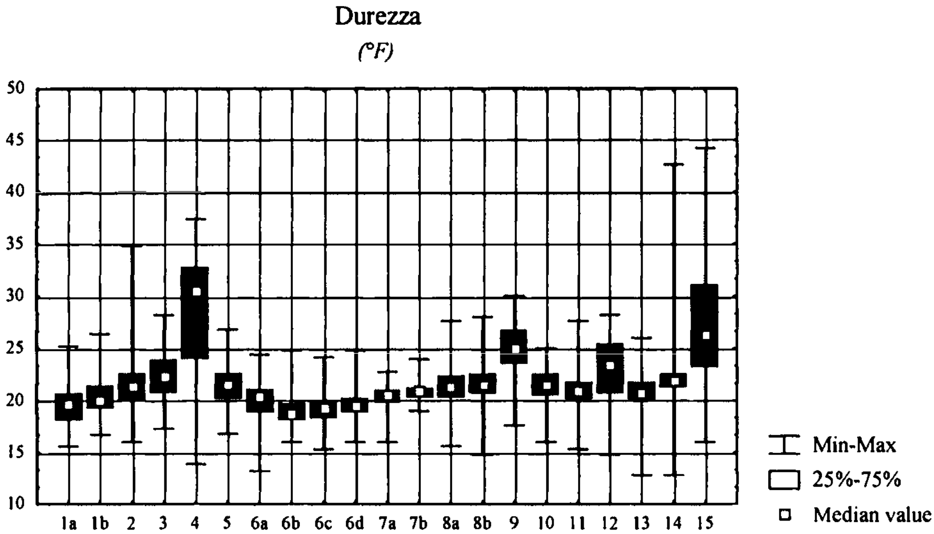

Figure 3: *Determined Values of Hardness in all the Sampling Points.*

Obtained values are in the usual ranges of natural uncontaminated water [4] and comparisons between values of the periods ante operam and post operam do not show any meaningful change. Measured pH, alcalinity, hardness and nitrates showed small percentage variation in all the monitoring period.

In an obvious way, variability of pH, hardness and alcalinity shows a strong correlation. Sporadic presence of nitrites points out a risk of nitrogenous organic pollution probably due to animals breeding in the area.

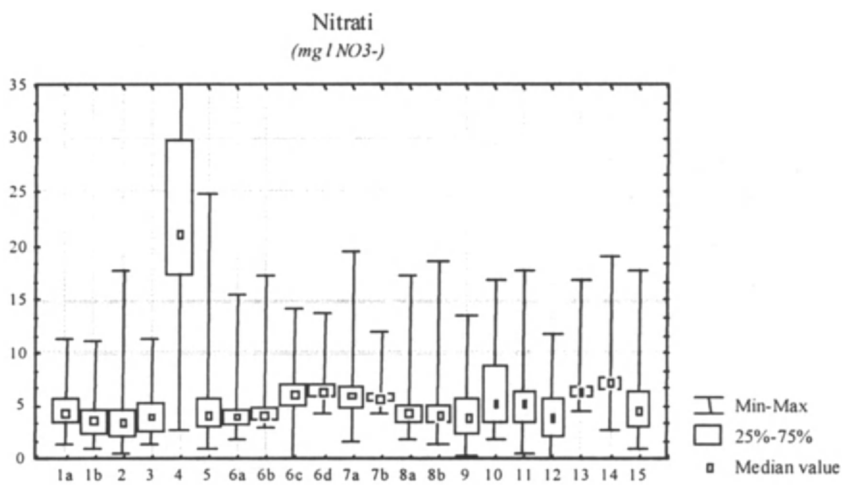

Figure 4: *Determined Values of Nitrates in all the Sampling Points.*

Figure 5 shows a comparison between average nitrates concentrations before and after the initiation of emissions. Figure 6 shows the nitrates concentrations moving average for all the sampling point except n°4 for which values hadn't been considered meaningful because of its site, contaminated by a farm animals breeding ground.

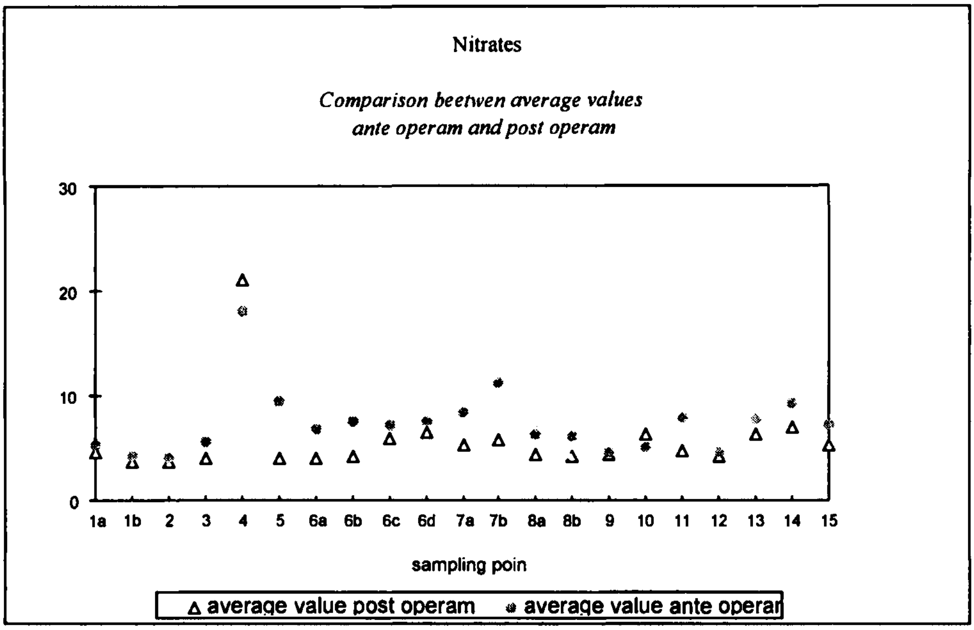

Figure 5: *Comparison beetwen Nitrates Averages before and after the Initiation of Emissions.*

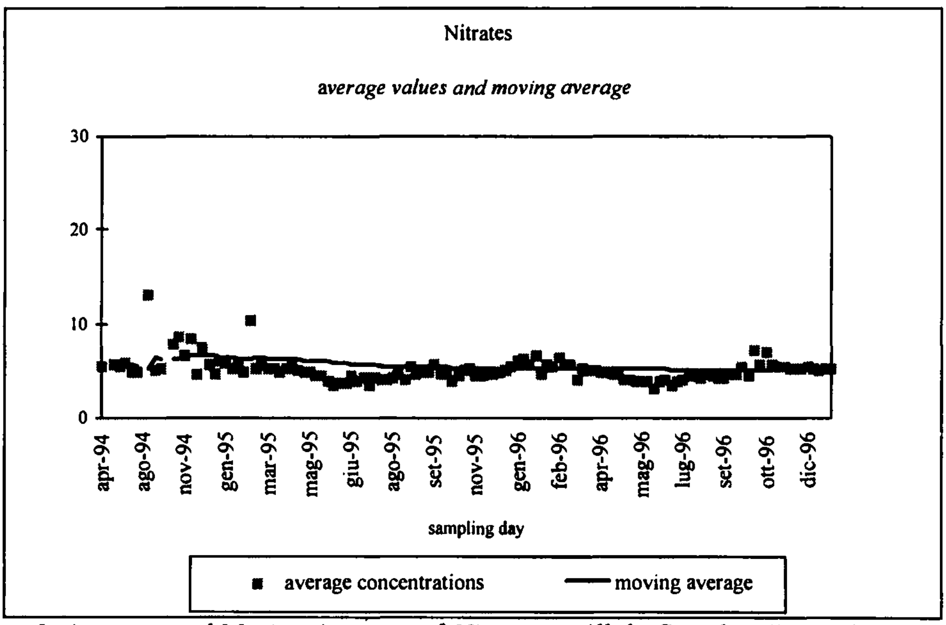

Figure 6: *Averages and Moving Averages of Nitrates in All the Sampling Points (except n° 4).*

In a quite unexpected way, figures 5 and 6 shown a general decrease of averages of nitrates concentrations after the initiation of the nitrogen oxides atmospheric emissions. Entity of diminuition looks meaningful in percentage terms but it is not as absolute values and it could be related to variability of groundwater flows or to the diminution of agricultural activity in the area subsequent to the starting of the industrial facility.
Mann Kendall test results to verify trend of nitrate concentration and nitrate mass (for sampling points where flows data are available) are showed in table 3.

Results aren't easily interpretable: nitrate concentrations related to six sample points (1B, 2, 5, 8A, 8B, 12) show an upward trend, nitrate concentrations related to nine sample points show an downward trend (6A, 6B, 6C, 6D, 7A, 7B, 10, 13, 15) and data series related to six sample points (1A, 3, 4, 9, 11, 14) show an unacceptable significance level. Data series of nitrates mass present an increase of nitrates in four sampling point (1B, 2, 5, 8B) and a decrease in three sampling point (6A, 6D, 13), each of them in agree with increase or decrease in concentrations, whereas for the majority of sampling points no trend was recognized.
Also seasonal Mann Kendall test was performed to detect trend of monitored parameters in each season. Due to only three years of data, tests on average of all sampling points did not give meaningful results and they were performed using averages nitrate concentrations for each sampling point.
Results, in table 4, show an acceptable significance level only for spring season showing a downward trend.

Table 3: *Mann Kendall Test Results for Nitrates Concentrations and Mass.*

	nitrates concentration			*nitrates mass*		
sampling point	samples	Kendall's τ	significanc e level %	availabl e data	Kendall's τ	significanc e level %
1A	118	- 0,04	-	34	-0,17	-
1B	117	0,21	0,1	34	0,22	4,5
2	121	0,29	0,0	34	0,35	0,3
3	120	0,11	-	34	0,06	-
4	119	0,12	-	-	-	-
5	121	0,13	3,9	34	0,50	0,0
6A	120	-0,39	0,0	34	-0,40	0,0
6B	121	-0,43	0,0	-	-	-
6C	120	-0,43	0,0	-	-	-
6D	119	-0,40	0,0	34	-0,39	0,0
7A	42	-0,37	0,1	-	-	-
7B	89	-0,34	0,0	-	-	-
8A	120	0,19	0,2	34	0,01	-
8B	120	0,19	0,2	34	0,24	4,2
9	112	0,00	-	-	-	-
10	121	-0,15	1,2	-	-	-
11	120	-0,05	-	-	-	-
12	113	0,14	3,3	-	-	-
13	120	-0,43	0,0	34	-0,50	0,0
14	119	-0,10	-	-	-	-
15	106	-0,30	0,0	-	-	-

Table 4: *Seasonal Mann Kendall Test Results.*

Season	Data available	Kendall's τ	significance level %
Spring	29	-0,58	< 0,05
Summer	32	-0,11	-
Autumn	31	0,49	-
Winter	29	-0,096	-

6 Conclusion

Nitrate content of drinking water is alarming authorities and scientist in many countries. The increase is primarily due to lack of proper sewage treatment and excess fertilizer application, but incidence of other contamination sources as atmospheric pollution isn't easily verifiable and it needs to be controlled.

This study described monitoring activities of groundwater in a rural area, performed in Southern Italy over a thirty month period on a total of 20 sampling points, to study the possible impact on water quality resulting from the initiation of an atmospheric pollution source.

Measured values for nitrates, hardness, alcalinity and pH attained on more of 2.000 samples were showed. Monitored water resulted suitable for human use, except for known polluted sampling points, in which random presence of nitrites confirm organic nature of pollution probably due to animal manures. Homogeneity of results obtained shows the absence of any significant cause of water pollution. Comparison between average values obtained before and after the initiation of the activity of pollution source does not indicate any degradation of water quality. Nitrates showed a small reduction, probably due to a small increase in groundwater flows.

After exploratory data analysis, performed with graphs, a well known statistical procedure, Mann Kendall Test, was quickly introduced and used to confirm absence of any meaningful increasing trend in nitrates quantities and concentrations after the initiation of the activity of the atmospheric pollution source.

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GROUNDWATER QUALITY OF THE STEPPE AND GOBI ZONES IN MONGOLIA

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Abstract

Water is one of the most essential human resources. During the hydrological circulation, the water exists as a solution with different concentration of solute materials and always varying components. So it is not suitable everywhere and every time for the human needs. Deteriorated quality (presence of toxic elements excessive salt content etc.) restrict or even prohibit water uses or the unrestricted uses may result in severe human or animal health problems. Water quality is one of the actual problems of Mongolian water policy too. It should be supported equally, with intensive Governmental policy, concerning the accomplishment of social and economical needs of the country, actually following the trend of world-wide development, which is formulated "The environment and sustainable progress". To determine the water management's duties, it is necessary to know both the quantity and quality of the water resources. These information are needed for the water management balances too, which are important tools of aims of the regional balances, the part units, must be distinguished, where the water demands are satisfied from groundwater resources.

1 Formation of Groundwater Quality in the Gobi and the Steppe Zones

The construction a model of forming the water quality of groundwater began with the studies of the physical geographic foundation of this process. For these studies the referenced literature, the works of well known authors must be used, some of them had been serving at the Mongolian Water Management Authority. The searches of Marinov, Bespalov, Murzajev, Junatov, the works of Hungarian hydrogeologists and geophysics gave many information about this process. The "Master Plan for the Complex Utilisation and Conservation of water resources in MPR" and series of "Regional scheme of rational Use and Protection of Water resources in the several River basins /Herlen , Hovd -Zabhan , Selenge, Onon, Ulz, Halh gol and the South of Gobi/. These long time plans were protected and made partly with assistance of the Hungarian Water Management Authorities.

Mongolia, including the investigated area of the steppe and the Gobi Lies in the arid zone of the temperature belt between the 42^{O}-th - 50^{O}-th latitudes. The average altitude of the country is 1580 m, the highest point of the investigated territory is in the west, the peak of the Ih Bogd /3957m/ on a range of Gobi-Altai. The deepest point is in the East the Huh nuur 552 m. The Gobi zone is bounded by the Hangai and Hentii mountains in the North, the Great Hingan /Ih Hingan/ in the East, the boundary of Mongolia in the South and East and the Mongol Altai in the West. The only mountains of the investigated territory are the ranges of Gobi-Altai in the central axis directed for west to east.

1.1 The Geographic Factors Influencing Groundwater Quality

1.1.1 The Relief

The character of Gobi zone is a high plateau being a basin position, which determines the most part of the geographical features. The mountains of the country form arches and between these arches extend basins. In the north are the Hangai mountain with ranges elevate to 2000-3000 m high, in 700 km long. This is the World water-sheet between the basins of Arctic Ocean and the basins of Gobi, having no connections with Oceans. The range of Hangai followed southward in the South Hangai plateau, with some river valleys draining the northern part of the Gobi. The Hentii at the boundary of the investigated zone shows hilly landscape and is drained only by the river of Herlen and its tributaries.
The Central and the Eastern Gobi have hilly relief too with an arch of isles of mounts of flat basins but inclining to north-east. The ground flow directed to the Herlen, which belong to the Pacific Oceans basin. This part of the Gobi was not formed by neotectonic movements , the only signs of these indicate the quaternary basalt plateau in Dariganga. The most part of the Central Gobi is a peneplainized surface. In West Mongolia between the ranges of Mongol-Altai and Hangai lies the deep basin of the Great Lakes. In the centre of the basin there are some great Lakes, some of them having fresh water /lake Har-Us, Har,Airag/ but at the end of the hydrographic system lie saline lakes, like the largest one in Mongolia the Uvs, and the Hyargas and the Doroo. The most part of basin are flat surfaces with salted soils, bordered with gently sloping pediments. The rivers entering to the investigated zone built up series of fans of proluvial or alluvial sediments. This conus belt has importance by its infiltration. At the centre of the basins are lacustric plains, which are transformed by wind erosion and eolic accumulation. There are large sand deserts, as the Mongol els, Borig deliin els and Bor Har els on the eastern coast of the lakes. In the bottom of dried lake basins we can find solontchaks- salt deserts, which are the sources of the salt dust.

1.1.2 Climate

Mongolia lying in the heart of the Asian continent has a very cold and arid continental climate. This fact determines the hydrological cycle too. The cold season is ruled by the Siberian anticyclone, forming from October in the North of Mongolia. The lowest temperature was measured in January. In the south side of Gobi in Dalanzadgad the average monthly temperature is -17^{o} C, while in Ulaangom in the North west is -36^{o} C.
The winter is very dry, snow is insignificant, the wind transported snow is mixed with dust having lower albedo. At the end of the cold season the activity of the anticyclone is finished with winds 17-39 m/s velocity, having the maximum in the Eastern Gobi. The weather of the summer season is determined by the development and position of the polar front. The 85% of the annual precipitation is connected with the cyclone activity along the polar front. The frequency of storms is higher in the south, which intensity sometimes increase 80 mm/h rain. The minimum of the annual precipitation fall in the Zungariin Gobi /60 mm/ and the maximum at Choibalsan /257mm / in the North west Gobi.

The few water courses that are involved in the hydro-chemical processes carry only the most soluble salts. The maximal temperatures are observed in July, which depends on the altitude of the station too in Sainshand +23,9° C and Bayanhongor =13,5° C. The annual average temperature is near 0° C. The 0°C isotherm runs from the northern part of Zungariin Gobi to Altai town , to the south slopes of Hangai and to Ondorhaan. In the Omnogobi the annual average temperature is +3° C. The fluctuation of the daily and the annual average temperature is high. The maximal annual one is wider than 90° C, while the daily one in October surpasses 50° C and in spring time 25° -30° C. It is minimum can be observed in January and in June. Evaporation in the Gobi is very high, the most part of the territory and most time of the year surpassing the quantity of the precipitation. So the areas with high level of the groundwater have a significant evaporation too.

1.1.3 Hydrology

The recent hydrographic system have transit character, where there sources are forming mostly outside the Gobi in the surrounding mountains. These rivers have ending in salt lakes, are absorbed on the alluvial and proluvial fans feeding the groundwater and artesian aquifers in the basins. These aquifers contain important resources, quickly moving toward the centre of the basins. In the transit zone on the slopes of the pediments determined by tectonic lines or denudation steps spring lines or groups are formed. Most of them yield fresh water. This picture is characteristic for the detailed map too: the central town of the province is Dalanzadgad, Which is named after the line of springs: "Seventy springs". The groundwater resources original from the summer rains. Infiltration is determined by the permeability of the surface deposits, soils and rocks. It is important for the quality of groundwater, that the deposits with a higher degree of permeability have less concentrated water, than the water in the less permeable deposits. The ground flow is forming around the watershed zone and is directed towards the erosion basis of the catchment area, to the centre of the basin. These are the accumulation zones, where the resources are evaporating and the groundwater assume, a high degree of salinity. The tectonic lineament facilitates, quick transflow, so the fault zones are characterised by low concentrations salinity of water. Quick ground flow can be observed in the alluvial deposits of the channels of dry valleys too.

In the Gobi zone great fluctuation of the runoff and ground flow too can be observed, which is verified by the fluctuations of the surface of the lakes in the Gobi. The fluctuation have a period of 10-15 years. The fluctuations in the hydrological cycle cause changes the chemical composition of the water. In the dry years the salt concentration become higher than in the years with important precipitation.

1.1.4 The Geology

The mountain systems of the investigated territory have caledonian and hercynian origin. The whole territory has continental development from the Mezozonic era. It consist of large granite massive, but there are intermediate and basic igneous rocks too, metamorphized sediments including crystallised limestone and dolomite, shale and sandstone of Paleozoic and Mezozoic origin. The newer tectonic movements transformed the region to a block mountain system. Formed the geotectonic lineament with long and wide fault zones which are very important for hydrogeology, storing the water resources of solid rocks and pre-formed the drainage system of the surface runoff and the most part of ground flow. The formed blocks are moving in horizontal and vertical directions too. In the quaternary begun an activity of the tectonic movements and these neotectonic movements strongly differentiated the surface, the blocks of the Altai ranges became high mountains and other parts of Gobi remained peneplain with shallow basins. At several places of the Gobi there was basalts volcanism, formed plateau in the East and mineral waters demonstrate still the postvolcanic activity. The magmatic activity formed metallic zones too, which affected the chemistry of ground water.

1.1.5 Soil and Vegetation

The formation of soils and the development of vegetation both reflect the influence of climates and the relief of them. The natural zones are changing from north to south, from the steppes to the desert. The changes of zones depending on altitude may also be observed. For the aims of mapping the a zonal phenomena of soils and vegetation are more important and are connected with the particularity of water regimes in the area. The vegetation and soils indicate the better or worse regime or quality of the groundwater. The trees growing in the Gobi indicate the high level of the groundwater. Other plants indicate the accumulation in the soils and in the groundwater.

2 The Classification of Drinking Water Quality for Human and Live-stock Needs

The described aims and duties require to build a space model which is possible with cartographic methods: that means to make a series of maps. In the knowledge of the territorial distribution of the water quality types, we can make a step forward to connect them with their quantity. The result of this work is a more detailed regional balance by water quality types for water management. The first step to realising all of these, a system of the water quality values must be set up and use that to quality the sampled material on the base their hydro-chemical analyses. The base of this quality values system is the Mongolian UST- 900-92 Water Quality Standard for Drinking water. The limits of the components were taken in account at the creation the system. It should be noted, there are two limits for the salinity and the hardness of water, a higher one for the best quality, and a permitted lower quality.
The UST-900-92 standard for drinking water quality as follows:

Table 1.1 Mongolian Standard For Drinking Water Quality

Constituent	Units	Detection limit	WHO water standard
Arsenic (As)	mg/l	0.05	0.05
Copper (Cu)	mg/l	1.0	0.05
Zinc (Zn)	mg/l	5.0	5.0
Lead (Pb)	mg/l	0.03	0.1
Bromine (Br)	mg/l	0.005	-
Iodine (I)	mg/l	0.001	-
Uranium (U)	mg/l	10^{-5}	-
Fluoride (F)	mg/l	1.5	0.6-1.7
Magnesium (Mg)	mg/l	3.0	30-130
Iron (Fe)	mg/l	0.3	0.1
Nitrate (NO_3)	mg/l	1.0	10.0
Nitrite (NO_2)	mg/l	0.2	-
Ammonia (NH_4)	mg/l g/l	2.0	2.0
Carbon dioxide (CO_2) ,free	g/l	0.25	-
TDS	g/l	1.0	0.5
Total hardness	mg.equ/l	7.0	-

Following step for classification of the waters is the case where the micro-elements content is higher than the limit of standard. In such cases either another source must .e sought for, or the concentration of the components has to be diminished by applying proper technologies. These technologies can be distinguished by cost, and the economy decides the reasonable use of them. On the theoretical basis of these principles the following classification was made, typifying the groundwater resources:

1. Water of good quality, of which the components meet the standards for drinking water.
2. Water of adequate quality, which requires low cost measures to resolve slightly exceeding indices of the standard.
3. Not sufficient quality, which needs high cost counter measures and treatments.
4. Unsuitable quality, which is impossible for utility of consumption uses.

For the single wells or springs higher limits of salinity and hardness are tolerated:

- suitable for drinking : salinity < 1 gr/l , hardness <7,0 mg.equ/l
- suitable for drinking without treatment /low quality/: salinity 1-2 gr/l, hardness 7,0-9,0 mg.equ/l,
- suitable for livestock and partial domestic needs: salinity 2-3 gr/l, hardness 9,0-10,0 mg/equ/l,
- not suitable for any domestic uses: salinity > 3 gr/l, hardness >10.0 mg. equ/l

The micro-components were grouped as follows:

- water polluted by chemicals would be purified through washing, draining of the aquifer around the wells or determination of the sanitation zone: nitrate /NO_3/, nitrite /NO_2/ and ammonium /NH_4/
- water polluted by chemicals of geologic origin, possible to resolve hardness by ion exchange and neutralisation which cost are quite high: magnesium /Mg^{++}/, fluoride /F'/, iron /Fe^{+2}/, /Fe^{+3}/, manganese /Mn^{+2}/.

These components are connected with the mineral components of the aquifer and the condition of dissolving.

Water with permanent chemical contamination impossible to remove by existing treatment methods. It contains much micro-elements as the follows: copper /Cu/, zinc /Zn/ , lead /Pb/, arsenic /As/, bromine /Br/ , iodine /I/, uranium /U/.

2.1 Development of Water Quality in the Investigated Territory

As a consequence of the arid climate, mechanical weathering is more important, that the chemical one. The biological factors are less important, although having higher level of activity in the steppe zone, than in the deserts. As the soluble minerals are few and the time of dissolving is short, chemical weathering affects a small group of minerals and only the most soluble salts take part in the migration by ground flow.

In consequence of the low level of biological activity, there is are a few product of CO_2, so the water contains it in low levels. In the feeding zone the infiltrated water has a low level of salinity, which results from the decomposition of orthoklaces and similar minerals. This process produces waters of Ca HCO_3, Ca Na HCO_3 types. Depending on the mineral content of the aquifer SO_4 or Cl can also exist, modifying the former types.

The forming groundwater flows along the fault system in the sediments of proluviums and alluviums towards the zone of fans and debris slopes. Owing to the quick flow, the quality of the groundwater remains good. In the basins where the flow, velocity becomes lower the concentration of dissolved components increases to higher levels. A higher presence of sodium (Na), in several places magnesium (Mg) ions, also the changing of the bicarbonate /HCO_3/ to sulphate /SO_4/ and chloride /Cl/ are observable. The alluvial groundwater near the channels have similar quality as the rivers.

The territorial distribution of water quality is sorted from the watersheds towards the erosion basis of the basins, on the other hand it shows a zonality from the pole to the Equator, connected with the changing of the water regime. It is expressed in the universally valid trend

of the increase is concentrations and the higher presence of sodium and magnesium. The significance of bicarbonate is diminishing relative to the chloride and sulphate anions.
The water in the highest aquifer is more concentrated under the effect of evaporation in the accumulation zone than the artesian water situated under it. So the quality in the second aquifer will be better than quality of open groundwater. The second aquifer is more homogeneous in quality, than the first aquifer having contact with the surface , which result the possibility the pollution by the infiltration of surface water. In the Gobi zone the pollution have human origin or caused by animal husbandry. So the pollution is expressed by the presence in the water of ammonium, nitrite, nitrate, organic components and microbes. This pollution is frequent in the mining wells for the animal use on the pasture. The pollution can be stopped by establishing sanitation zone, or by preventing the infiltration of sewage.
There are pollution of geologic origin too. This pollution depends on the mineral content of aquifer. Around the metallogen zones exposed to chemical weathering some micro-elements in the water increase to high levels of concentration and the water quality deteriorates. Removal this water under the possibilities of Mongolia is difficult and expensive. In the Gobi zone there are waters with concentrations over the limits of the standard for drinking water of such micro-components like iron, manganese, fluoride and uranium. In several places magnesium attains very high concentrations causing illness in the town of Altai and it is neighbourhood.

2.2 Analysis of Database

The construction of the map begins with the collection of the geological, hydro-geological, hydro-chemical data. The sampled data must be systematised in a cadastre of springs and wells. An example is shown in the annex to this paper.
The cadastre consists of the follows: data of the topographic place / name of province, rayon, name of the place/, the geographic co-ordinates /latitude and longitude/, the data of sampling /year/, the depth of wells /m/, the geological age of the aquifer and hydro-chemical data /the Curlov's formulae, which express the genetic type of the sampled water, the compounds being higher than the limits of the drinking water standards/.
On the base of these parameters the points were determined by quality.
The first question in the connection with the data base: are the sampled materials enough for a map in the scale of 1:1000000. It is necessary to do an analysis of the data, which help to determine the way and the methods of the edition and the design of the map too.
The sampled data were elaborated, in the laboratories of Ministry of Geology and the former Ministry of Water Management. These are representing the situation in the time of the establishment of the wells or the time of the geological and hydrological surveys in the last 40 years.
As the climate is fluctuating from year to year, the comparison of these single data of the sampled points is very difficult. The fluctuation of the climate influenced the groundwater flow and this influence is proved by the fluctuation of the surfaces of the lakes in Gobi region. These lakes have a 10-15 years long cycle of transgression and regression. These fluctuation are expressed in the size of salinity and the contents of the salt too.
The quantity of the sampled data is shown on the detailed map for a part of Omnogov' province. The province has nearly 400 sampled point for it is 160000 km^2 territory, including 300 mining wells and 90 bored wells some springs. The distribution by depth is the following: 4 - 10 m depth; 39%, 10 -20 m depth; 42%, 20 -50 m depth; 5 %, 50 -100 m depth; 7 %, 100 - 165 m depth; 7 %.
The hydrological units are represented with different quantity of points too: aquifers of quaternary age are represented with 78%, while the others with 22%. Most of them have only single data for their qualification.

The topographic position of the points and the relation between them determined, that the edition can use the extrapolation around the points, with the help of the geographic indications and connections between the hydro-chemical characteristics of ground water and some other features of the environments.
Necessary were to use the indication of soils, the vegetation, rocks, and the geo-tectonic lineament interpreted from aero-photos. These gave possibility to make amore exact demarcation for the classes of water quality.
So the edition of the maps is based not only on the facts of hydro-chemical analyses, but on the wide of range of geographic and geologic data, represented in literature or on the thematic maps and the aero-photos.

2.3 The Result of the Measurement

The groundwater composition changes in the Cobi-steppe zone in direction from its northern frontier to the south, that proves its dependency a climate. On the other hand, it depends on relief too: near the watershed line the water quality is better than around the erosion bases. The hydrological basins occupy 48,3% of the total area of the Gobi zone and in 87.8% of their area the water resources unfit for drinking. The groundwater wells located in the main pasture lands are polluted with nitrogen compounds. In many cases the micro-elements in the groundwater in the investigated area are above the limits of the standard, for example: the manganese on 8,4%, the iron on 5,8%, fluoride on 6% and radioactive components /uranium, radon/ on 0,9% of the total area.
These result show the needs for an active environmental policy to prevent the pollution of the water resources. This policy means the control of land use in the supply areas of the catchment, on the other hand in the basins, which is the accumulation part of the catchment with poor, quality water resources. New water treatment technologies must be used suitable for supplying the existing little communities in the Gobi zone with sizes of 10-20, 50-100, 500-1000 members of each. The study on the quality fluctuations groundwater must be continued by the construction of a monitoring system. This would furnish more data for mapping.

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MAN-MADE RECHARG OF THE GROUNDWATER RESOURCES OF CENTRAL AND UPPER SOURCES FOR ULAANBAATAR CITY WATER SUPPLY

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Abstract

The water supply to Ulaanbaatar is entirely from ground water sources. There are two water sources of groundwater that are named central and upper in the plain of the Tuul river. Except these two sources there are 3 water sources for water consumption of Industry, Meat processing factory and Thermal Electra-station which are located along the river. About 163000 m^3 water per day consuming from these sources by Ulaanbaatar city. But we recall that at times we have problems with seasonal water deficits, especially in winter and spring season. According to the investigations which were carried out by Geo-ecological Institute in water sources, it was established that the groundwater table drops up 3.5-14 m in some year, particularly in winter and spring season, from January to April. Tuul river was dried up in some place in spring 1997.
Results of the Tuul river discharge and precipitation measurements done from 1937 to until now shown that long term annual discharge and precipitation are not decreased in record period, even can see a tendency of increasing. But useable ground water resources of the water sources for Ulaanbaatar city water supply declined and in the consequence of this the ecological balance could lose. Some specialists at the scientific organization proved that regulation of the Tuul river flow very important for rational using of river water and the place for regulation was selected by them and Feasibility study was carried out. All these documents are enough basis for regulation of the Tuul river flow.

1 Man-Made Rechaging of the Groundwater Resources of Central and Upper Sources for Ulaanbaatar City Water Supply

The city of Ulaanbaatar, the capital of Mongolia, is the center of industry and commerce, has high concentration of population in the nation. The main facility continuously providing the water supply for city Ulaanbaatar is the groundwater resources so-called central and upper resources of water supply located in valley of the Tuul river. Totally, 112 wells are operated and 160 000 m^3 water is produced per a day for citizens' consumption.

By 2010 year, the water consumption will increase up to 218000 m 3/ day in accordance with a growth of population in the city. However, the dynamic reserve of groundwater for the above two resources is nearly a permanent in the nature. If water is used from this permanent reserve, its level will lower and there will be a lack of water. Specially, the water level is lowering during the winter and spring time when opportunity of water renewal is less. (as water consumption is increasing groundwater table is rapidly lowering).

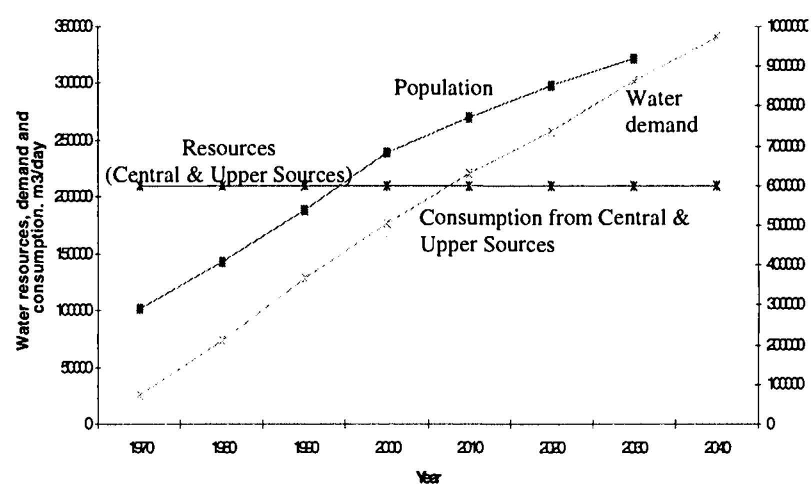

Figure 1: *Variation of Water Table of Central Sources for Ulaanbaatar*

According to the study of regime, it is proved that the groundwater table along the valley of the Tuul river, the main resource of water supply for city Ulaanbaatar, is changing much. This fact influences to the flow of the Tuul river. In 1997, there was a temporary interruption of its flow.

Water sources totally depending upon the groundwater withdrawn from alluvial aquifer, distributed in Tuul river basin, which mainly located at the southern part of the City. The water infiltration of precipitation and the Tuul river are directly influencing to the regime of alluvium composed of gravel and sand groundwater. But researchers have different opinions on majority role of these. For instance, In the report made in the Institute PNIIS, former USSR, 1979, it stated that groundwater mostly renewed by the water from the river. Another description of this that runoff of the Tuul river is relatively restricted and has a seasonal influence to renewing groundwater was given in the reports of 1992 and 1996 years processed in the Institute of Water Policy, Mongolia.

From the above mentioned there is unclear meaning that whether groundwater feeds by the river or the water from the river feeds groundwater in the natural hydrological regime.

However, it is observed that the maximum groundwater table raising happens at the same period with the maximum of precipitation fall or July, August, and September and the maximum groundwater table lowering is during the period when ground is frozen up to 3m depth or January, February, March and April in disturbed hydrological regime.

Depending on a season, ground water level is fluctuating. This fact has a direct link with weather and the Tuul river factors but it connects by features with geological factors.

The utilization of water supply facilities for the Ulaanbaatar city effects to the change of groundwater table.

For instance, when water wells continuously in operation the groundwater table under surroundings lowers on a definite depth. It causes to a fall of water level. During the reconstruction of water well, when its operation is stopped, the ground water level raises rapidly. According to gauging made in this period, it has been proved that groundwater is renewing when operation of wells is stopped .

From the research and operation reports of previous years, it shows that the quality and content of groundwater changing in the process of its existing. For instance, The quality and chemical content of groundwater for the central water sources are relatively constant. But the quality and chemical content of ground water spread under surroundings of the Meat Processing factory are disturbed by human's activity and have an approach to be polluted. There is no more proved study on other factors influenced to ground water regime. In the reports of hydrologists' survey for a short time, it is shortly described that large amount of water appeared from the steam condensation in the basin of the Tuul river. Apart from it, ground water feeds additionally during the thawing_seasonal and permafrost soil.

In 1997, there was made a survey on the natural and disturbed hydrological regime of ground water for some wells of the central sources from the Geo-ecological Institute. In order to give a detailed description of the survey results, an average monthly change of the groundwater table was determined basing on the recorded data of changes of the water level. The variation of water level of the Tuul river and an average monthly fall of precipitation is presented to compare with the average monthly change of water level. From the curve shown these three factors, the river water level raises on the same volume with rain water.

The ground water level is increasing slowly and it reaches a peak level in 1-1.5 month. In other word, the infiltration of precipitation and the Tuul river water provide directly renewing and discharging of the ground water level spread on a field.

Due to this fact, the Tuul river water is playing the majority role in feeding groundwater. From a survey of the precipitation, it was observed that the static ground water level of the Tuul river's valley is 1.6m /in September/ and the minimum level is 3m depth /in April/. According to this survey ground water slowly feeds by the river water in August and September. But in other period, ground water is feeding by river water.

However it requires a detailed study in order to prove these survey results on the natural regime made for a short time.

In disturbed regime, apart from river and rainwater discharges, the groundwater table depends on consumers' water need. Due to the fact that ground water is regularly feeds by an infiltration of rain and river water, the water level of wells lowers relatively little and raises a dispersion funnel during the warm period. In the cold season, the Tuul river is completely frozen as well surface soil up to 3m depth. Therefore, groundwater is not feeds during this time. For this reason groundwater table fall was observed in all operated wells in January, February, March and April.

The water level in the operated wells located far from the riverside was comparatively less than the water level in the wells alone the riverside. It depends on a capacity of pumps installed in wells. Alone with it, the Tuul river may be feeds depending on the seepage co-efficient of a water layer in some cases.

A lot of wells are being observed in the central resource area. Basing on this observation material it has been worked out the hydrological plan and section demonstrated a peak and low point of the groundwater table. As well, the influence radius of the peak and low water level period was determined by the hydrological calculation for each observed wells and the ground water reserve of the low feeding period under the central source field was calculated by the hydrodynamic method using the observation material. Considering the hydrological plan and section and calculation, the water level lowering and its influence radius are little because water reserve is regularly fluctuating during the summer. In other word, its effecting to environment.

In winter season, the water level lowers and its influence radius increases conforming to growth of the city's water demand and operation activity. Therefore it is necessary to pay an attention to the operation in winter season.

For instance, It has to be considered that the water level should not exceed the minimum lowering point. And it requires to choose a proper pump and to hesitate of using too powerful ones in winter.

The hydrological section shows that the minimum lowering level can be 12 m in the central resource area. It will be the maximum limit of using groundwater without losing of the ecological balance depending on the central source.

From the survey results the river and alluvial ground water resource is used seasonally for supplying the potable water consumption of the city Ulaanbaatar. However the city's water consumption is increasing according to a population growth. As a result of this, it requires to increase a water volume to supply the city and to observe lowering of the ground water level exceeding the limit without losing the ecological balance on water level. /FIGURE 1/

Sometimes specially in winter and spring the citizens face with water lack due to an intensive lowering of the groundwater table.

During the melting ice and flooding at the end of spring and in the beginning of summer, groundwater feeds by river water, the deflection originated in winter renews by flood and the static level raises. It was defined that 882 m^3 water per 1 meter length of a river absorbed into ground at these time according to the survey carried out in the Institute of PNIIS, 1979. Little snowing in the last winter and firing around the Tuul river cause to a low spring flood. It is the first time when river water has interrupted for a temporary period (at the moment of renewal) because this year's spring flood water was less than the average annual figure as well it mostly absorbed into ground.

Concluding the above mentioned, the citizens will have a lack of water consumption in coming years if the water use from the central and upper resources is the same with the present need. As well, the Tuul river will interrupt at the beginning of spring and summer and the ecology of its surroundings will worse. Therefore, it is necessary to study the possibility to increase artificially the water reserve on these resources.

It was considered that the water discharge would be increased on 187000 m3/day by flowing surface water alone the 5-15 m width channel in a definite period around the central water resource according to the investigation made in the Institute PNIIS former USSR, 1978.

The Tuul river is frozen completely in winter. Therefore, it is impossible to do an artificial renewal during summer and winter season.

The Ulaanbaatar city's water supply consists of not only these two potable water sources but also of sources for Industrial, Meat Processing Factory and Thermal Power Plant4 or three independent consumers located in the Tuul river side.

Basing on study of the above mentioned possibility, the only way to provide reliable water supply for coming years and to protect the ecology of the Tuul river is to do a regulation of the Tuul river flow.

Apart from enhancement of the Ulaanbaatar city's water supply and protection the Tuul river's ecology, regulating flow of the Tuul river gives an access to develop tourism, to build up a small hydropower station and to feed fish.

Taking into consideration the present situation, the city's management have to start investigation and research works on the future water consumption of the city and to find a foreign investment for this purpose.

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NEW REGULATION FOR WATER MANAGEMENT IN ITALY

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Abstract

The aim of this paper is to illustrate the impact that Italian law n. 36, passed on January 5, 1994, has had on the water management in Italy.
This legislation. Known as the Galli law after its initiator, has prompted a change in attitude towward water resources, which for the first time are being treated as a public asset to be used rationally and sparingly and managed with future generations in mind.
The law has also reduced the big number of water resource managers according to specific criteria. Each of the 20 regions in Italy has been subdivided into areas in which water management , from source to post depuration, is entrusted to just one manager.
The article will deal with water management under the new regulations from both the technical and administrative/managerial perspective. Particular attention will be paid to managerial responsabilities toward consumers, who must be assured efficient management; to the Public Authority, whic must be paid the fixed rates; and to the safeguarding of a natural resource; planning measure and appropriate interaction between development and the environment.
The Italian system will be compared to current management systems in other European countries.

1 Introduction

Water resources, which in the past were considered inexhaustible, may soon became insufficient, both in quantity and in quality.
It is necessary to introduce modern planning processes and rational management.
It is therefore necessary to adopt measures to predict the impact of human action on water resources, to control its development and to minimize its negative effects.
Water management can be considered from three different aspects water supply, water pollution control and water resource management.
Population and industrial development, water use increases, water scarsity and limitations on water resources, higher public expectations for a better environment particular in developed

countries, lead to necessary of more coherence between these three aspects which have been treated separately.

2 Italy

Based on the above stated principles, in 1994 the Italian passed Law no. 36, "Water Resource Provisions" better known as the Galli law.

The new legislation brought about significant change to resource management in Italy and most importantly, a change in the philosophical approach to water use.

The role of water was elevated to that of an essential element to animal and plant life and a resource to be conserved for future generations. Water use is geared toward conservation and resource regeneration with a mind to safeguarding the environment.

The identification of conservation measures was translated into law and into objectives for water resource managers who, as we will see later on, have been given the responsability for the integrated water system in a specific territory defined as an Optimal Territorial Unit.

These territories have been defined according to physical characteristics in terms of the integrity of the watershed, and sub-watershed, as well as actual resource location. The goal is to create watersheds large enough to allow for efficient and economical management and in which the individual managers of the integrated water service are ultimately accountable to a single authority.

The manager is responsible for maintenance of the integrated water system which includes retrieval, feeding and distribution of water for civil consumption, sewage systems and purification of waste waters.

The Galli law covers two distinct areas:

- administration of the water service
- day to day management of the service itself.

Administrative functions are carried out jointly by the local authorities which lie within the Optimal Territorial Unit as described above. Representation by the various administrations within this public body is regulated on a regional basis. Generally speaking, we can state that representation within the Authority is proportional to resource use.

We will not dwell on the legal aspects of this public body as such, nor elaborate on administrative technicalities at this point. Suffice to say that not only are these units responsible for choosing Optimal Territorial Unit managers but above all for the efficiency and effectiveness of the water service; the setting of consumer rates and water use planning which is based on studies on the current state of water sources and infrastructure and estimates of potential investiments by the water service manager.

The manager, to whom the infrastructure is given in concession (using a sort of rental system with a symbolic fee and giving certain responsibilities to the beneficiary beyond ordinary and extraordinary infrastructure maintenance) is responsible for the running of the service and the risks that it may incur.

The relationship between the management and entrepreneurial levels is governed by "Conventions" and the related "Code of Discipline" which regulate the conditions of managerial appointments.

The main features of the conventions are:

- the requirement to achieve economic/financial equilibrium;
- the length of the allocation which by law cannot exceed 30 years;
- the method of monitoring for correct business practices;
- the minimum level of service efficiency and effectiveness to be guaranteed to the consumer;
- the requirement to return the plant in good working condition;
- financial and insurance guarantees on the part of the manager;
- rate application criteria and methods, with reference to consumers.

Eventually, a "Committee for the Control of Water Resource Use" will be established by the Ministry of Public Works. Its task will be to create programmes and initiatives to guarante consumers efficient, effective and economically sound management.
Thus the aim of the legislation (which four years after its enactment has just barely been reached thanks to delays on the part of local administration) is to identify suitable managers in terms of entrepreneurial ability and financial resources.
In 1994 there were often numerous water service managers in a single territory, some of them running tiny waterworks or perhaps a purification infrastructure. This is still the situation in many areas of Italy today and is responsible for inefficient distribution and apart from the large scale structures, ineffective purification with serious environmental consequences. In addition, the lack of designated resource planners has led to hoarding of the most usable resources by local managers, without consideration for renewability and environmental effects. The result is a perennial state of emergency which has made it difficult to block operations of dubious cost benefit effectiveness.
The fragmentation of responsibilities has made it difficult for consumers to pinpoint who is responsible for inefficient service and wastage.
And lastly, but importantly, this kind of ill-functioning system is forced to seek financial assistance for modernization and expansion from the state which in recent years has been under increasing financial pressure.
The system introduced by the Galli law completely overhauls the water resource management system employed up until now in Italy. In particular, it takes into consideration the need for entrepreneurial growth spurred by the increasing complexity of the service which in turn is the result of resources that are ever more difficult to manage, increasing consumer needs and growing environmental constraints. Above all, it addresses the need to transform a financial system based primarily on the transfer of public funds into a model in which financial resources are garnered from within the system itself via water service users.
To this end, managers have been authorized to issue debenture loans, underwritten exclusively by consumers who can convert them into ordinary shares. At the same time, the service manager must provide users with accurate information on water quantity and quality and on the thecnology used in the plants. In addition, managers must promote initiatives designed to heighten awareness of the need for resource conservation. In this way, water culture" will spread among citizens who are increasingly being asked to pay according to resource use and pollution levels while at the same time expecting a high level of service.
It is too soon to say where the new legislation has succeeded in reaching its goals and where it has failed.
Currently only a few regional authorities in Italy are in line with the deadlines established by the legislation. However in some regions the pre-existing organizational model differed little from the one introduced by the Galli law, except for administrative aspects linked to competence, and thus do not constitute a valid test of the new legislation. On the other hand, not even in these regions has management's economic viability and effectiveness been assessed according to the parameters that the public bodies have yet to establish.
Rather more interesting is an overview of different approaches to water service management adopted by other European countries.

3 Great Britain

In Great Britain, as in Italy, the organizational aspect of water service management is being taken out of municipal hands and given to larger scale entities.
In 1973 a series of Water Authorities was established. Each WA was given jurisdiction over 10 large hydrographic areas. In 1980 with the election of the pro-private enterprise Thatcher government, the Water Authorities were privatized and the National Rivers Authority was

established. It was given full responsibility for water use planning, the iusuing of permits and monitoring, in addition to maintenance, to protect waterways from flooding.
In terms of the integrated water service cycle, the Water Authorities were left with just the management role and were trasformed into joint-stock companies which were listed on the stock exchange. Shares were sold to the public with restraints on share concentration following the model of a public company with many shareholders where the state maintains a "golden" share with special privileges.
In this way, the cost of running the WAs was removed from the public financial sphere and the authorities are forced to finance long term investments themselves via water rates.
However in order to avoid hefty rate increases, an economic regulating body (Ofwat) was established. Its main function is to authorize rate increases every five years for all ten WAs.
It is difficult not to appreciate the clear division of labour and healthy conflict of interest generated between the various players that this kind of well-organized management model offers. It all translates into improved service with manageable costs, with respect for environmental safeguarding.
The reputation of the National Rivers Authority and Ofwat depends on the effectiveness with which they perform their institutional roles and whether they carry out the job assigned to them in a scrupulous manner. At times this means they are greatly affected by powerful companies which the NRA cannot force to make investments because of complaints due to resource insufficiency, and OFwat is unable to ascertain the congruency of the investment and cost plans as it does not have the necessary information which is the exclusive domain of the manager.
Thus in Great Britain one is frequently subject to mechanisms including yardstick competition and market corporate control (control by the share market) directed toward inefficient managers.

4 France

In contrast to Italy and Great Britain, the French water service industry, established in the 19th century, has an important tradition of service to local administrations in a relationship based on mutual trust.
The result is that the French industry is highly concentrated in terms of management, but extremely fragmented in terms of service entitlements which number approximately 36,000 primarily small holders, compared to 8,000 in Italy.
Among the various contracts which regulate the relationship between municipalities and managers, one of the most common is a form of rental through which the municipality maintains ownership of the infrastructure which it must construct at its own expense. It is then repaid over the years through a rental fee paid by the managers which they in turn obtain through water rates. Thus in France, all the financial resources required are generated within the system itself without state involvement.
Increasingly, municipalities are handing over responsibility for the most complex aspects of the cycle to higher levels of government. This tends to create a modular system in which various players are responsible for parts of the actual water cycle according to their complexity.
Thus we have a territorially integrated system in which managers of local water services progressively tend to buy service packages from operators who act on a higher governmental level, achieving an economy of scale sought by other means in Italy and Great Britain. It is interesting to note that the need for these operators comes from the bottom , that is from the municipalities themselves in order to make up for technical and entrepreneurial deficiencies.

When municipalities are capable of independent assessment and regulation and have suitable technical structures, they tend to establish a collaborative relationship with management companies which does not exclude actual direct involvement in the administration itself.
In Paris water production and feeding is handled by a "mixed" company (SAGEP) controlled by the municipality, while distribution within the city has been allocated to the General des Eaux for the right bank of the Seine and to the Lyonnaise des Eaux for the left bank. The city of Paris is directly responsible for water quality control. The existence of such high quality management has allowed for the activation of yardstick competition measures with excellent results in terms of quality of service and increased cash flow for network modernization.

5 Germany

German water service organization is similar to the pre-Galli Italian model.
Municipalities are officially responsible for water service. Management is handled by municipal companies (Stadtwerke) or directly by the municipality. The private sector has a minimal role which is concentrated primarily in the purification sector.
The organizational model developed on the strength of local public institutions. However, in Germany, as in France, higher levels of government are now becoming responsible for the most complex aspects of the water cycle for which economy is scale is most appropriate.
The result is that German consumers obtain a relatively high level of service, while the level of purification is one of the highest in the world.
This success undoubtedly stems from the tremendous sense of responsability on the part of the German Stadtwerke compared to their Italian counterparts and the entrepreneurial autonomy they enjoy, which allows for free access to capital markets.

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THE TREATMENT OF DRAINAGE CANAL WATER THROUGH LAGOONS. THE "FOCE CAVONE" EXPERIENCE

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Abstract

During the summer months, drainage water from irrigation is a pollutant which is very hard to eliminate; especially, along the coasts that border the intensely cultivated plains.
The essay presents the initial results achieved by means of an experimental lagooning treatment plant devised to reduce the polluting effect of drainage canal water from the Metapontino area (Basilicata, Italy) at the mouth of the Cavone river.

1 Introduction

The treatment of non-conventional pollution sources, such as drainage canal water, requires a careful analysis of the system producing the drainage, of the ecosystem in which the treatment will take place and specific information on the individual polluting elements.
It is evident that the classic treatments guarantee neither low costs nor depurative efficiency, especially in relation to the great variability of the quantity of polluting substance and the rate of flow.
Alternative systems such as biological ponds or more generally the inverted lagooning treatment techniques clean water quite economically. Lagooning techniques are also being closely evaluated by researchers and project heads in many European countries both for post- and final treatment of water that has already been conventionally treated and as a single treatment on particular types of water such as drainage canal water.

2 The Present State of Lagooning Systems

Lagooning techniques are not very widespread in Italy, especially considering that due to the existing climactic characteristics and drainage types they could reach high qualitative

standards at relatively low costs.
The sectors in which the use of these techniques seems most promising are without doubt the final treatment techniques in conventional plants as well as the direct treatment of limited flow and highly variable drains.
In some countries, the use of this technique is very widespread. Plants of varying size and type can be found in the United States (7000 plants), Germany (2000) and France (1500).
The type of plant may be classified in various ways, based on its :

- biological characteristics (aerobic ponds, anaerobic ponds, etc.)
- functional characteristics (maturing ponds, finishing ponds, deposit ponds)
- characteristics of the biomass (microphytes, macrophytes, rooted macrophytes, etc.)

This plant is based on treatment/maturing pond of a prevalently aerobic type based on the plan shown in figure 1.

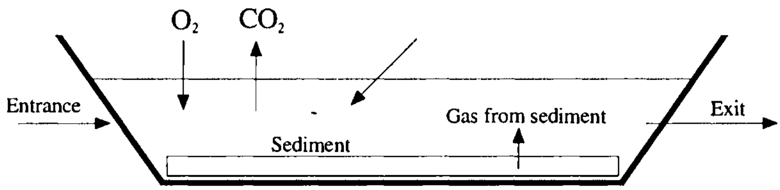

Figure 1. *Plan Showing How a Scheme of Biological Pond Functions*

The transformations which the liquid mass undergoes in a biological pond vary from the oxidation of organic and nitrogenous substances to the absorption of phyto-nutrients and the reduction of the microbial load:
the removal of the substrate, which is extremely important during primary treatment, is a secondary phenomenon with regard to finishing systems as the organic substance is greatly reduced, as well as being extremely stable. Insofar as the direct treatment of drainage waters is concerned, the reduction can be significant although very variable.
Simulation models of biological ponds show - for micro-organisms such as coliforms- first order decay kinetics depending solely on the temperature for natural decay.
We must add to this the important action of solar radiation, the strength of which is directly proportional to the depth of the basin.
On the average, the constant for bacterial reduction can be estimated with the following formula [1,2]:

$$k = k_d + k_s \cdot (S_0 / KH) \cdot (1 - e^{(-KH)})$$

in which
- k_d is the coefficient of bacterial reduction w/o light;
- K is the coefficient of light attenuation;
- k_s is the coefficient of mortality per luminous radiation;
- S_0 is the daily solar radiation;
- H is the depth of the pond

Experimental trials on ponds less than a meter deep and with a time factor of two days have allowed us to devise the following formula:

$$k = 1{,}156 + 5{,}244 \cdot 10^{-3}(S_0 / KH) \cdot 1/d$$

According to the Marais formula [3], the reduction of micro-organisms, and in particular of coliforms, can be calculated as follows:

$$N = N_0 \cdot (1 + k_b \cdot t_r)^{-1}$$

in which
- N is the amount of micro-organisms at exit (MPN/100 ml)
- N_0 is the amount of micro-organisms at entrance (MPN/100 ml)
- k_b is the coefficient of bacterial reduction
- t_r is the retention time of tretment in days

At our latitudes, we may use the following values (albeit with care):

For E. Coli	K_b= 2 1/d
For S. Typhi	K_b= 0.8 1/d

There are optimal results for nematode eggs which practically disappear.

3 The Environmental Context of the Treatment Plant

The plant would be situated in an area which is highly exploited for irrigation and crossed by the five rivers of Basilicata which flow into the Gulf of Taranto just a few kilometers apart from each other. The entire area presents homogeneous characteristics both for morphological structure and land use and this allows us to consider the entire, wide estuary area as the context for the insertion of the lagooning plant.

The rivers cannot be considered excessively polluted due to the pre-existing treatment plants, mainly for urban wastewater domestic use drainage water. In general, the watercourses can be divided into a high and medium area in which the main inhabited areas and dams for the use of water and final tracts are located along a length of about 30 km. The principal sources of pollution along these areas are the result of agricultural activities.

In the mountain tracts of the river, therefore, the sources of pollution may be identified as the urban and industrial agglomerations; for each of these, the right type of traditional purification plant along with an efficient network for the collection and distribution of drainage water can guarantee the protection of the recipient water body. Regional planning will shortly require the implementation of such an efficient network.

The situation along the coastline is very different. Here, there are anomalous pollution sources that have eluded sector planning and are the result of agricultural drainage waters and drainage canal systems. Created for a completely different purpose, these canals have become the vectors of many contaminating agents of different nature, origin and quantities.

Among the main polluting substances present in these systems the most significant quantitatively are the residues of agricultural activities:
- nitrogenous substances
- phosphorated substances
- complex chemical compounds (phyto-drugs and pesticides)

The presence of residues from zoo-technical and agricultural-industrial activities are increasingly on the rise. In addition to the above mentioned pollutants, these release:
- bacterial loads
- organic substances

The damage to the ecosystem which can be traced back to these sources of pollution (which are often undervalued and considered secondary) is especially related to the distance between the drains and the sea (if the drainage is not released directly into the sea). The intense tourist activity in coastal areas is constantly at risk due to the fact that safe swimming water parameters have been exceeded.

Estimates of the consequences from these pollutant sources are difficult to assess as they are related both to the amount of the pollutant found on land and to the possibility of it ending up in a receiving hydric body. Factors such as the seasonal nature of rain and irrigation cycles which condition the presence of water in drainage canals regulate the quantity of pollutants which will reach the rivers. It is self-evident, however, that sooner or later the pollutant will find its way into a water body and give course to its negative effects.

4 The Treatment of Drainage Canal Water

It is evident, so far, that the treatment of such anomalous sources can hardly be accomplished by means of traditional biological or chemical-physical systems.
The elements which condition this are:

- the variability (seasonal nature) of the flow depending on the hydrological and irrigation regimes. Extreme conditions vary from a total absence of flow (even long-term) to flood potential.
- nature and concentration of the pollutants. Pollutants present in drainage canals vary from high loads to practically zero.

Most treatment plants have been developed to process sufficiently concentrated quantities of drainage water with little variation in its characteristics. On the contrary, in the specific condition we are examining, biological purification systems would be extremely inefficient, if they managed to remain active at all. Similarly, chemical-physical systems would not function as they require extremely complicated qualitative and quantitative controls in order to dose the reactants and regulate the treatment cycle.
The systems based on lagooning techniques, on the other hand, are more easily adapted to the variable conditions of flow rate and load. These systems remain in a condition of continuous "inactivity hold," auto-regulating their own biological cycle (i.e. during periods of drought), and begin to function only when water and contaminants are present in the drainage networks. Moreover, large volumes ensure a greater breakdown action and produce water with constant characteristics. Even from the point of view of costs, investments, and especially management, lagooning treatment systems are more adaptable. They never require constant maintenance only simple seasonal check-ups. The system efficiency may be tested through periodical checks on the quality parameters of the treated water- an operation which would have to be conducted on any other system.

5 The Cavone Experience

5.1 Structural Characteristics of the Plant

The plant was installed close to the estuary of the Cavone river. The plant set-up shown in figure 2 illustrates the "environmentally friendly" integration of the plant into the coastal ecosystem.
The operation takes place in two main phases: one treats the drainage canal water and the other entails the reconstruction of the coastal habitat and its "re-naturing".

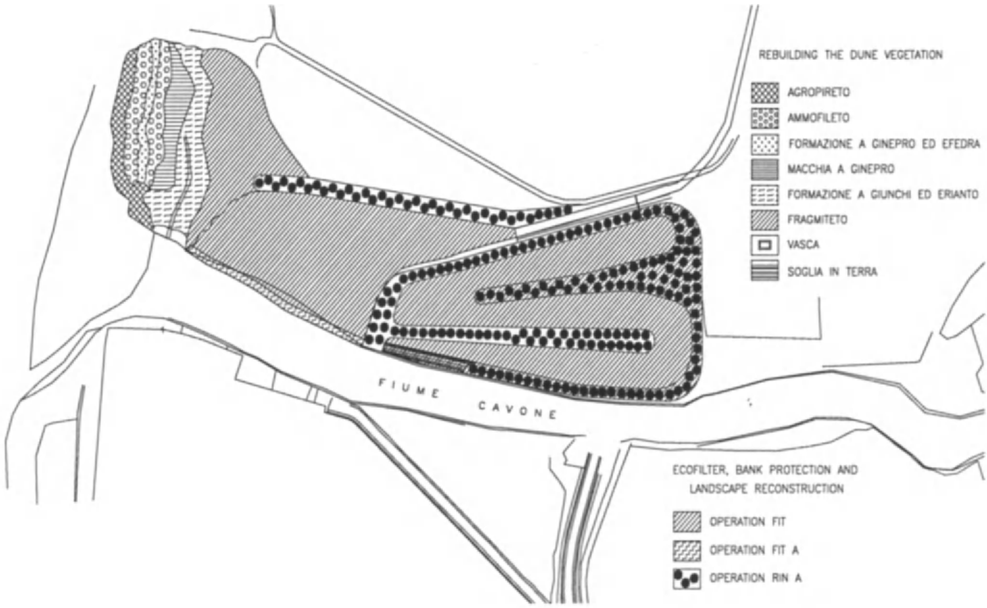

Figure 2: *Plant Planimetry*

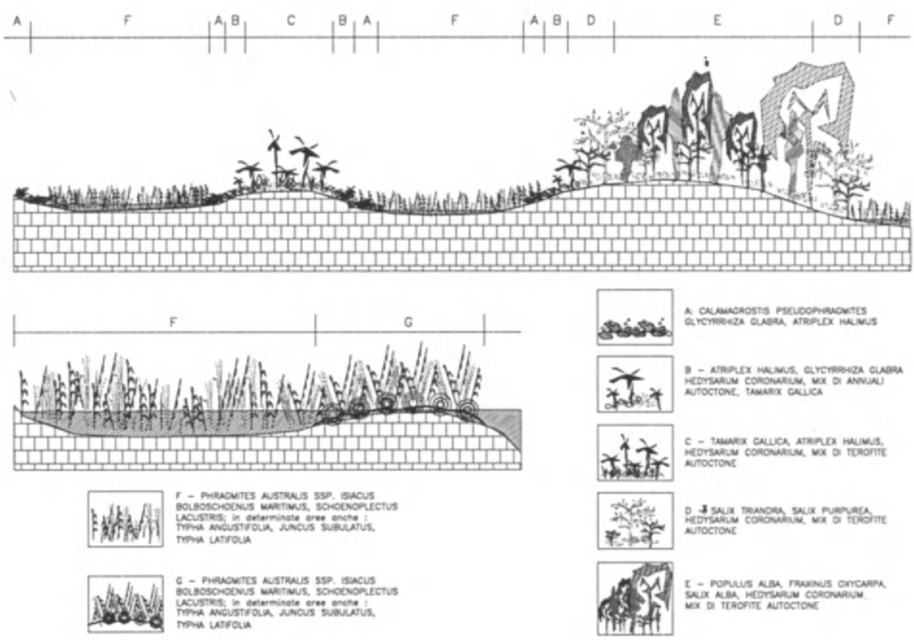

Figure 3: *Plant Section Types*

The channel delivering the water to the plant runs through the metapontina irrigation plain for 4 km. draining water from 600 hectares.
The lagooning section is spread over 30,000 m^2 and runs a length of 1200 meters. In this area, the average summer flow rate may continue for about 5 days with a stay of about 50 cm.
The diagram of figure 3 shows the main plant sections and its setting on the Cavone river.
The environmental aspect was respected during the set-up of each plant section: there are as

few masonry constructions as possible, most were made with compacted earth.

Table 1: *Numerical Data*

Element	Dimensions		Notes
Water intake	Canal 4 m^2. Threshold width 7 m. Hydraulic stay at max. flow 0,50 m.		
Lagoon basin	Surface 100.000 m^2 Average water path 1.200 m. Hydraulic stay 0,40 m.		
Plants	Phragmites Australis (cav.) Trim SSP. Isiacus Typha Augustifolia Bolboschoenus Maritimus (L.) Palla Juncus Subulatus Forsskpl	1 m^2 1 m^2 1 m^2 1 m^2	On banks in the basin flood area coastal dunes
Return to river	Threshold width 150 m. Hydraulic stay at max. flow 0,35 m.		
Cavone river bed by the plant	≅ 60 m.		

6 Plant Performance

The transformations undergone by the pollutants that are treated in such a manner may be summarized as follows:

- assimilation of nutrient compounds (nitrogen and phosphorous) through the synthesis of the increasing plant biomass.
- decomposition of complex organic substances through the microorganism microbes present in the system.
- decay of the bacterial and viral presence through ultra-violet radiation and the presence of superior life forms in the recreated ecosystem.

The following figures provide analytical results from the plant operation in October 1997. This period, just a few months after the plant began functioning, can definitely be used to describe the actions of a lagooning basin which is nearly fully operational (to be achieved in spring/summer 1998).

The diagrams of figures 4 and 5 provide information with regard to ammoniacal and nitric nitrogenous substances. In both cases, the reducing effect is positive, even with small concentrations. The average reduction is about 50% for ammoniums and 80% for nitrates (the increase in nitrites is insignificant).

The diagram of figure 6 shows the phosphate pattern. The average reductions are above 70% with peaks of nearly 90%.

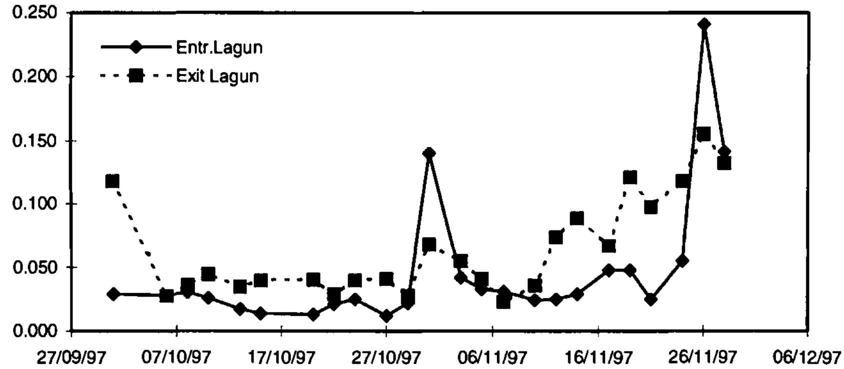

Figure 4: *Diagram-Ammonial Nitrogen Concentration Patterns Between Plant Entrance and Exit*

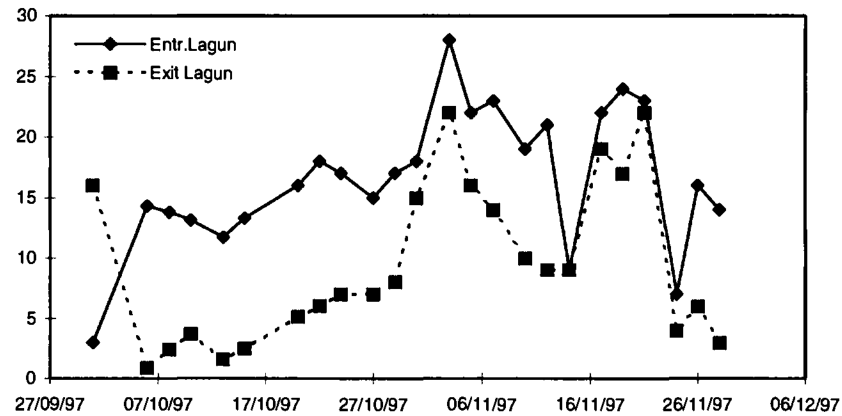

Figure 5: *Diagram - Nitric Nitrogen Concentration Patterns Between Plant Entrance and Exit*

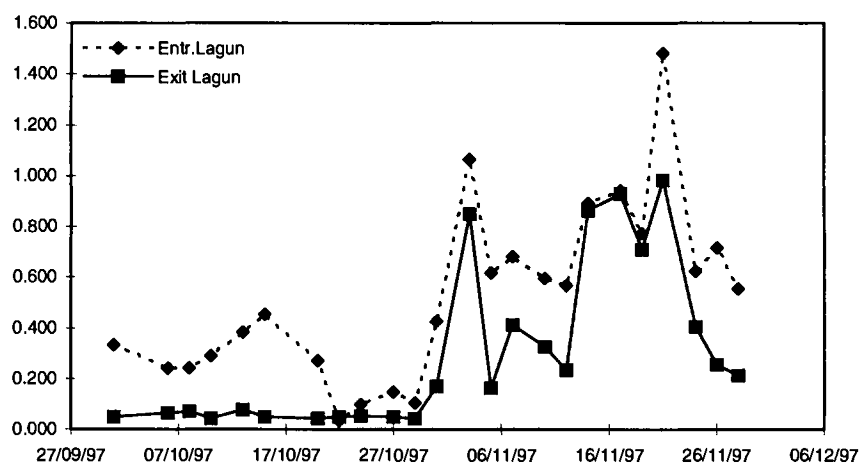

Figure 6: *Diagram - Phosphate Concentration Patterns Between Plant Entrance and Exit*

The diagrams of figures 7,8 and 9 show the pattern of fecal coliforms, total coliforms and fecal streptococci. The most evident result is the absorption capability for load peaks. For example, the water entrance of 10/10/97 with elevated microbial contents, probably caused by occasional drainage of sewage or zootechnical waste, and which would have flowed directly into the river and then into the sea, were significantly purified by the micro-organism present in the lagoon.

Thus, the water let into the receiving body had a completely physiological microbial content.

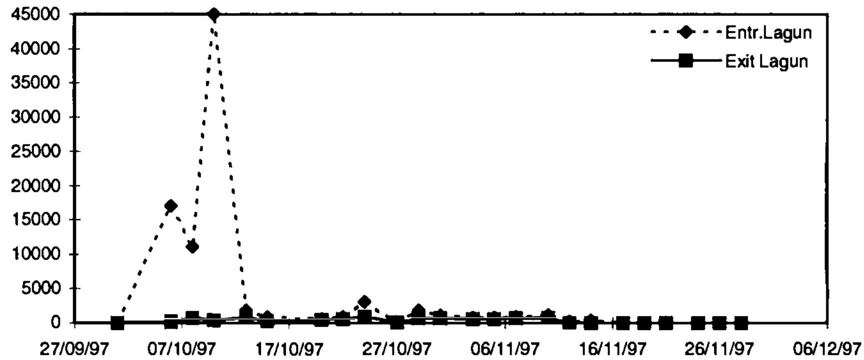

Figure 7: *Diagram - Fecal Coliform Concentration Patterns Between Plant Entrance and Exit*

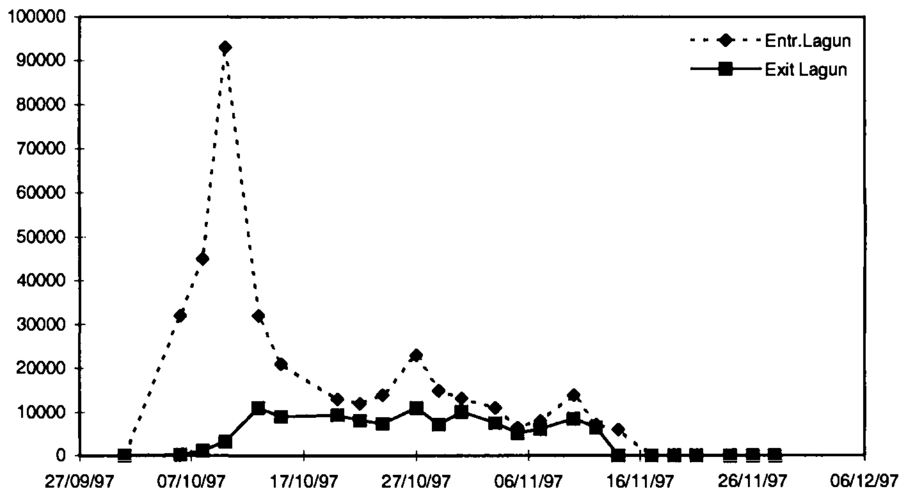

Figure 8: *Diagram - Total Coliform Concentration Patterns Between Plant Entrance and Exit*

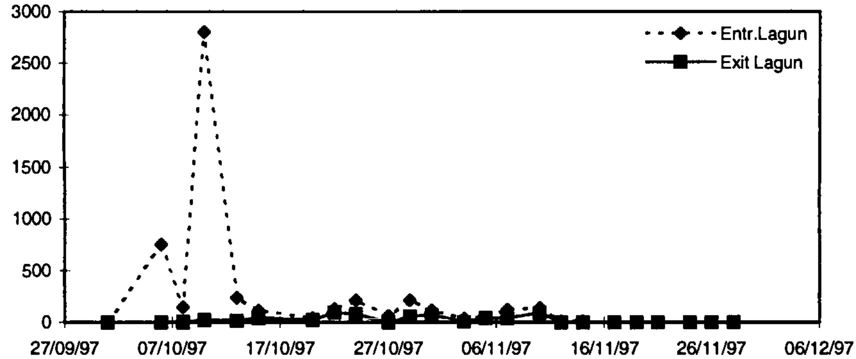

Figure 9: *Diagram - Fecal Streptococci Concentration Patterns Between Plant Entrance and Exit.*

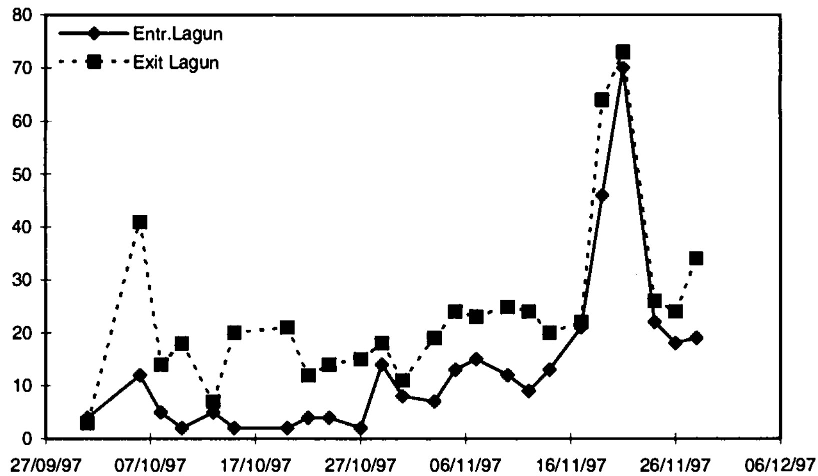

Figure 10: *Diagram - BOD_5 Concentration Patterns Between Plant Entrance and Exit*

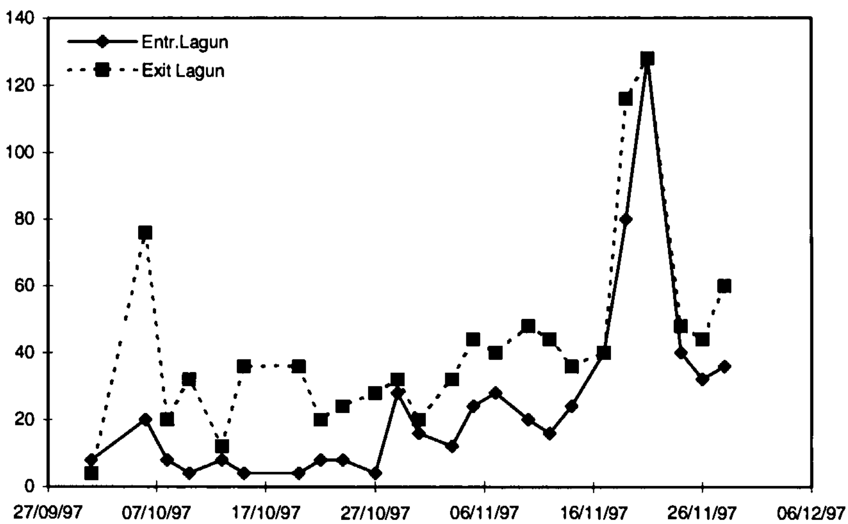

Figure 11: *Diagram - COD Concentration Patterns Between Plant Entrance and Exit*

The diagrams of figures 10 and 11 refer to the presence of organic substances expressed as COD or BOD_5 and confirm the valid activity of the biological system.

The increase in the concentrations between the entrance and the exit may be correlated to the release of organic elements by the plants that synthesize inorganic carbon.

7 Conclusions

The proposed plant fits in with the present operation plan for the protection of watercourses and faces a problem which has still not been tackled by the existing plans: the treatment of drainage canal water.

The potential damage to the environment by these drains does not lie solely in the objective characteristics of the pollutant loads, but in the fact that these waters would drain directly into areas with a great density of coastal/sea tourism.

The solution described in this article seems to be the best for treating water which, due to the pattern of flow and pollutant characteristics load quality, could not be treated in traditional type plants (which are not even present in the area). Although the proposed intervention plan is innovative, it has already proven its validity in similar situations.

The data presented in this article regarding the Cavone plant demonstrates the positive effects of lagooning with regard to the principal polluting agents.

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WATER RESOURCES DEVELOPMENT AND MANAGEMENT OF MONGOLIA

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Abstract

Mongolia is landlocked country located in central and northeast Asia. It has vast but very sparsely populated territory, totaling 1.566.500 square kilometers.
The country is divided into three main topographical zones; mountains, with the three largest ranges located in the north and west; the intermountain basins; and the steppe/ desert, which covers three fourths of the national territory. Mongolia has a population of 2.3 million with a current growth rate of 2.4, one of the highest in Asia.
The Mongolian economy is currently in transition to a market economy.
The country still faces significant challenges in the difficult process of replacing one economic system with another. In particular , all the old relations that regulated socioeconomic and other activities no longer hold for the new conditions. As a result Mongolia has a great need to reconsider and redevelop strategies, policies, programs, and action plans with regard to all tyros of natural resources, including water. At the same, it must ensure that natural resources management and the development system grow in sustainable manner. Mongolia is currently attempting to formulate overall strategy and clearly delineated policy on sustainable water resources development and management.
The country paper presents an overview of water resources quantity and quality aspects, provides information on water management practices and gives some recommendations for further actions.

1 Mongolia Water Resource and Its Use and Protection

1.1 Water Resource and Distribution

Water resource in Mongolia is mutual different distribution and has most variation depended on time and space. Water resource allotted to unit square is small (22 thousand m ^{3}) compared with other countries, but water quantity imposed to one person is biggest (15thousand m ^{3})

Total amount water resources is 38.8 km^3 and using possibility quantity is 34.6 km^3 occupied water of river and lakes is 22 km^3 and12.6 km^3 of underground water. 78% of total water resource or 30.2 km^3 is belong to 30% of total water resource or
low losing discharge region as well as remained 8.6km^3 of resource is included in more losing discharges region or 70% of territory.

2 Observation-Study and Survey

Annual mean precipitation is calculated 230 mm or 36 km^3 of surface water is filled in whole territory of our country. By 1997water regime, quality and composition are studied by 107observation point and 114 meteorological station in 70 river,1 springing and 9 lakes. 54 of biological samples and 8 record of evaporation and water discharges are studied by 81 of observation stations. About 140 of ground water resource deposits are covered by underground water surveys, Drinking water exploitation resource is calculated as 1.5 million m3 by the result of estimation of resource and water quality hydrogeological survey with scale 1:500000 was completed in 340 thousand km2 of Gobi area. Detailed hydrogeological survey work with scale 1:200000 - 1:100000 are completed in over 110 thousand km2. Also hydrogeological map with scale 1:500000 of Mongolia was created using collected materials and survey works.
We are planning to estimate ground water resource for water supply resource in Ulaanbaatar, Center of Aimag, ober 20 plants area and 70 of center soum during 2005 - 2015. Also we have calculated under groundwater resource deposit in over 30 area for irrigation system.

3 Current Situation of Water Supply

Amount 80% of water consumption is provided by ground water resource.

3.1 Urban Water Supply

Drinking water consumption for population are provided by 30.8% of central water supply system, 24.8%water tank car, 35.7% of kiosk and wells and 9.1% of spring, rivers, surface water like ice and snows. Quantity of Ulaanbaatar water consumption is larger than some developed countries in the world. This is confirmed that natural water is used like irrational use water resource. Also maintains for equipment and network of water supply pipeline are not sufficient.
The view of problem that it will posed the difficult for urban water supply.

3.2 Rural Water Supply

70 center soum for water supply are decided from 345 of soums and 170 center soum are located in hydrogeological suitable condition of for groundwater resource and it is not necessary to study ground water resource nearly future years. It will take to make the survey for water supply resource in remained 100 center soum. Recently, 21 of center soum for water supply is very difficult because of water resource. Water composition in 38.5% of soum and settlements are not suitable for drinking water standard.
According to attention pay for issue of agricultural water supply, pasture water supply, development of irrigated cultivated land and increasing crop capacity taking from 1 hector. At the result of 29 thousand engineering designed wells and 17 thousand shift wells were set up, 64.5% of pasture was provided with water supply. Also 150 irrigation system were set up for

150 thousand hector area. Last 10 years 25% of total wells were disappeared 18% is not possible to use and new wells setting up will reduce 10 times per year.
In 1970 irrigated cultivated land of 2.7 thousand hector were used and increasing 15.7 thousand hector in 1980 and 41.9 thousand hector in1990, but after 1990 years quantity of irrigated land was reduced and water consumption (68.6) for 1993 was reduced 2 times compared with 1992 (122.7)

4 Water Quality And Sanitary Issue

The view of study result by special organization, 20% of population use drinking water with less iod and ftorium that's why it is increased sick rate as kidney urine disease and tooth-ache. In quality of drinking water is bad for use population and has pollution, connection with filling industrial and domestic waste and cattle mane solid waste fertilization without control. Sanitary zone of drinking water for population use was established in 32.4% of total water resource.

5 Water Resource Pollution

Some water resource is polluted by chemical harmful substance depended on its store and protection. Natural soil, rivers and water resource are polluted by king of solid waste, petrol products and industrial and domestic waste water and removing waste is not good completed. Over 120 sewage construction do not reach to work appropriate level because of equipment for is out of date and high expenses of maintenance and reconstruction for cleaning sewage water. At 1995, 65.6% or 882.9 m3 of industrial and domestic waste water were cleaned by sewage constructions and 43.5 m3 of waste water were not cleaned and filled in natural surface. 37.6% of total waste water is cleaned by mechanic method, 62.1% by biological and 0.3% by chemical method. Water resource and rivers still are polluted by processing of mining and exploitation.

6 International Cooperation and Situation of Loan and Assistance Use

We have cooperated for rational use water resource with foreign countries as Holland, France, India, Russia and China as well as World and Asian Development Bank. At last years we have carried out some project used by soft loan and free grant of supporting countries for municipality sector as follows " Project of development of national water, sanitation and hygiene education programme" Financed by free grant of UNDP and World Bank implemented first phases in the framework of this project 27 production wells were set up in 5 aimags and installed water pumps and sanitation and hygiene education were and made. A second phases the project will be inverted 2.8 million USD and implement in about 50 rural soum centers pen-urban ger areas in five to six aimag also included in setting up 200 production well. Now Urban services rehabilitation project is carried out in Ulaanbaatar with total amount is 23.8 million USD financed by World Bank. Geological survey of ground water resource will be implemented in Altai city financed by assistance of Government of Japan and amount of project is 1.242 million USD. Also Japan International Cooperation Agency (JICA) begins to implement project for water supply rehabilitation for Ulaanbaatar included in redeveloping equipment for central chloridesation station, installing 56 water meters for residential apartment heating pipelines, redeveloping 11 production wells, setting up new 8 production wells and installing 35 water pumps in production wells. The project cost is 20 million USD. " Project of services rehabilitation in 5 western aimag " is began to

carry out with total amount is 6.8 million USD financed by Asian Development Bank. This project will decide the issues of sewage construction, solid waste hot water etc.
We have made negotiation with Russia (1995) and with China (1994) on protection and rational use for ground water resource in border area.

7 Management of Water Policy

The following article on water resource is included in Documentary of " State policy regarding ecology".

1. One of State Policy is Mongolian surface and ground water resource which is life resource and water resource, quality will be protected and provided by State Policy.
2. Establish zone for water use and saving water resource based on update of record on control - observation study and ecological - economic estimation.
3. Water resource will be rational used for energy, health - resort traveling proposal based on restored natural capacity of river, lakes and other surface water resources.
4. Protect water resource mitigation and pollution, making vegetation plants in water resource area like water point and well, establish pond for rainfall water collection.
5. Urgent issues

The following measurement will be implemented in future 2 years.

1. Government will establish unofficial national committee for improvement between sectarian ministries.
2. Become exchange some articles of Mongolian water law for the purpose of improvement for update of management and farm activities according to rational use water resource.
3. Work out special guidlines of water supply for center and settlement which have met the difficulty for water resource.
4. Ministry of Agriculture and Industry will be planning and implementing measurement for water supply in Gobi area in case of become dried up.
5. Establish legislation right for allot payment for water pollution
6. Work out project for improvement of sewage construction
7. Concerned Ministries will work out policy and implement for supply of natural water for population and stop pollution in water resource.
8. Make the measurement to stop cutting forest where located in water shed area and protect forestry.
9. Decide to installing water meters in center settlement specially in Ulaanbaatar for new buildings and constructions.

Note: Abbreviation and Mongolian terms
Aimag - Mongolian administration unit. Territory of Mongolia is divided into 21 aimag.
Soum - Aimag is divided is into some soum depending on territorial conditions.

A SURVEY OF THE FEASIBILITY OF ALUMINUM RECOVERY FROM COAGULATION SLUDGES

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Abstract

Coagulation - flocculation processes are at present widely applied for both surface water (in colloidal particles and heavy metals removal) and wastewater treatment (in tertiary processes such as phosphorus precipitation).
The most common coagulants are aluminum (Al^{3+}) and iron (Fe^{2+}, Fe^{3+}) salts. Precipitated metal hydroxides, collected in the subsequent sedimentation or filtration units, may result in the production of bulky gelatinous sludge suspensions that are difficult to thicken and dewater.
The high metal content in the resulting sludge allows the coagulant to be recovered and reutilized within the water treatment plant itself. The main advantages and the subsequent economic benefits obtainable by applying the coagulant recovery and reuse process lie in the following aspects: 1) the reduction in the quantities of commercial coagulant to be used (roughly around 80% under the same turbidity removal conditions); 2) the dramatic reduction in metal content of the sludge to be disposed of; 3) the reduction in sludge volume and weight due to the lower total solids content and to the improvement in sludge dewaterability.
The paper presents an overview of the basic principles of aluminum recovery and shows a number of data as obtained by some experimental lab-scale investigations.

1 Introduction

Coagulation - flocculation processes are at present widely applied for both surface water and wastewater treatment.
As far as surface water to be used for drinking purposes is concerned, it may contain large amounts of suspended matter due to the solid transport, especially during the wet season, when the flow is largely from rainfall and runoff. The colloidal fraction of suspended solids is

generally made of clay particles, which often get a negative surface charge as a result of isomorphic replacement of one or more Si atoms within the crystal lattice by other elements (such as trivalent aluminum atoms), resulting in a net negative charge on particle surface. Since like charges repel, similarly charged particles are held apart from each other by their electric charges and thus are prevented from aggregating into larger particles, forming stable suspensions, which are difficult to remove by means of particles settling only.

Coagulation - flocculation processes are thereby applied to remove the colloidal fraction of total solids through destabilization of the stable suspensions.

Concerning wastewater treatment, addition of coagulants is quite often adopted as a tertiary treatment for chemical phosphorus precipitation.

A coagulation - flocculation process may also be successfully applied as a primary wastewater treatment, since it results in several advantages due to the considerable reduction of organic matter and nutrient concentrations of the effluent to be treated by means of secondary biological processes. The direct consequence of such a reduction is that smaller volumes of the aeration tank are required and lower oxygen supplies to the mixed liquor are needed.

Besides, such a coagulation treatment may be suitable when innovative secondary treatments based on attached-film growth (e.g. biofiltering units) are to be used, that require low suspended solids concentrations in the influent in order to minimize the frequency of back-washing.

The most common coagulants are aluminum (Al^{3+}) and iron (Fe^{2+}, Fe^{3+}) salts (sulfates and chlorides). Through formation of gelatinous polymeric metal hydroxides at near-neutral pH values, these metal salts are effective coagulants for particulates and some complex dissolved contaminants.

Precipitated metal hydroxides, collected in the subsequent sedimentation or filtration units, may result in the production of bulky gelatinous sludge suspensions that are difficult to thicken and dewater.

The operating costs of a coagulation - flocculation treatment are by no means actually high, and are related both to the acquirement of commercial coagulant and to the disposal of the resulting sludge. However, the potential exists for noticeably reducing the operating costs of such a treatment on the basis of the following two remarks:

- the metal hydroxides in the resulting sludge constitute a major portion of the volume and mass of solids;
- aluminum and iron hydroxides have elevated solubilities under both highly acidic and highly alkaline conditions.

If the dissolution of the metal hydroxides from the sludge is accomplished, this can therefore result in two beneficial purposes:

- the removed coagulant metal can be beneficially reused;
- the volume and mass of the sludge to be disposed are strongly reduced.

Although the recovery treatment can in principle be performed on both aluminum and iron coagulation sludge, the following will focus on the fundamentals of coagulant recovery from aluminum sludge, since alum is more widely used as a coagulant in water treatment.

2 Chemistry of Coagulation with Aluminum

A log C - pH diagram is a useful tool in describing metal species in solution following addition of coagulant to water. In Figure 1 such a diagram for aluminum is shown. Numerous positively charged (Al^{3+}, $AlOH^{2+}$, $Al(OH)_2^{+}$, $Al_3(OH)_4^{5+}$, $Al_{13}(OH)_{24}^{7+}$) and negatively charged ($Al(OH)_4^{-}$) aluminum species exist in equilibrium with solid aluminum hydroxide ($Al(OH)_3 \cdot 3H_2O$), which has a minimum solubility at a pH of about 6.2.

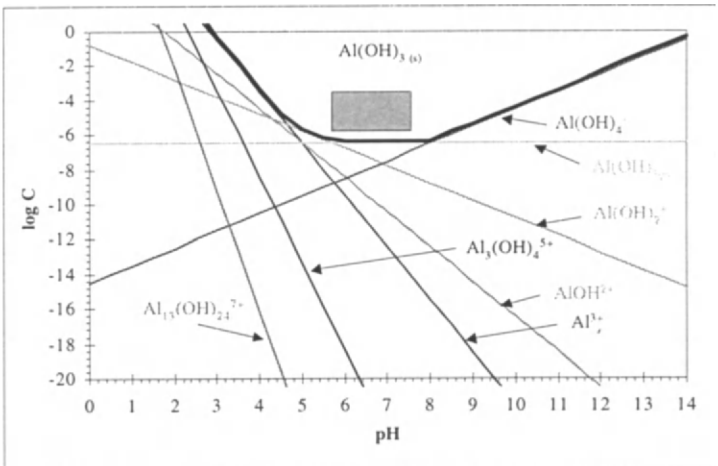

Figure 1: *Log C - pH Solubility Diagram for Aluminum (III)*

Since aluminum is an hydrolyzing metal ion, addition of, for example, aluminum sulfate to a water results in an immediate coordination of the aluminum ion with six water molecules, which thus forms the aquometal complex $Al(H_2O)_6^{3+}$. This complex ion then passes through a series of hydrolytic reactions in which H_2O molecules in the hydration shell are replaced by OH^- ions. This gives rise to the formation of a variety of soluble species, including mononuclear species (one aluminum ion), such as $AlOH^{2+}$ and $Al(OH)_2^+$, and polynuclear species (several aluminum ions), such as $Al_3(OH)_4^{5+}$, $Al_8(OH)_{20}^{4+}$, $Al_{13}(OH)_{24}^{7+}$ and many others. A scheme for the hydrolysis of aluminum (III) is given by the following series of reactions:

$$\xrightarrow{\text{Increasing pH}}$$

$$Al(H_2O)_6^{3+} \rightleftharpoons [Al(H_2O)_5OH]^{2+} \rightleftharpoons [Al(H_2O)_3(OH)_3]_{(s)} \rightleftharpoons [Al(H_2O)_2(OH)_4]^- \qquad (1)$$

$$Al(H_2O)_6^{3+} \rightleftharpoons Al_8(OH)_{20}^{4+} \rightleftharpoons [Al(H_2O)_3(OH)_3]_{(s)} \qquad [Al(H_2O)_3(OH)_3]_{(s)} \rightleftharpoons AlO(OH)_{(s)} \rightleftharpoons Al_2O_{3(s)}$$

(Other polynuclear species) (Crystalline phases)

According to [12], aluminum (III) accomplishes destabilization of colloidal suspensions by two mechanisms: *(1)* adsorption and charge neutralization and *(2)* enmeshment in a sweep floc. If the concentration of aluminum (III) added to water is lower than the solubility limit of the metal hydroxide, the hydrolysis products will form and adsorb onto the particles, causing colloids destabilization by charge neutralization. When the amount of aluminum added to water exceeds the solubility of the hydroxide, the hydrolysis products will form as kinetics intermediates in the formation of the metal hydroxide precipitate. In this situation charge neutralization and enmeshment in the precipitate both contribute to coagulation. Interrelations between pH, coagulant dosage, and colloid concentration determine the mechanisms responsible for coagulation.

The charge of hydrolysis products and the precipitation of aluminum hydroxide are both controlled by pH. The hydrolysis products possess a positive charge at pH values below the iso-electric point of the hydroxide; these positively charged species can cause destabilization of negatively charged colloids due to adsorption and charge neutralization. The negatively charged species ($Al(OH)_4^-$), which predominates above the iso-electric point, is ineffective for destabilizing negatively charged colloids.

Precipitation of amorphous aluminum hydroxide is necessary for sweep-floc coagulation. The solubility of $Al(OH)_3 \cdot 3H_2O_{(s)}$ attains a minimum at a pH value of about 6.2 and increases as the pH increases or decreases from this value. In practice, the pH values corresponding to the minimum solubility range vary between 6 and 7.5 units.

Obviously, control of pH value must be provided in order to establish optimum conditions for coagulation, that is complicated by the fact that the aquometal ion of aluminum (III) is acidic in nature, therefore releases hydrogen ions according to the following reaction:

$$Al(H_2O)_6^{3+} + H_2O \rightleftharpoons Al(H_2O)_5(OH)^{2+} + H_3O^+ \qquad (2)$$

Hydrogen ions liberated by the hydrolysis reactions will react with the natural alkalinity in the water as follows:

$$Al_2(SO_4)_3 \cdot 14H_2O + 3Ca(HCO_3)_2 \rightleftharpoons 2Al(OH)_3 + 3CaSO_4 + 14H_2O + 6CO_2 \qquad (3)$$

Stoichiometrically, each mg/l of alum will consume approximately 0.50 mg/l of alkalinity as $CaCO_3$. If the alkalinity of the water is insufficient to react with the alum and buffer pH, it may be necessary to add alkalinity to the wastewater in the form of lime or soda ash.

2.1 Characteristics of Aluminum Hydroxide Sludge

At the operational values of pH (6.5 ÷ 7.5) and alum dosage (2 ÷ 3 mg/l as Al) commonly adopted in water treatment, it is expected that the aluminum hydroxide $Al(OH)_3 \cdot 3H_2O_{(s)}$ is the predominant form of aluminum present at equilibrium.

Aluminum hydroxide forms gelatinous flocs and settles down sweeping out the suspended matter. Aluminum hydroxide precipitates typically contain large amount of bound water, making the sludge a voluminous suspension, with low solids concentrations and poor dewatering properties.

Solids concentrations in the sludge usually vary from 4 to 120 g/l, while aluminum concentrations range between 300 to about 20,000 mg/l.

Slow initial settling velocities, ranging from about 0.06 to 0.15 cm/s, are reported [4].

3 Aluminum Recovery

Referring to the solubility diagram of aluminum presented in Figure 1, due to its amphoteric behavior aluminum concentration in solution increases dramatically as the pH increases or decreases from the point of minimum solubility.

Thus, if the aluminum hydroxide sludge is conditioned by addition of an alkaline or acidic agent so as to cause pH to turn away the iso-electric point, aluminum is dissolved to form again polynuclear and mononuclear species and hydrolysis products.

When reused as a coagulant in the optimal pH range, these soluble aluminum species produce analogous effects, with respect to colloids coagulation, to those of commercial aluminum products.

Aluminum recovery therefore provides two main advantages. The first is obviously the potential to reuse the recovered coagulant solution, thus saving money for the acquirement of commercial coagulant. The second advantage attained from aluminum hydroxide dissolution lies both in the significant reduction of sludge mass and volume and in the improvement of sludge settleability and dewaterability. From this standpoint, alkaline or acidic treatment of coagulation sludge may be regarded as a means of beneficial sludge conditioning prior to final disposal.

The liquid extraction procedure for separating aluminum species from sludge is often referred to as liquid-ion exchange, in that it is analogous to resin ion exchange processes. Rather than the aqueous aluminum being exchanged for Na^+ or H^+ onto a solid resin, the aqueous aluminum is exchanged for a cation in another liquid (the acid solution).
Among the two available extraction processes (alkaline and acidic extraction), the latter has been deserved the major attention due to the higher recovery efficiency attained.
Both sulfuric acid and hydrochloric acid have been investigated for acidic aluminum hydroxide dissolution. The reactions between the acids and aluminum hydroxide can be written as follows:

$$2Al(OH)_3 \cdot 3H_2O + 3\ H_2SO_4 \longrightarrow Al_2(SO_4)_3 + 9H_2O \qquad (4)$$

$$Al(OH)_3 \cdot 3H_2O + 3\ HCl \longrightarrow AlCl_3 + 6H_2O \qquad (5)$$

Despite of the comparable efficiency in aluminum recovery attained by the two acid treatments, the costs associated to the use of hydrochloric acid are by no means prohibitively higher. This is the reason why sulfuric acid has been extensively employed for aluminum recovery.
The stoichiometric sulfuric acid requirement for dissolution of aluminum hydroxide is equal to 1.5 moles/mole Al, or 1.1 kg/kg $Al(OH)_3 \cdot 3H_2O$, or 5.45 kg/kg Al.
These stoichiometric acid requirements are based on complete dissolution of solid aluminum species, represented by the hydrated aluminum hydroxide, to soluble aluminum as Al. Formation of hydrolysis products can result in lowering the acid requirement for aluminum dissolution: for example, dissolution of aluminum to the soluble species $Al(OH)_2^+$ would require one-third of the amount of acid as evaluated based on the previous stoichiometric calculations. It is therefore evident that acid demand can be significantly affected by aluminum speciation following acid addition.
Data from several investigators [4], [10] showed that aluminum recovery can be actually attained according to stoichiometric predictions (see Figure 2).

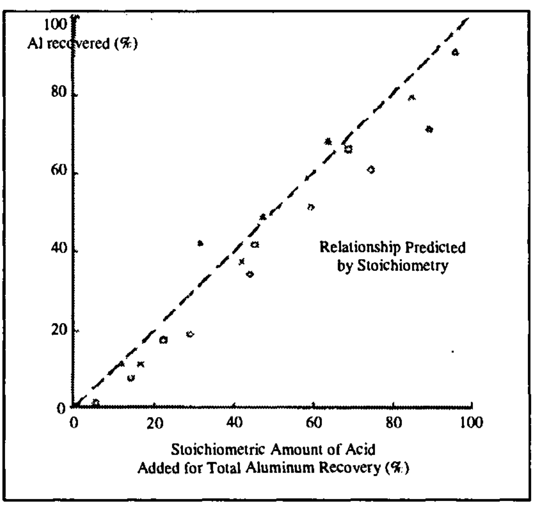

Figure 2: *Percentage Aluminum Recovered as a Function of Amount of Acid Added*

However, complete aluminum dissolution is usually not accomplished, due to two main reasons:
- other acid-demanding materials (such as iron and manganese hydroxides) may be present in the sludge. Thus, only a portion of the amount of acid added will be effective for

aluminum dissolution, which therefore will not be complete when dosing the stoichiometric amount;

- the aluminum present in the sludge, other than as aluminum hydroxide, may also be associated to clay particles. In this case it is present in the form of oxides ($Al_2O_3 \cdot nH_2O$), which are much more resistant to acidification than the aluminum hydroxide. Therefore, if the raw water has a high suspended solids concentration, the efficiency of aluminum recovery may be noticeably reduced.

3.1 Quality of the Recovered Coagulant

Many factors, such as stoichiometry of acid requirement, operating pH value and kinetics of the extraction affect aluminum recovery.
Aluminum recovery as a function of pH is illustrated in Figure 3 for a number of sludges coming from different water treatment plants [4], [8]. It can be seen that percent recovery at a given pH value may dramatically vary depending on sludge characteristics.

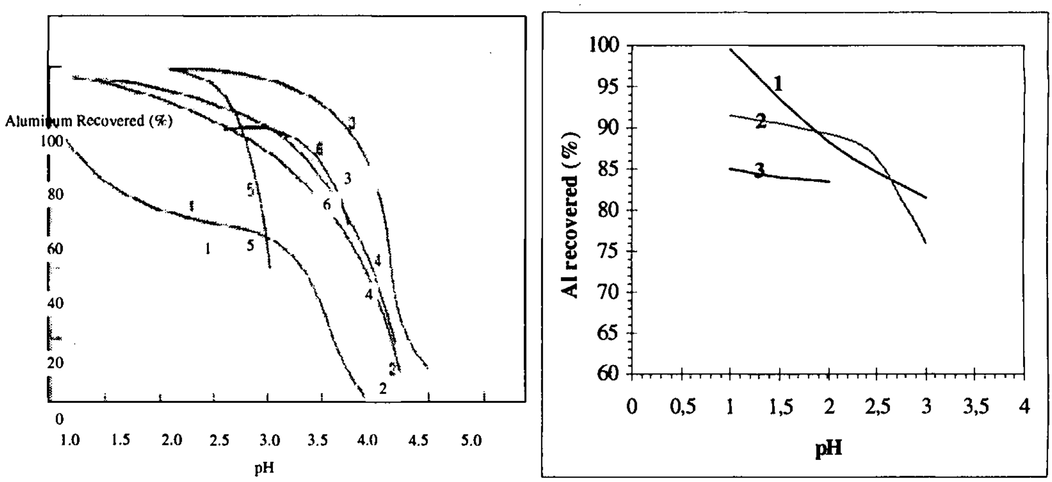

Figure 3: *Aluminum Recovery as a Function of pH*

Determination of the optimum contact time for the acidic dissolution of aluminum is of relevance in order to allow chemical equilibrium conditions to be attained. A number of investigators [5] found that a detention time of approximately 5 minutes is required to reach about 80 percent equilibrium, while 100 percent equilibrium was obtained in less than 20 min. It has been shown that a contact time of 15 minutes is sufficient to obtain aluminum recovery close to 100 percent.
When evaluating the overall effectiveness of the aluminum recovery process, not only the percent recovery has to be measured, but other aspects should be also taken into account. Coagulation efficiency of the recovered aluminum and organic matter, color, iron, manganese and trace contaminants concentrations are also of major concern.
In Figure 4 [8] the residual turbidity of two suspensions of initial turbidity of 3.2 and 450 NTU is shown as a function of aluminum dosage for a commercial coagulant and for two coagulant solutions recovered at pH values of 1 and 2 respectively. It can be observed that the two recovered coagulants exhibit similar effectiveness with respect to turbidity removal, but not comparable with the one of the commercial coagulant, especially at low dosages. According to the observations of other authors, residual turbidity increases dramatically at high aluminum dosages, indicating some particles restabilization. This could be due to an overdose of coagulant (which may reverse the particle charge, thus resulting in restabilizing

the colloidal suspension) or to the depressed pH of the coagulated water (attributable to the acidic nature of the recovered coagulant).

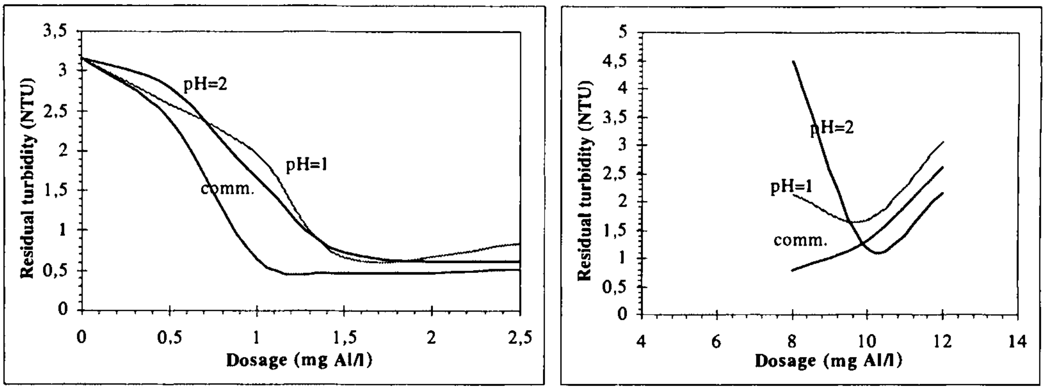

Figure 4: *Residual Turbidity as a Function of Aluminum Dosage*

The effect of use of the recovered coagulant on the quality of the water to be treated may be evaluated in terms of organic matter and residual aluminum concentrations and toxicity of the effluent from the coagulation treatment. Some investigations on organic matter concentration, carried out through TOC and absorbance UV 254 nm measurements on the supernatant from coagulation tests (the latter providing an indication on humic and fulvic acids concentration) showed similar trends for both recovered and commercial coagulants [9].
Besides, some bio-toxicity measurements performed on the treated water revealed the absence of toxicity induced both by the commercial and the recovered coagulant [9].

3.2 Characteristics of the Residual Sludge

Acidification of aluminum hydroxide sludge results in a considerable reduction in residual sludge volume.
As previously mentioned, acidic extraction dissolves the gelatinous aluminum hydroxide flocs and releases the bound water associated with the sludge. The volume of the remaining solids is thereby reduced, decreasing the volume of sludge to be disposed of.
This also results in improving the settling and dewatering characteristics of the sludge, as shown in Figure 5 [4], which indicates that the initial settling velocity of the sludge after the acidic treatment increased with increasing the amount of aluminum recovered.

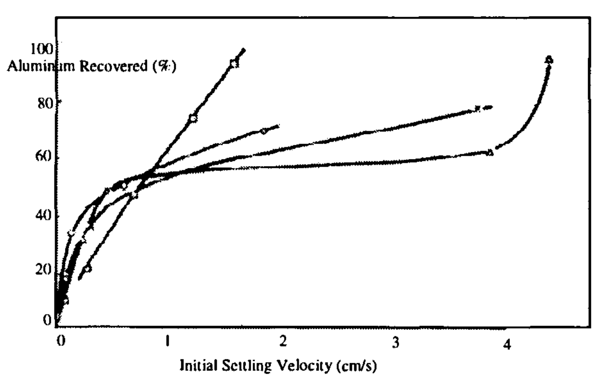

Figure 5: *Settling Velocity of the Acidified Sludge as a Function of Aluminum Recovery*

Some evaluations of the residual sludge dewaterability through specific resistance measurements (see Figure 6, [4]) showed a sharp reduction in sludge filterability in the range of 60 to 80 percent aluminum recovery, while a considerable increase was detected as aluminum recovery increased beyond 80 percent, thereby indicating a deterioration in sludge dewaterability.

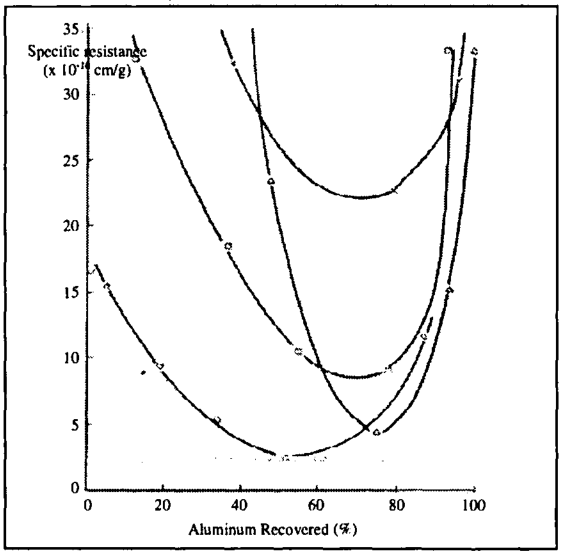

Figure 6: *Specific Resistance of the Acidified Sludge as a Function of Aluminum Recovery*

4 Conclusions

The present paper provided a survey of the basic principles demonstrating the viability of aluminum recovery from coagulation sludges. The results obtained from some experimental lab-scale tests carried out both by the authors and by a number of other investigators were presented.
Some more experimental tests are anticipated to be performed on a pilot scale in order to evaluate the actual possibility of transferring the obtained results to full-scale applications.
The possibility to apply the coagulant recovery process to sludges from wastewater treatment will be also examined. Though lower recovery efficiency are expected, a recovery-and-reuse coagulation treatment in wastewater treatment plants is believed to be useful for two main purposes: *1)* improving the overall removal efficiency with respect to organic matter in under-sized conventional wastewater treatment plants; *2)* reducing the back-wash frequency when attached-growth technologies are used as secondary treatments.

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ACTIVATED SLUDGE MULTISTAGE PLANT WITH STEP SLUDGE RECIRCULATION: PROCESS OPTIMIZATION

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Abstract

Results of experimental tests carried on a multistage step sludge recirculation activated sludge plant are presented.
The main objective of this experimentation regards the characterization of the plant configuration that presents the maximum removal rate for carbonaceous and azotate substrate. The removal efficiency and the kinetics constants, as a function of the sludge recirculation flow in each stage, were also determined.

1 Introduction

One of the purposes of the biological wastewater treatment is the organic matter removal by means the microorganisms growth (1,2). The treatment effect is attempted by the optimal association between the bacterial growth and the substrate removal (3,4).
Previous works (5,8) stated that a multistage step sludge recirculation reactor (S.S.R.), improves the multistage treatment plant rate: such a system is characterized by the partialization of the return sludge flow among the different stages of a series of continuous flow stirred reactors.
S.S.R. configuration lets, for a fixed quantity of biomass and a fixed complessive reaction volume, a better depuration rate than the traditional monostage plants. Different factors contribute to this conclusion, in fact this configuration realises a better specialization of the biomass, and, increasing biomass concentration along the reactor, establishes an optimal ratio between substrate and biomass.
In this experimentation, which treats a municipal substrate rich in nitrogen, a denitrification stage it has been inserted at the top of the plant; such a configuration, which finds its application since 1960 (Ludzak - Ettinger), lets to use the carboniousus substrate presents in the wastewater as the carbon source for the denitrification process (9-13).

The purpose of this experimentation, in consideration of the advantages of biomass distribution, is to optimize the return sludge flow, and once determined the optimal configuration, to evaluate the kinetic of the transformation process.

2 Plant Description

The plant studied, belonging to the Azienda Comunale Energia ed Ambiente (ACEA) of Rome, was designed for the municipal wastewaters treatment of a community of about 7000 people equivalent. The average design flow was 300 l / capita d, about 90 m^3/h. The biological oxidation takes place in about 440 m^3 tank, in which four surface turbines were installed, achieving an air tranfer of 10 kg/h. The tank was divided in four stages by baffles; each stage has a volume of about 110 m^3. The plant scheme is reported in figure 1.

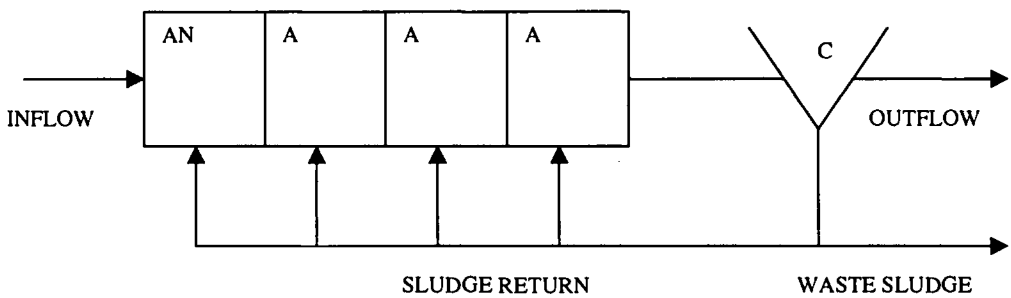

Figure 1: *Plant Scheme (AN= anoxic stage; A= aerobic stage; C= claryfier)*

The first stage was an anoxic one, while the next three stages were aerated by surface turbines. Two different return flows were arranged: the first one which provided for the recirculation of the mixed liquor directly to the anoxic stage, with the aim to funish the nitrate concentration for the denitrification process, the second one, distributed among all the four stages, which provided for the recirculation of the sludge drawn from the secondary claryfier. The average temperature in the tank during the experimentation period was of about 10°C.

3 Experimental Methodology

3.1 Experimental Program

The experimental work was devoted to the evaluation of the treatment efficiency variation in function of the distribution of the return sludge flow among the four stages.
Five tests were carried out: in each of them different return flow percentages were adopted in each stage, according to the scheme shown in table 1.

Table 1: *Experimental Program: Distribution of the Return Sludge Flow as Percentage of the Total Return Sludge Flow*

	Configuration				
Stages	1	2	3	4	5
1° Anoxic	100	60	50	30	10
2° Aerobic	0	40	0	30	0
3° Aerobic	0	0	20	20	10
4° Aerobic	0	0	30	20	80

3.2 Analysis

For each configuration a weekly test program has been established; during these periods the inflow and outflow values in each stage of the following characteristic variables were determined:

- organic substrate concentration, as COD, determined with potassium dichromate volumetric titration (14);
- ammonia concentration, with reflectometric analysis (14);
- nitrate concentration with reflectometric analysis (14).

In each stage was also determined the biomass concentration, with a sample filtration on a 0,45 micron cellulose filter, and drying at 105 °C.

The average characteristics of the wastewater inlet the plant and the operative conditions are summarized in table 2. During the experimentation period a variable distribution of the inlet flow and of the wastewater composition, in term both of COD and ammonia concentration has been observed.

Table 2: *Average Characteristics and Operative Conditions in the Plant*

COD	mg/l	280 ± 55
BOD_5	mg/l	160 ± 35
TSS	mg/l	185 ± 20
VSS	mg/l	145 ± 25
$N\text{-}NH_4^+$	mg/l	37 ± 12
$N\text{-}NO_3^-$	mg/l	6 ± 2
P total	mg/l	10 ± 3
inlet flow	m^3/h	90
sludge return	m^3/h	90
mixed liquor return	m^3/h	225

4 Results

4.1 The Carbon and Nitrogen Cycle

In the following tables the experimental results, as average values of the weekly tests carried on, are shown. In particular table 3 shows the removal rate, defined as ratio between outflow and inflow amount of soluble organic substrate or ammonia, besides it is just to point out that for each considered configuration about the same content of biomass, in term of TSS, was measured.

Table 3: *Removal Rate for Each Configuaration*

Configuration	Removal rate COD (%)	Removal rate NH_4^+ (%)
1	84,4	68,6
2	85,1	72,4
3	86,0	73,1
4	88,2	76,5
5	90,5	78,2

The substrate concentrations in the tank are reported in table 4, in term of total COD, at different point in the plant working in the configuration number 5: data are related to a week of analyses.

Table 4: *Soluble Carbonaceous Substrate Concentration in the Optimal Configuration*

	COD (mg/l)						
Feed	286	345	256	238	354	365	307
1° Anoxic	98	89	145	70	92	154	108
2° Aerobic	90	82	70	59	62	110	79
3° Aerobic	49	66	58	45	49	67	56
4° Aerobic	28	26	26	29	31	34	29

The nitrogen cycle in the plant, when the configuration was the optimal one, previously determined, was regular. The data reported in tables 5 show how in conformity with a decreasing of the ammonia concentration there was an increasing of nitrate concentration.
The outlet nitrate concentration values, even if lightly above the italian regulation limits (20 mg/l), may be decreased in the secondary clarifier in which anoxic conditions were settled, with sludge rising as a consequence.

Table 5: *Ammonia and Nitrate Concentration in the Optimal Configuration, as mg/l N*

Feed	**NH_4^+** (mg/l)	34,7	38,3	29,3	30,2	43,1	45,0	41,3
	NO_3^- (mg/l)	6.4	5.6	7.2	4.7	4.9	8.1	5.9
1° Anoxic	**NH_4^+** (mg/l)	29,0	31,2	22,4	25,2	36,9	37,1	35,3
	NO_3^- (mg/l)	13,4	14,8	17,2	11,9	11,6	16,2	12,4
2° Aerobic	**NH_4^+** (mg/l)	20,2	24,3	15,5	20,6	30,4	30,1	28,4
	NO_3^- (mg/l)	15,3	16,4	18,4	13,9	14,3	18,0	15,5
3° Aerobic	**NH_4^+** (mg/l)	15,5	18,1	11,4	16,2	24,5	22,6	21,2
	NO_3^- (mg/l)	17,1	17,9	19,6	15,8	16,9	19,8	18,7
4° Aerobic	**NH_4^+** (mg/l)	6,2	7,1	4,5	8,8	11,5	10,3	8,7
	NO_3^- (mg/l)	20,6	21,9	23,4	19,8	19,8	24,8	21,6

Table 6: *Biomass Concentration in the Optimal Configuration*

Stages	TSS (mg/l)
Feed	185
1° Anoxic	2100
2° Aerobic	1950
3° Aerobic	2450
4° Aerobic	4700

Mean obtained results are reported in figure 2, that shows the behaviour of carbonaceous substrate concentration and of ammonia and nitrate concentration along the reactor for the optimal configuration (number 5).

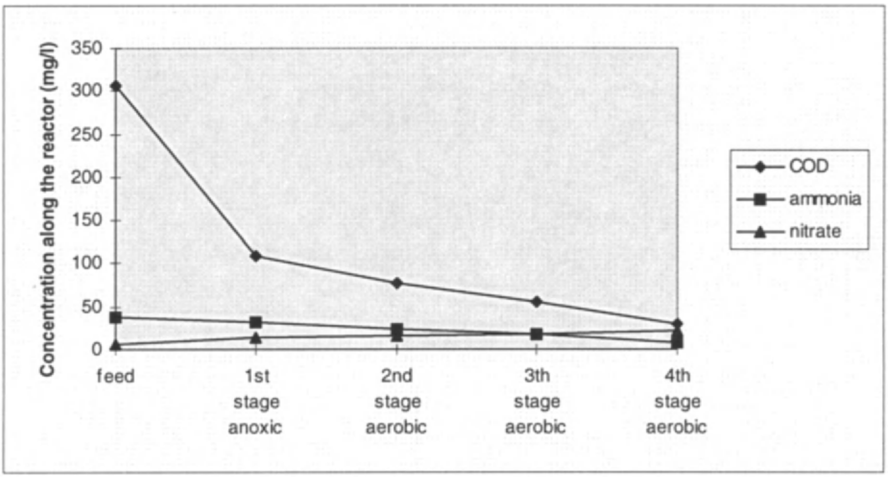

Figure 2: *COD and Nitrogen Concentration Along the Reactor in the Optimal Configuration*

This configuration was also characterized by a light increasing of sludge settleability, this is confirmed by a decrease of the sludge volume index (SVI).

5 Experimental Data Evaluation

The first stage of the plant was an anoxic reactor, in which the denitrification process takes place, utilizing the experimental data a kinetic study without positive results has been attempted (16). The back mixing phenomena between the anoxic stage and the first aerobic stage, with the consequent difficulty to keep anoxic conditions in the first stage, hindered to find effective kinetic coefficients.
The other three stages work, instead, in aerobic conditions; then, considering the wastewater treated nature, it is supposed that the nitrogen transformation is the controlling phenomenon for the whole depuration process. So that a modelling study for the characterization of the nitrification process in the different plant stages has been attempted.
At this aim the following kinetic equations has been used (15 - 17):

1) $-dS/dt = KXS$ (eq. of Wezernak and Gannon)
with K = constant (1/ mg TSS d)

2) $-dS/dt = K'XS / (K_T + S)$ (eq. of Lawrence and McCarty)
with K_T = semisaturation constant (mg $N\text{-}NH_4^+$/l) e K' = constant (mg $N\text{-}NH_4^+$ / mg TSS d)

Where: S = limiting substrate concentration (mg $N\text{-}NH_4^+$ / l)
X = biomass concentration (mg TSS / l)
t = time (d)

For each stage, basing on the avilable experimental data, the previous equation for the determination of the kinetic coefficients has been used. Those equation has been linearized, determining the correlation coefficients (r), as reported in table 7.

Table 7: *Correlation Coefficients (r) Obtained*

Stages	Equation 1	Equation 2
1	<0,5	<0,5
2	<0,5	0,51
3	0,85	0,86
4	0,91	0,78

By the analysis of the correlation coefficients obtained, it can be supposed that the nitrification process in the second and third stage can be well described by the kinetic equation of Lawrence and McCarty, while in the fourth stage both the considered equations well foresee assimilation process.
Once the kinetic of the nitrification process has been found, the kinetic coefficients have been determined, the results are reported in table 8.

Table 8: *Kinetic Coefficients Obtained*

Stages	K =1 / mg TSS d	K'= mg N-NH_4^+ / mg TSS d	K_T=mg N-NH_4^+/l
1	---	---	---
2	---	0,096	13,25
3	0,0046	0,154	44,04
4	0,0037	0,063	4,54

6 Conclusions

From the experimentation results it can be seen how the depuration process rate increases with the distribution of the return sludge flow among the different stages of the aeration tank.
In the optimal configuration the 10 percent of the return sludge flow has been recycled to the top of the plant, another 10 percent has been recycled to the second aerobic stage, while the remainder has been recycled the last stage.
In a such configuration the nitrogen cycle was studied: in the last tank there was a nitrate concentration higher than the italian regulation limits (20 mg/l), but the respect of the law limits has been gained by a light denitrification in the secondary clarifier.
The controlling phenomenon in the treatment system is the ammonia transformation in nitrite and nitrate. At the top of the plant, in the first stage, it wasn't possible to determine the kinetic coefficients values for the denitrification process, because in the reactor the strictly anoxic conditions aren't kept. In the third and fourth stages, where the assimilation reactions of nitrogen constitute the controlling factors of the process, the nitrification follows a Monod kinetic, as described from the Lawrence and McCarty equation.
The adopted step sludge recirculation (SSR) system lets to improve the treatment rate and sludge settleability by means the specialization of the biomass along the reactor.

Acknowledgement

Many thanks to professor M. Beccari for his precious suggestions.

Contributions

The authors declare that an equal contribution was made by each as regards shaping the work, carrying out the experimental tests and drafting the paper.

Nomenclature

COD = chemical oxygen demand (mg/l)
BOD_5 = chemical oxygen demand at five days (mg/l)
VSS = volatile suspended solids concentration (mg/l)
TSS = total suspended solids concentration (mg/l)
$N\text{-}NH^+_4$= ammonia concentration (mg/l)
$N\text{-}NO^-_3$ = nitrate concentration (mg/l)
P = total phosphorous concentration (mg/l)
SVI = sludge volume index (ml/g)
K = Wezernak and Gannon kinetic coefficient (1/mg TSS d)
K_T = semisaturation coefficient (mg $N\text{-}NH_4^+$/l)
K'= Lawrence and McCarty kinetic coefficient (mg $N\text{-}NH_4^+$ / mg TSS d)
S = limiting substrate concentration (mg $N\text{-}NH_4^+$ / l)
X = biomass concentration (mg TSS / l)
t = time (d)
r = correlation coefficient (dimensionless)

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DRINKING WATER AND WASTE WATER DISINFECTION: STRATEGIES AND PROBLEMS

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Abstract

Within the European Union, many different disinfection systems are being used. They are applied both in facilities for the potabilization of ground and surface water, and for the disinfection of wastewater after a biological treatment. Although chemical and physical processes are usually employed, treatment procedures and results are quite different. In this work, main disinfection systems used in European Countries in water potabilization facilities are described. The growing use of surface water for the production of drinking water, underlines the necessity to minimize the formation of by-products with potentially toxic long-term effect. This leads to define adequate control strategies in potabilization processes: both used reagents and process schemes must be analysed considering this important aspect. In the second part of the paper, problems dealing with the disinfection of wastewater and the main characteristics of the most important disinfection systems (as far as their applicability and efficiency are concerned) are analyzed. The results of a research carried out in order to compare four different disinfection systems (ozonation, disinfection with chlorine dioxide, UV radiation, peracetic acid disinfection) are also shortly presented.

1 Introduction

Within the European Union (EU), many different disinfection systems are being used. They are applied both in facilities for the potabilization of ground and surface water, and for the disinfection of wastewater after a biological treatment. Although chemical and physical processes are usually employed, treatment procedures and results are quite different.
The main issues which must be considered to evaluate the suitability of a chemical or physical disinfection treatment are the following: removal efficiency with respect to microbiological

agents, treatment costs, disinfectant residues in treated water, formation of potentially dangerous compounds (Disinfection By-Products: DBP).

2 Drinking Water Disinfection

2.1 Characteristics of a Disinfected Water

The first problem in drinking water treatment is how to define a disinfected water. In all EU member States, a disinfected water must comply with microbiological characteristics required by the current Directive 80/778/EEC:

Total coliforms	Maximum Allowable Concentration	0/100 mL
Fecal coliforms	Maximum Allowable Concentration	0/100 mL
Fecal Streptococci	Maximum Allowable Concentration	0/100 mL
Sulphitic-reducing clostridia	Maximum Allowable Concentration	0/100 mL
Colonies on agar at 36°C	Guideline Value	10/1 mL
Colonies on agar at 22°C	Guideline Value	100/1 mL

Standards required in the proposal of a new Council Directive (COM(94) 612) are more specific:

E. coli	Parametric Value	0/100 mL
Fecal Streptococci	Parametric Value	0/100 mL
Sulphitic-reducing clostridia	Parametric Value	0/20 mL

It is also specified, in the integration COM (97) 228, that water for human usage must not contain pathogens, parasites, or substances which are dangerous for the endocrine system or other substances which can be dangerous for human health in certain concentrations.
Drinking water must also be free of risk of viral infection: in order to achieve this goal, the evaluative approach, according to the World Health Organization (1993), is the multi-barrier approach (pollution prevention, removal technologies and pathogen inactivation processes), to obtain a 4-log reduction of enteric viruses or 7-log reduction of fecal coliforms.

2.2 Pollution Prevention

Pollution prevention requires the adoption of protection strategies which involve several human activities. Water contamination can be determined in fact in many different ways, coming in general from not correct procedures for industrial and domestic waste and wastewater disposal.
Many cases of groundwater contamination have been found in EU countries, due, for example, to landfill leachate leakage or to waste disposal on the soil without protection. Accidental spills can also occur during waste transportation or during normal industrial activities.
Wastewater treatment must be carried out with proper treatment processes, depending on the recipient body characteristics (quality and quantity) and water usage (for example: potabilization). As far as microbiological contamination is concerned, municipal wastewaters

are of prior importance, together with zootechnical and some industrial wastewaters (e.g. food industry).
Pollution prevention activities must be carried out in several directions, in order to achieve waste and wastewater minimization, recycling, treatment/detoxification and safe disposal (as stated by EU Directives in this field). The increasing use of clean technologies and the adoption of waste and wastewater proper treatment schemes are the expected results.

2.3 Approaches Towards Removal Technologies and Pathogen Inactivation in European States

Removal technologies are useful for abatement of biological contaminants as protozoa, spores of sulphitic-reducing clostridia (highly resistant to disinfectants) and, to a lesser extent, viruses. The processes are chiefly physical treatments, as coagulation-sedimentation and filtration by conventional and advanced technologies. GAC treatment before chlorination is used in Great Britain to remove as much organic material (organic DBP precursors) as possible. The aim is to balance short-term infective health risk and long-term health-risk deriving from disinfection by-products. The involved DBP are the following [4], [8], [9], [10]:

- Trihalomethanes (bromoform, dibromochloromethane, bromodichlmoromethane, chloroform)
- Chlorinated acetic acids (mono-, di- and trichloroacetic acid)
- Trichloroacetaldehyde
- Chloropropanones
- Haloacetonitriles (dichlo- and dibromoacetonitrile, bromochloroacetonitrile, trichloroacetonitrile)
- Cyanogen chloride
- Chloropicrin

Multibarrier treatment approach allows to use a low dosage of disinfectant; but in several EU States, mandatory or common practices require the disinfection before pumping water to the distribution network (post-disinfection), in order to avoid microbiological re-growing in the network and to protect water from potential contamination (coming from system leakage and negative pressure, cross-connection problems, etc.) along the distribution system.
Among the EU member States, chlorination is the dominant drinking water disinfection method. The trend in advanced countries is to abandon chlorine disinfectants, whenever possible, in order to avoid the formation of organic DBP.
In Finland, chlorine was practically banned because of the high content of humus in surface waters, resulting in high concentrations of disinfection organic chlorinated by-products.
On the contrary, in other European States, as Belgium, Spain, Great Britain, Greece, Ireland, Portugal, there is no policy to ban systematically the use of chlorine and other chlorination agents in water treatment practice.
The Netherlands, Belgium and Germany are trying to abandon chlorine-containing disinfectants whenever possible; but in the case of ground water with a high content of both iron and organic matter, oxidation with chlorine has to be applied, to destroy the iron humic complexes and to assist the precipitation of iron hydroxide flocs after aeration.
The main chemical substitute is chlorine dioxide, dominant in the Netherlands but widely used also in Germany, France and Italy [5].
In other EU States, chlorine dioxide is not widely used due to some reasons, included relatively high cost and formation of inorganic DBP like chlorite and chlorate. Recently, there is a shift also toward ozone and UV radiation.
Chloramine is not commonly used as primary disinfectant; in Great Britain, it is used for post-disinfection due to its low tendency to cause taste problems.

In the European States where pollution in raw water sources is minimal, as Norway and Finland, water-treatment processes are rather simple; but some cases of epidemics (due to spills) happened, in connection with the conscious avoidance of chlorine. In some European States, ground water contains detectable concentrations of bromide ion, so preventing the use of ozone if stringent standards for bromate ion must be respected.

2.4 Strategies

There is no standard treatment approach to disinfection: each plant needs to be considered separately, taking into account the local situation and existing treatment processes to be upgraded.
The suitable strategies are the strategy of hygienic prevention, the pipe network strategy and the chemical strategy.
The first requires an accurate protection of water resources (promotion of the formation of protection areas [6]), with the aim to avoid disinfection.
The second consists in the proper maintenance and upgrading of the pipe network, in order to reduce post-chlorination requirement.
The chemical strategy deals with integrated treatment schemes with the following characteristics:
- using physical treatments to improve the removal of Trihalomethanes (THMs) precursors (and also to remove biological contaminants like Giardia cysts, Cryptosporidium, spores of sulphitic-reducing clostridia, etc.);
- possibly, using alternative chemical disinfectants in the pre-treatment step (peracetic acid, ozone if the bromate ion is not a critical parameter, chlorine dioxide, UV)
- introducing biological catalytic processes for ground water,
- removing THMs precursors by GAC filtration and PAC addition.

Some treatment flow-sheets are reported in Figures 1, 2 and 3 [3].
Removal of pre-chlorination, optimization of the removal of organic matter and better control of chlorine levels at the end of the system and in the network seems to be the best way to reduce short-term health risk (infective) and minimize long-term health-risk.
Epidemiological informations provide little reason to abandon chlorine as water disinfectant [7]; but a more sophisticated approach to disinfection, without increasing the risk of waterborne infection disease, is required not only for minimizing long-term health-risk but also because of the consumer pressure against chlorine taste in drinking water.

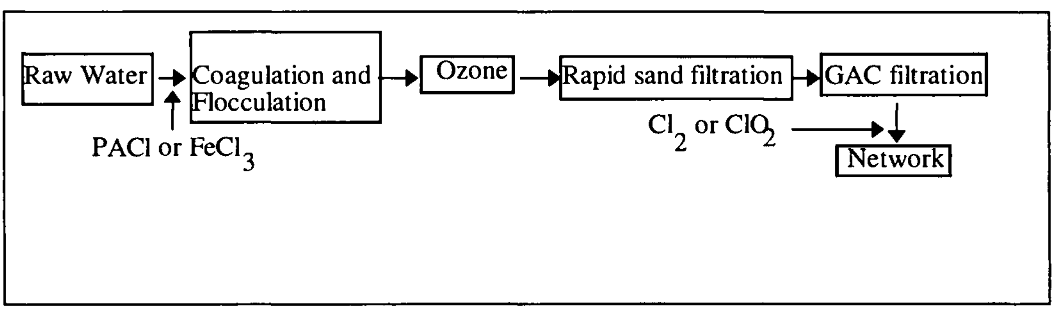

Figure 1: *Conventional Treatment Upgraded with Ozonization and GAC Adsorption*

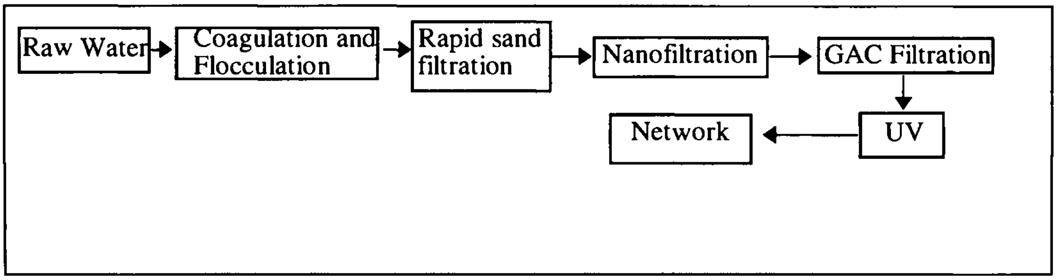

Figure 2: *Advanced Physical Treatment*

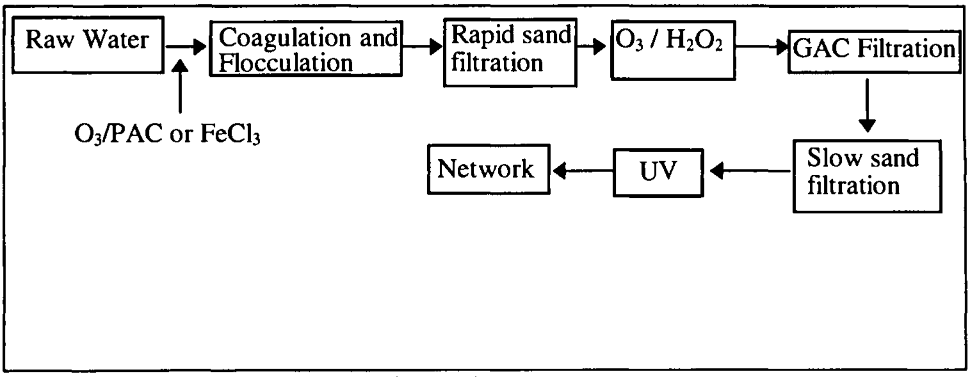

Figure 3: *Advanced Chemical Treatment*

3 Wastewater Disinfection

3.1 Characteristics of Treated Water

Conventional primary and secondary wastewater treatment remove about 99% of the initial microbiological content. This is not enough in general to comply with discharge standards. Indeed, disinfection is not always required by regulations: in Italy, in fact, microbiological standards must be considered only when the wastewater is discharged into a recipient body where, for example, recreative activities are carried out or which is used for water potabilization. In these cases, treated wastewater must comply with the following standards (more restrictive limits can also be applied):
Total coliforms 20,000 MPN/100 mL
Fecal coliforms 12,000 MPN/100 mL
Fecal Streptococci 2,000 MPN/100 mL
More stringent limits must be considered when agricultural soil disposal of wastewater is carried out: 2 or 20 MPN/100 mL for Colibacteria. The first limit deals with soils where vegetables which can be consumed uncooked are cultivated.

3.2 Applicability of Disinfection Treatments

The main differences between disinfection for potabilization and for wastewater discharge are related to the characteristics of the raw water (concerning both the microbiological content and the concentrations of substances influencing disinfection efficiency - like COD and suspended solids - or by-products formation - DBPs precursors) and of the treated water (different standard to be considered for microbiological content, different importance of disinfection by-products and disinfectant residue). For example, suspended solid content is very important: disinfection efficacy is in general reduced due to adsorption - protection of microorganism due to suspended solids. This effect depends on the particle size and nature (organic or inorganic). Anyway it suggests that very high efficiencies can be reached only with the integration of disinfection/inactivation processes with removal treatments (like filtration).

Disinfection systems can be divided in chemical treatments (chlorine and its compounds, ozone, peracetic acid, etc.) and physical systems (UV radiation). Other systems can be employed, without the use of disinfectants: lagoons or other natural systems, membrane technologies.

The main factors which must be analyzed for the choice of right disinfection system are the following: treatment efficiency, plant and operating costs, suitability for the specific situation (simplicity, space requirements, reliability, regulations, etc.), possible negative effects on the treated water (by-products).

The main characteristics of the most important disinfection systems, as far as their applicability and efficiency are concerned, are reported in the following paragraphs.

3.3 Chlorine

Chlorine activity is due to the hypoclorous acid ($HClO$). Nevertheless, also inorganic and organic chloramines are formed due to the presence of ammonia (> 1 mg/L) and organic nitrogen (e.g. proteins) in the wastewater. In particular, organic nitrogen reacts fastly with chlorine producing organic chloramines which have very low disinfection activity [13]. Also inorganic chloramines (which can be hydrolyzed to free chlorine and ammonia, so giving disinfection activity) can be transformed in organic chloramines. The higher disinfection efficiency of a secondary effluent can be reached with a chlorine-ammoniacal nitrogen ratio of 6 to 1 (if pH is approximately 7) [12]. Recent experiences have shown that monochloramines (for pH<8) are less influenced than chlorine by suspended solids concentration.

High concentrations of residual chlorine require dechlorination (with chemical compounds or activated carbon).

Disinfection by-products are formed especially when high concentrations of free chlorine (as $HClO$) are present: this happens when nitrified/denitrified effluents are disinfected and in general when ammonia concentration is lower than 1 mg/L [12].

3.4 Chlorine Dioxide

Chlorine dioxide reacts weakly with nitrogen and organics, reducing the formation of by-products. Anyway, during its oxidation/disinfection activity, chlorites and chlorates are formed. Besides it must be produced "in situ", with higher costs with respect to chlorine. For these reasons, despite its high disinfection efficacy, it is not widely used in wastewater treatment facilities.

3.5 Ozone

Ozone reacts with many organic and inorganic compounds (ozone demand can range between 1 and some tens of mg/L). In particular, it reacts weakly with ammonia, while oxidizes nitrites to nitrates.

The following factors can be considered for ozonation [11]:

- effluent standard: no tertiary treatment is required (for organics and suspended solids removal) when a fecal coliforms concentration of 200MPN/100mL must be reached. Tertiary treatment is required to reach lower concentrations.
- Coliforms initial concentration: it determines the required dosage (higher for higher concentrations), considering also the consumption of ozone for its chemical activity. Dosage

requirement can be reduced by means of a pre-treatment aimed to reduce initial microorganism content.
- Wastewater characteristics: ozone demand depends on wastewater characteristics. If industrial wastewaters are discharged in the sewerage, ozone demand could be higher. Nitrite concentration should be lower than 0.15 mgN/L.

Since ozone must be produced "in situ", costs are generally high in comparison with other systems, so that in general ozonation can be applied in medium-large size facilities.

3.6 UV Radiation

The most important factors affecting UV radiation efficiency are the following:
- wastewater characteristics: some substances can absorb UV light so reducing the actual intensity of the radiation;
- radiation power: it determines, together with wastewater characteristics, the intensity of UV-light reaching the microorganisms;
- exposition time: the amount of UV-light absorbed by microorganism is proportional to the exposition time; the dose (D) of radiation (actual amount of radiation) is given by the product Intensity x time ($D = I \times t$). Generally, very low exposition times are required for UV disinfection: in some cases, only a few seconds can be enough.

Using UV light as disinfection system, an important aspect must be considered: microorganisms can repair damages caused by UV light after treatment (photoriactivation and repair [1]). This requires to use higher UV-doses.

3.7 General Considerations

In general, the following considerations can be drawn, about the examined processes:
- disinfection efficiency depends from wastewater characteristics (COD, suspended solids, nitrogen in various forms, pH, etc.), from the reactivity of the disinfectant with respect to the non-biological component of wastewater and from initial concentration of microorganisms and their form (e.g.: free in water or adsorbed on suspended particles);
- every disinfection system allows to reach 2-3 Log removal efficiency of fecal indicators (this corresponds to the inactivation of free bacteria);
- to achieve higher efficiencies it is necessary to increase in a significant way the disinfectant dosage, because there is not, in these conditions, a linear relationship between dosage and microorganism survival (tailing effect); to reach 4-5 Log abatement efficiencies the removal of suspended solids is required (pre-treatment);
- good mixing between water and disinfectant must be achieved; the reactor should have a plug-flow behavior;
- recently, viruses (enetero virus) and some protozoa (Giardia cysts, Cryptosporidium oocysts) have been considered, instead of fecal indicators, to asses the process suitability; they seem to be in fact mainly involved in some epidemics due to drinking water consumption and swimming.

3.8 Experimental Results

The Authors carried out an experimentation to assess the efficiency and applicability of different disinfection systems [2]. Four systems (peracetic acid, chlorine dioxide, ozone, UV-light) were tested by means of pilot-scale plants fed with the same wastewater (parallel operation). The following main considerations, which are valid for the examined case (in fact many aspects are still under investigation), were drawn:
- every disinfection system allowed to comply with effluent standards (see Paragraph 3.1); in particular, for chemical systems, the following operating conditions were maintained:

peracetic acid: 1 mg/L, Cxt = 20 min mg/L (Cxt = 50-60 min mg/L to achieve 2 Log removal efficiency); chlorine dioxide: 1,5 mg/L, Cxt = 20 min mg/L (Cxt = 30-40 min mg/L to achieve 2 Log removal efficiency); ozone: 3 mg/L, Cxt = 60 min mg/L (Cxt = 110-180 min mg/L to achieve 2 Log removal efficiency). With the UV-light reactor, removal efficiencies higher than 4 Log were always obtained. Chemical treatments required contact times lower than 20 min (about 15 for chlorine dioxide). With UV radiation, 4 to 11 seconds were enough to reach very high efficiencies.

- Disinfection by-products were determined only for ozone and chlorine dioxide: organic solvents were always below 10 μg/L for both ozone and chlorine dioxide; for the latter, chlorite and chlorate ions were detected in concentrations lower than 0.7 and 0.2 mg/L respectively. No significant disinfectant residues were detected for chemical systems. Ichthyotoxicity was always under regulation limits, especially for chlorine dioxide and ozone. Mutagenic activity was also assessed: it was greater with respect to undisinfected wastewater (higher values for chlorine dioxide and ozone) but it never reached significant values.
- Investment costs are higher for ozone and UV-light plants. As far as operating costs are concerned, there are not significant differences among the different systems; nevertheless, UV-light system is the cheaper for medium-large size plants, while, for small plants, ozone and peracetic acid are characterized by the lower costs. Operating costs are higher than investment costs, so, the specific global cost (Lit./m^3 of treated wastewater; Lit. = Italian Lira: 1 US$ ≅ 1,800 Lit.) is approximately the same for the different systems, for large-size plants (15-17 Lit./m^3); for small size plants, the cheaper is peracetic acid system (about 18Lit./m^3), the most expensive are those using ozone and UV-light (26-27 Lit./m^3).
- as far as operating and plant simplicity are concerned, peracetic acid plant is the simplest, ozone plant the most complex; UV-light plants are characterized by operation simplicity but they require specific maintenance for periodic lamp cleaning and substitution.

In the following table, the main advantages and disadvantages of different systems, from the technical point of view are summarized.

Table 1: *Comparison among disinfection systems: technical aspects*

	PAA	ClO_2	O_3	UV
Efficiency	+	+	+	+
By-products	?	+/-	+/-	?
Toxicity on fishes	-	+/-	+	?
Mutagenic activity	+/-	+/-	+/-	+
Plant complexity	+	+/-	-	+/-

+ = positive judgment - = negative judgment? = test was not carried out

Considering also economical aspects, it can be concluded that systems with peracetic acid, chlorine dioxide and UV light can be used for every plant size, even if peracetic acid plant is simpler and cheaper, so that probably it is the most suitable for small size applications. Ozone plants, due to their complexity, are more adequate for large size applications.

Authors Contribution

Carlo Collivignarelli, Giuliano Ziglio and Giorgio Bertanza developed the analysis of wastewater treatments.

Osvaldo Conio and Vincenzo Riganti were involved in the discussion of the issues dealing with drinking water disinfection.

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INTEGRATING CONSERVATION AND WASTEWATER TREATMENT

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Abstract

The continuing growth of the Earth's human population is causing serious problems for both people and wildlife. Among the more important of the problems facing human communities are lack of access to fresh water supplies and inadequate sanitation. For wildlife the increasing pressures caused by expanding human populations are threatening increasing numbers of animal and plant species. At present those responsible for meeting the water supply and wastewater treatment needs of human communities appear unaware of the potentially important role that appropriately designed treatment plants can play in promoting wildlife and plant conservation. The types of modifications that can be made to treatment plants, and how these benefit wildlife are reviewed and the obstacles to their introduction are discussed. It is shown that treatment plants designed to incorporate conservation measures can lead to both direct financial rewards for local communities as well as less tangible benefits.

1 Introduction

The seemingly relentless growth in Earth's human populations is causing problems in many parts of the world. Many of these problems are connected in one way or another with water or wastewater, and the numbers of people affected by water-related problems are staggering. For example, according to Parish [9], at present 1 billion people lack access to fresh water and 1.7 billion lack adequate sanitation. Moreover, if current projections are correct and the human population grows by a further 3 billion in the next 30 years, the situation will worsen considerably. Under such a scenario more than a third of the world's population will be living in severely water-stressed countries by the year 2025 [9].
Another major problem brought about by burgeoning human populations is an intensification of the pressures being placed on natural ecosystems. Severe degradation of many habitats has already occurred and in many parts of the world the pace of habitat degradation is still accelerating. This has had serious consequences for many wildlife and plant communities. The 1996 Red List of Threatened Animals reportedly shows that the percentage of animal

species at risk of extinction is much higher than formerly believed [12]. It estimates that 25% of mammal species, together with 11% of birds, 20% of reptiles, 25% of amphibians and 34% of fish are presently under threat of extinction.

The numbers of threatened species are particularly high in a number of heavily populated, less developed countries, countries which in many cases are also experiencing serious problems with water supplies or treatment of wastewater. For example, in the Philippines 15% of the bird species and 32% of mammal species are considered threatened. For Indonesia the corresponding figures were 7% and 29%, and these are likely to have worsened since the catastrophic forest fires of the past two years. Severe declines in the numbers of many larger bird species have also been recorded in Thailand, with several species that were formerly common in the vicinity of Bangkok now being extinct in Thailand or confined to a few remote rural areas [7]. An even more striking example of the pressures being experienced by wildlife, especially species with specific water-related habitat requirements, is the Spot-billed Pelican *Pelecanus philippensis*. The numbers of this bird, once widely distributed over south, south-east and north-east Asia, have fallen from around 1 million in 1900 to less than 12000 today [11].

As far as the first of the problem areas identified above is concerned, concerted attempts are currently being made to alleviate water-related problems in many of the world's poorer countries. To provide more reliable drinking water supplies, much effort has gone into well construction, development of improved water distribution systems and water purification. To deal with problems of inadequate sanitation, facilities for sewage and wastewater treatment are being extended to more and more communities. Despite this, it has been estimated that improvements are only just keeping pace with the expansion in populations, *i.e.* the number of people lacking access to adequate water supplies and proper sanitation is not reducing. Massive investment is needed if real progress is to be made in addressing these issues; according to Parish [9], this is of the order of 600 billion dollars over the next 10 years.

Engineering developments on the scale envisaged above are bound to exert still greater pressures on natural environments than they are currently experiencing. Particular pressures will be placed on aquatic ecosystems and those associated with streams, rivers, lakes and other wetlands that serve as water sources or receive wastewater discharges. People concerned about these environments are only too aware of present and impending pressures on water-dependent ecosystems and much effort is currently going into the protection of water-dependent natural habitats and the conservation of endangered species and natural communities associated with such habitats.

Because of their common interest in water resources and their protection and proper use, it might be expected that the engineers and planners responsible for improving water supplies and sanitation would be in close touch with conservation bodies. After all, it would seem eminently sensible for the two groups to work together to minimise the damage to wetlands and other water-related habitats that people's ever-growing demand for water makes inevitable. Sadly, such cooperation is almost totally lacking at present and both groups appear to go about their activities in almost complete isolation from one another.

On a positive note, there is within the Water Industry a strong move towards a more holistic approach when addressing water-related problems. This is evident from publications like Stockholm Water Front, in which the findings of workshops conducted at the prestigious annual Stockholm Water Symposia are summarised. Further evidence of moves towards a more holistic approach is provided by Parish [9]. He discusses the results of the first World Water Forum, held in Marrakech, Morocco in March 1997, and the *Marrakech Declaration* it gave rise to. He described the progress made at this meeting as "one small step towards ensuring that the protection and management of wetland ecosystems is integrated into the management and sustainable use of all land and water resources".

Despite these encouraging moves, we still seem to be far from a situation where there is regular contact and dialogue between engineers building water supply or wastewater treatment plants and bodies concerned about conserving natural systems and preserving endangered or threatened species. This is unfortunate as there appears to be considerable scope for integrating measures to promote wildlife conservation into, in particular, wastewater treatment plant design. It is the purpose of this paper to examine the prospects for doing this and the potential benefits that can result.

2 Wastewater Treatment and Conservation Issues

It is well-known, especially to birdwatchers and other natural history enthusiasts, that wastewater treatment plants can be havens for a variety of animal, bird and plant species. This is particularly the case where land-intensive processes such as ponds, lagoons or sludge drying beds form part of the treatment system.

A good example of a treatment plant of major conservation importance is the Western Treatment Plant (WTP), which lies to the south-west of Melbourne, on the coast of southern Australia. This 10850 ha property processes around 450 ML each day of a mix of domestic and industrial wastewaters from the western and northern regions of Melbourne. It treats the wastewaters it receives by a combination of grass filtration, land filtration and lagoon systems. In both the first two techniques the irrigation of the land with nutrient-rich wastewaters results in the development of a heavy grass cover. This is removed after an appropriate interval by allowing cattle and sheep to graze on it, but for lengthy periods during the year the land is marshy or unused. The lagoon systems are extensive, occupying a total of around 1670 hectares. This combination of land and water habitats, together with the trees planted as windbreaks or for other purposes, is very attractive to wildlife and especially birdlife. It is currently a declared sanctuary for wildlife, an important refuge for waterfowl and a world renowned birdwatching site.

A further environmental benefit has resulted from the proximity of the WTP to Port Phillip, the bay around which the city of Melbourne has developed. The treated effluents from the WTP discharge through 4 licensed outlets into the western side of this bay. These effluents still carry a significant nutrient load and have stimulated the development of a rich invertebrate community in the benthic zone underlying the shallow waters immediately offshore. This provides an important food source for migratory wading birds, many of whose original feeding grounds have been destroyed or degraded by the intensive development that has occurred in and around Melbourne over the past 150 years.

Of course, very few wastewater treatment plants are as large as the Western Treatment Plant and consequently the diversity of habitats at the WTP is rarely encountered elsewhere. It is also true that in some areas there is a trend towards using more compact and capital-intensive processes in place of the land-intensive processes in use at the WTP. Nevertheless, these smaller, more compact plants can also have significant conservation importance if appropriately managed.

2.1 Conservation Benefits of Treatment Plants

Many wastewaters treated in land-intensive plants consist primarily of domestic sewage or have a similar composition. Such wastewaters contain substantial amounts of readily degradable organic material together with significant quantities of nutrients such as nitrogen and phosphorus (a so-called "moderate" sewage contains: 250 mg/l BOD_5, 30 mg/l ammonia nitrogen and 16 mg/l total phosphorus [5]). These inputs stimulate the already high primary productivity of wetland systems and much of this primary productivity is used in the secondary production of animal species [6]. A diverse mix of animal and plant species results.

For treatment plants with suitable layouts and features, a number of other benefits are apparent. A major benefit is often safety. Islands or sandbanks can provide relatively

predator-free roosting, loafing or breeding places for waterbirds and various reptiles and amphibians. Dead trees standing in water or on islands can provide safe nesting areas for both solitary and colonially nesting bird species. In addition, the restrictions usually placed on access by the public to wastewater treatment sites affords the animal and plant species present an enhanced level of protection against activities such as unauthorised hunting and harvesting.
A good example of a plant exhibiting some of the above features is the Western Treatment Plant referred to earlier. One of the older lagoons at this plant is Lake Borrie, a relatively shallow body of water from which emerge the remains of a large number of dead trees. These provide nesting sites for a large colony of Pied Cormorants *Phalacrocorax varius*, the only sizeable breeding colony of these birds near Melbourne. Further south in the WTP, an isolated sandy coastal spit is an important roosting site for waders and terns. And the entire plant, being a sanctuary with limited human access, serves as an important waterfowl refuge and breeding area.
Another example that illustrates the potential importance of protected wastewater treatment areas is the waste treatment facility operated by the CETREL S.A. Environmental Protection Company in Bahia State, Brazil. This company treats and disposes of a wide range of wastes from the nearby Camaçari petrochemical complex [3]. The final treatment step for wastewaters from the waste treatment complex takes place in a series of marshy areas and ponds. In a move quite remarkable for a waste treatment company, especially one from the Third World, CETREL S.A. has taken the step of appointing a resident treatment plant ecologist, and under his guidance the entire plant area has become a refuge for a wide variety of species. Waterbirds have benefited particularly as they are heavily persecuted in that area of Brazil; in fact the ecologist informed me that ducks like the Bahama Pintail *Anas bahamensis*, a resident at the treatment plant, were only vagrants elsewhere in the area.
The above example demonstrates the important role that suitably designed, well-protected wastewater treatment plant systems can play in conserving regionally threatened wildlife and even plant species. They also have potential importance as protected staging areas for migratory birds and waders in particular. In recent years it has become apparent that the major threats to a number of migratory birds occur as they move from their breeding grounds to their wintering grounds. In the case of a number of the waders that breed in Asia and winter in Australia, hunting and trapping along the flyway is taking an enormous toll, and in the case of species such as the Oriental Pratincole *Glareola maldivarus*, the harvest of migrating birds appears to have reached an unsustainable level. As pressures on natural wetlands and staging posts along the flyway intensify, the potential for protected wastewater treatment areas to assume a major conservation role can only increase.
The above-mentioned benefits relate primarily to birdlife. However, the potential for treatment plants to play a role in protecting natural plant communities should not be underrated, especially where access by domestic stock is restricted. There seems no reason why, if carefully managed, they should not do as many cemeteries in the developed world have been found to do, *i.e.* to act as refuges for locally threatened or endangered plant species. They could also conceivably play a role in tree conservation in areas where there are fuelwood shortages and natural woodland or forest communities are threatened by illegal or poorly regulated harvesting.

3 Integrating Conservation Values into Plant Design Procedures

3.1 Obstacles to Integration

At present the kinds of benefits described above generally arise only as an incidental consequence of a treatment plant's establishment. There are occasional exceptions to this. For example, a scheme established in Riverside County, California to reclaim water from treated sewage had environmental enhancement and wildlife-habitat creation as two of its objectives [1]. In addition, Kadlec and Knight [6] suggest that wetland and impoundment design for wildlife enhancement is relatively well known. For the most part, however, the primary objective of wastewater treatment plants is seen as purification of the incoming wastewaters, and conservation benefits are regarded as, at best, secondary or ancillary.

Why this should be the case is a question that needs addressing. One possible explanation is that the engineers responsible for development of water supply and wastewater treatment systems lack both environmental awareness and an appreciation of broader community and regional needs. Certainly, engineering curricula of the past tended to concentrate heavily on technical subjects, and intending engineers were taught to evaluate the suitability of their designs solely on the basis of technical soundness and economic viability. This is changing but it is still rare to find an experienced engineer whose university course provided in-depth coverage of topics such as principles of ecology or biological conservation. Even today, graduating engineers still appear to have both a limited understanding of concepts such as biodiversity, conservation and ecosystems and also a tendency to treat them as of only minor importance. Particularly in this world of economic rationalism, it seems that engineers continue to view their task as one of successfully completing the design and construction of a project - on time, within budget, and with due regard only to those environmental and safety aspects specified in legislation.

Of course it is not only engineers who lack insights into environment related matters. Engineers in the water field have traditionally worked under the direction of local government and lack of vision on the part of councillors and other municipal officials is probably just as much to blame for the failure to consider conservation issues when designing new water supply or wastewater treatment infrastructure.

Other groups must also assume a share of the blame. Economists and others on the financial side of companies designing and constructing treatment plants probably have, on the whole, an even poorer appreciation of ecosystem complexities than engineers and officials of local government. What is more, they frequently gain only a superficial picture of conditions at and around plant construction sites, and hence are even worse placed than their engineering staff when it comes to understanding local needs and environmental pressures. Perhaps most importantly, their predominant concern tends to be with money matters and so they tend to be unreceptive to the idea of design modifications that do not translate into a readily quantifiable monetary return on investment.

A last group that must take some responsibility for the current unsatisfactory state of affairs is the radical fringe of the environmental movement. There is no doubt that their uncompromising and sometimes irrational opposition to many new developments has greatly hindered contact and dialogue between conservationists and those charged with the responsibility of improving the living standards of poorly served or disadvantaged communities.

Even where the obstacles discussed above have been overcome and agreement has been reached to consider conservation-promoting plant modifications at the design stage, most engineers face yet another serious problem. This very real problem, in part associated with most engineers' lack of training in ecology and the dynamics of natural systems, is ignorance of how plant designs should be altered to enhance their value to wildlife. There is as yet no established body of reference material within the engineering literature on how treatment plant designs can profitably be modified to promote wildlife or plant life conservation. This problem is aggravated by the fact that no two situations are similar and so only general principles are readily transportable from one region to another. Some of these are discussed below.

3.2 Potentially Beneficial Treatment Plant Modifications

As indicated above, there is little information in the traditional engineering literature to help the conservation-minded engineer, and what little there is relates predominantly to constructed wetlands. Nevertheless, this material can be quite useful. A key feature that emerges from such sources is the desirability of providing a diversity of habitats [6]. Suggested design and operating strategies include [6]:

- Planning for a diversity of plant species and growth forms, as well as varying plant and seed maturity dates. This helps to create a diversity of niches for wildlife.
- Arranging for occasional fluctuations in water levels, since intermittently flooded areas are attractive to a greater range of species than perennial waters.
- Including living and dead trees in both the wetland and surrounding areas; these are valuable as nesting and perching sites as well as providing microhabitats for smaller creatures.
- Creating a range of small islands, some vegetated to provide concealment and protection for ground nesting birds like ducks or rails while others should be kept bare to provide roosting and loafing sites, and possibly even safe breeding sites for plovers or terns.
- Ensuring there are both areas of moderately deep open water and also smaller, more enclosed ponds with well-vegetated fringes.

Outside of the engineering literature, much useful information is available in a range of both scientific and popular natural history publications and reports. Until recently this tended to take the form of more anecdotal information that provided insights into the kinds of habitats that were attractive to particular species. Typical of such articles are papers about the Mai Po Marshes Nature Reserve in Hong Kong [2][10]. This sanctuary is not a wastewater treatment plant but an area managed by the World Wildlife Fund specifically for conservation purposes. However, it contains many of the features that a conservation-promoting treatment plant might include, most of which are the same as those discussed above.

Whilst this information is valuable, the fact that it is fragmentary and dispersed through a range of fairly specialised publications with an often restricted readership has hindered access to it by those unfamiliar with the field of natural history publications. Fortunately, this is starting to change and a recent publication by the Wildfowl and Wetlands Trust [8] provides a most useful compilation of material relevant to industry-serving wetlands.

4 Benefits

It would be naïve to assume that integration of conservation-promoting features into wastewater treatment plant design will occur if there are no perceptible benefits to local communities and authorities. One of the lessons that conservation bodies have learned the hard way is that reserves have little chance of receiving support unless there are clear advantages to those who live nearby.

Of particular importance, especially in poorer regions of the world, are direct financial benefits. Not every plant will be in a position to deliver these but for those that support large numbers of birds or provide opportunities to view exotic or rare species, there is the potential to attract birdwatchers and other "ecotourists". The chances of doing this are enhanced if the plant is equipped with hides and other facilities for viewing wildlife without disturbing them. At first sight, this might appear to be at best a minor revenue earner. However, a report from the American Birding Association contradicts this [4]. This report states that recent research shows that birdwatchers in the United States spent 14.4 billion dollars on that activity in 1991, much of it in the communities adjacent to key birdwatching sites (especially if those communities provide appropriate accommodation and eating facilities). The report goes on to provide concrete examples of this. For instance, the 30000 visitors each year to Ramsey

Canyon in Arizona are estimated to inject $5 million into the local economy while the 6000 people who visit High Island, Texas, during the annual Spring bird migration spend around $2.5 million locally [4].

Other potential financial benefits are usually less obvious though nonetheless real. For example, where the treatment plant serves as an important breeding ground for traditionally hunted species, this benefits those formal and informal sectors of the local economy that are associated with hunting. Whilst this is as yet unusual as far as treatment plants are concerned, wetland management for wildlife production is well established in countries such as the United States [6]. There may also be opportunities for controlled grazing of some areas by livestock. In general this would be considered undesirable but experience at the world renowned wetlands at Bharatpur in India suggests that, when properly managed, this may assist in the maintenance of habitat types favourable to particular animal or bird species.

There are also a number of less tangible community benefits associated with the inclusion of measures that promote conservation into treatment plant designs. If thoughtfully done such measures can provide the local community with additional recreational opportunities. They can also be a valuable educational tool, helping to create an enhanced awareness of environmental concerns among local residents and particularly children.

5 Conclusions

Those concerned with installing water related infrastructure at present pay little attention to ways of designing water supply and wastewater treatment systems that promote environmental conservation. The reasons why this is the case are both historical and also related to the traditional structures that exist within our society. Nevertheless, as pressures on wildlife and plant communities intensify, the useful role that appropriately constructed wastewater treatment plants in particular can play in the area of environmental conservation is becoming increasingly apparent. It is also clear that designing such plants to increase their conservation potential can have both direct and intangible benefits to local communities as well as reducing threats to endangered plants and wildlife.

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PRESENT TRENDS IN THE REDUCTION OF ACCEPTABILITY LIMITS AT THE DISCHARGE OF WASTEWATER AND TECHNOLOGICAL IMPLICATIONS

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Abstract

During the last years, several new laws and regulations imposing quality limits to discharges of civil and industrial wastewater can be observed in Italy and EU, with relevant implications for wastewater treatment plants. This is a recent, significant evolution from the 1976 law that disciplined the quality of discharge waters for the first time in Italy. At present, such rules are promulgated by the EU, the State and the Regions, that took place in defining laws concerning environment control and protection. The present trend is to plan objective quality characteristics of the receiving waters with reference to their planned uses, and to consequently define differentiated acceptability limits for the discharges. This trend can be observed in the EU directives so as in the most recent National and Regional laws.
Moreover, a new discipline of the territory government and the water-cycle control introduced new characters - the River Basin Authorities and the Optimal Territorial Precincts - which will play important roles in the future water quality management and control.
The rules already promulgated, particularly, by the most advanced Regions in Italy, like the Lombardy, are very strict and impose severe criteria in designing new treatment plants and upgrading the present ones, with remarkable cost implications. This trend will probably be generalised in the next years, and also more strict limits must be expected for the future.
In this paper an examination of these implications is carried out, with considerations to the foreseeable evolution of wastewater quality discipline.

1 1 Introduction

At present in Italy, as in almost all other EU countries, the discipline of the treatment and discharge of wastewater is in evolution, with an evident trend to reach more severe requisites for acceptability limits and discharge conditions into surface waters.
There is also a tendency to assign quality limits for the surface waters themselves (rivers and lakes) defined with respect to their planned uses, rather then acceptability limits for single

discharges, attributing to specific Authorities the responsibility to make such limits be respected, with reference to their uses, and taking care that the entire water cycle be under the responsible of the same authority, avoiding possible competence conflicts. The only exception to this trend is the 91/271 EEC directive that defines precise water quality limits fixed for the single sewer discharges.
This trend implicates the need of new river-basin strategies to correlate the quality limits fixed for the receiving waters with the treatment plants of the single discharges, with new needs of planning methods and integrated forecast models able to estimate the possible improvements of surface water quality consequent to the upgrading of existing plants, the building of new ones or the possible non structural discipline of diffuse pollution sources.
With specific concerns to the wastewater treatment plants (WWTPs), it is important to understand the connections between the discharge quality limits and the treatment phases necessary to reach and maintain them with continuity and reliability.
A cost estimation of such improvement, connected with the consequent benefits for the receiving waters, is also an important tool for the assessment of water quality control strategies to adopt at basin levels. In this article the possible connection between technological aspects of WWTPs and quality limits at the discharges is evaluated, while the corresponding cost implications will be evaluated in a future work.

2 Present Discharge-Water Discipline for Public Sewers in Italy and EU and Future Trends

In Italy the discipline of wastewater quality is constituted by the Law n. 319 of 1976, with the amendments of the L. 650 of 1979, that defined strict and constant quality limits for industrial wastewater discharging into the environment, and local laws for the discipline of public sewer and civil wastewater, promulgated by the twenty Italian Regions. Particularly, the authority to discipline the discharge of public wastewater into the environment was delegated to the Regions by the same 319/'76 law, which stated that the Regions had to define the so called «Regional Water Reclamation Plans» fixing future objectives for the quality of Regional surface waters, and acceptability limits, differentiated for each single public wastewater discharge, defined to attain such objectives.
Several surface water quality prescriptions connected with the planned uses were defined by some EEC directives, all subsequently fulfilled by the Italian Government and used as a reference by the Regions in the definition of their «Regional Water Reclamation Plans»:

- Directive 75/440 concerning the quality of surface water intended for the abstraction of drinking water;
- Directive 80/778 relating to the quality of water intended for human consumption;
- Directive 76/160 concerning the quality of bathing water;
- Directive 78/659 and 79/923 concerning the quality of fish and shellfish waters;
- Directive 76/464 on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community.

The EU also promulgated a directive (91/271/EEC, recently emended with minor changes by the directive 98/15/EEC) concerning the collection, treatment and disposal of urban wastewater and the treatment and disposal of wastewater originated by some industrial sectors, with the purpose to protect the environment from the negative effects of such discharges. This directive represents the only exception to the trend to define quality limits for the receiving waters rather then for the single discharges, with the sense to represent a minimum quality level to be eventually overcome by other specific prescriptions deriving from the planned uses of the receiving waters. Because this directive was planned to be inserted in a more general legal provision concerning the entire water-cycle discipline, it was

not fulfilled by Italy [1]. Successively this discipline was promulgated (Law n. 36, 1994), but the directive n. 91/271 EEC wasn't still fulfilled at present.
The main EU actions expected for the near future are as follows [2]:

- A proposal for a directive on the ecological quality of water is under examination of the EU [3], with the specific objective (Article 1) to control pollution from point and diffuse sources, as well as other anthropogenic factors affecting water quality, so as to «maintain and improve the ecological quality of Community surface waters with the ultimate aim of achieving good ecological quality». «Ecological water quality» is defined (Article 2) as «an overall expression of the structure and function of the biological community taking into account natural physiographic, geographical and climatic factors as well as physical and chemical conditions, including those resulting from human activities. The aesthetics of the area should also be taken into account». A list of relevant elements (e.g. dissolved oxygen, diversity of animal population, etc.) determining ecological quality are given in Annex I. «Good ecological quality» is defined as a condition sufficient for aquatic ecosystems to be self-sustaining (relevant elements given in Annex II), while waters of «high ecological quality» are defined as those which are not «significantly influenced by human activities». Rules for «Best Environmental Practice» and «Best Available Technology» are given in Annexes III and IV respectively.
- The EU Commission is expected to come up with a ground water action plan (to eventually develop into a directive), that would cover four areas of action: programmes for integrated management of ground water resources; establishment of authorisation systems and general rules for abstraction of fresh water; establishment of authorisation systems and general rules for point sources pollution, establishment of codes of good practice and other measures for diffuse sources of pollution. The purpose of the action plan will be to promote the introduction of integrated programmes and licensing at national level in order to support sustainable ground water use and «good» agricultural practices. Action will be based on the subsidiarity principle, providing the Member States with flexibility on the measures to be taken.
- The EU Commission intends to draw together much of the quality objective related legislation, including the above mentioned proposal for the ecological quality of waters, into a Framework Directive on water resources, in which more effective Community controls will be taken into account, particularly for the protection of the natural ecological state, the functioning of the aquatic environment and the management of water quantity issues. The main reason of this is the need for greater integration in the implementation of water legislation between: water quantity and quality issues; surface water and groundwater management; water use and environmental protection; control of pollution through emission control and quality objectives; water policy and other policies. The Framework Directive will probably require integrated water management plans, containing an assessment of the overall situation in the water body, its environmental quality, its resource potential and the environmental pressures impacting on it so as an establishment of the specific objectives of water policy and a programme of measures designed to achieve those objectives within a specified timetable. These integrated water management plans will probably have to be established on a river basin basis, especially for dealing with transfrontier river basins.

3 Role of the State , the Regions and the Other Authorities - Environmental Planning Strategies

The integrated water management planning stated by the above mentioned proposal of EU Framework Directive finds similar interpretations in two recent, important Italian Laws: the

Law n. 183 of 1989 concerning the organisation of the soil protection service and the Law n. 36 of 1994 about the discipline of the water cycle management.

The Law 183/1989 instituted the «River basin Authorities», responsible of the soil protection, the water reclamation and all the connected environmental aspects by drawing up, at a river-basin level, the so called «River Basin Plans» and controlling its put into practice.

The Law 36/1994 revolutionised the Italian organisation of the water-cycle management stating that the Regions must define the so called «Optimal Territorial Precincts» as the best sized parts of territory in which to unitary manage the whole water cycle, from the collection of the fresh water to the disposal of the wastewater. The Local Authorities of every Precinct must co-operate to assign the management of the integrated water service to one or more Companies, and to control that it is done with efficiency, effectiveness and economy.

By means of this normative construction, the water quality planning and control is made up at three levels:

- at a Precinct level, by the Company responsible of the water cycle management under control of the Local Authorities of the Precinct;
- at a Regional level, by means of the «Regional Water Reclamation Plans» instituted by the Law 319/1976;
- at a river-basin level, by means of the «River Basin Plans» drew up and put into practise by the River Basin Authorities.

Since the Precinct planning seems to have a strictly operative function and the Regional Water Reclamation Planning tends to assume a transitory function towards the complete effectiveness of the River Basin Planning, this latter will probably assume the fundamental role in the water quality planning, even if the Regional Water Reclamation Plans will maintain their important disciplining role at a regional level.

All this complex Italian legislative mechanism is presently formed by a series of laws promulgated in different times and not completely coherent each other. To harmonise them, a draft of a «unified text on water protection from pollution» is actually under examination by the Italian Ministry of the Environment, that is expected to finally fulfil the 91/271/EEC directive on the wastewater pollution treatment.

As the Regional Water Reclamation Plans were instituted in 1976 with a more precise definition in 1979, today several Regional planning experiences are available, even if their applications are, in most cases, recent and not completed because of the very delays in their application. For this reason, the objectives of the planning activities that, stating to the istitutive laws, would have to be reached in 1992, in most cases are not still reached at present.

Let's consider, for instance, the case of the Lombardy, probably the most advanced Region in Italy, which presents a serious degradation of the surface water and groundwater quality. The Lombardy Water Reclamation Plan was made active for the first time in 1985, with a partial definition that included the WWTP and interurban main sewer definitions, but not the urban sewer definitions. In this Plan, a quality classification of the surface waters was carried out based on four quality classes named (from best to worse) A - B - C - D. This definition was made by means of a multiple-uses classification based on the EU directives mentioned in chap. 2 and some other international rules on the quality levels for several other uses of the water (irrigation, natural environment conservation, industrial uses) [4].

The completion and first revision of this plan is presently in phase of adoption by the Regional Council. A posterior verification of the quality of Lombardy's surface waters shows that the mean quality level is still bad, after many year from the adoption of the Law 319/1976 and few years from the adoption of the first edition of the Regional Water Reclamation Plan [5]. In fact, presently most of the natural water courses in Lombardy don't reach the quality limits of the worse quality class of the Water Reclamation Plan, the D class. The reasons are probably three [5]: the application of the Water Reclamation Plan goes on very slowly; there are still many industrial discharges that don't respect the limits of the table A of the Law 319/1976 and, probably, this limits are not adequate in some situations.

4 Structural and Non-Structural Provisions. Extending the Sewer Systems or Refining the Present Treatments?

The newest experience in the water quality planning is the River Basin Planning, assigned, together with many other planning activities concerning the soil and water use and management, to the River Basin Authorities instituted by the Law 183/1989. Even if the normative function of such plans isn't still clear, and the very recent institution of the River Basin Authorities needs a transition period before their complete effectiveness, this planning activity will probably be the most important and significant because of the completeness of the approach, by the geographical and competence points of view.
Specifically speaking of the surface water quality management, the River Basin Plans have to assess the present water quality situation, to fix some precise objectives and to define the structural and non-structural provisions necessary to reach such proposed objectives.
The term «structural provisions» defines the buildings and structures necessary to improve the water quality level, specifically the sewers and the Waste Water Treatment Plants, while the term «non-structural provisions» defines the normative limitations to be imposed to the productive and civil use of territory.
The most important River Basin Authorities, the so called «National Relevance Basin Authorities» are presently preparing their Basin Plans, but some preliminary consideration on this planning activity is already possible.
For instance, let's consider the Basin Plan of the Tevere river, the second Italian river, which flows through Rome. This plan is presently under construction, but some preliminary data on the water quality planning activity are already available in the literature [6].
The water quality aspects of the Tevere basin plan were tackled by means of the following phases of activity:

- classification of the present water quality conditions by means of a quality scale based on the EU directives on the uses of water and a global water quality index;
- building of a global balance model of four main pollutants (BOD, COD, N, P) and calibration on the present water quality conditions;
- definition of differentiated plan objectives based, primarily, on the water quality index;
- simulation of several future scenarios based on different, homogeneous structural and non-structural provisions;
- choice of the best future scenario by means of a costs - benefits comparison.

While the last, decisional, phase was not already completed, some considerations can be made on this approach and on the first preliminary results of the mathematical simulations carried out to verify the effects of various possible future scenarios:

- the costs-benefits comparison is a less pragmatic approach, making possible a better modulation of the structural and non-structural actions to undertake in the near future;
- the present water quality conditions are bad, mainly in the most populated areas, and it is possible a significant quality improvement with cost effective provisions, but the continuos respect of the water quality conditions defined by the EU directives on the various uses of water cannot be always guaranteed only with acceptability limits at the urban and industrial discharges similar to those defined by the law 319/1976 or the 91/271 EEC directive;
- a fundamental role in the nutrients pollution (nitrogen and phosphorous) is played by the agricultural use of the soil; so some kind of non-structural provision intended to decrease the nutrient diffuse pollution from the agriculture is determinant;
- as a relevant part of the populations is still not connected to wastewater treatment plants, the most cost-effective provision seems to be the expansion of sewer systems and

treatment plants, more than the refining of existing treatments (figure 1). The refining of present treatments can be justified only in the areas of very high dwelling density with large treatment plants - practically only the urban area of Rome;

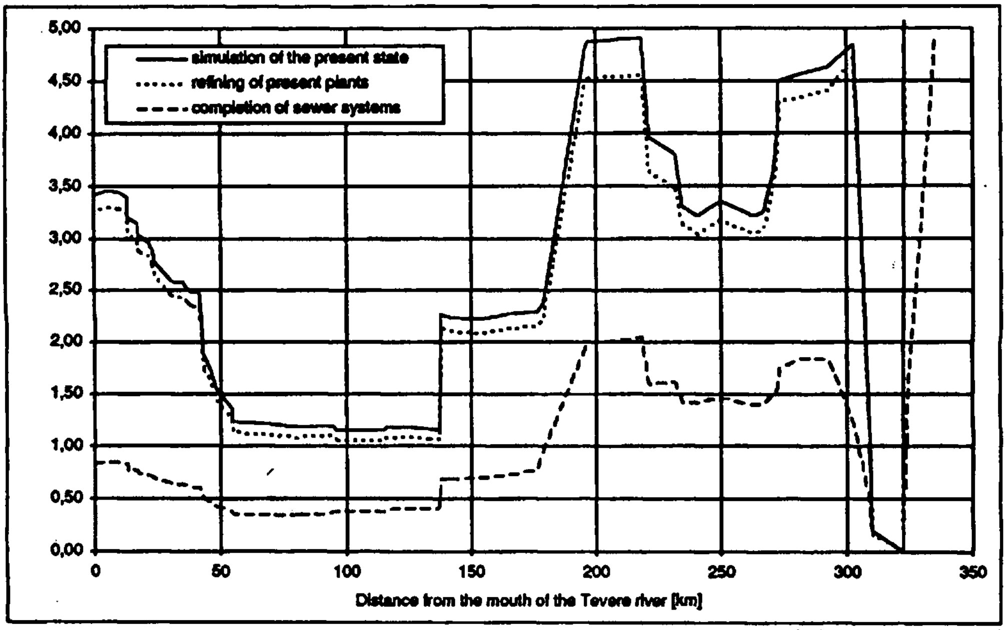

Figure 1: *Mean Forecast BOD Concentrations Along the Main Branch of the Tevere River in Cases of Maximum Possible Completion of the Sewer Systems vs. Maximum Possible Refining of Existing Treatment Plants (pollutant-balance simulation with modal flows). Comparison with the Simulated Present Situation (from [6])*

- the regional water reclamation planning can't influence the agricultural and industrial discharges, but only the civil pollution effects, while the river basin planning doesn't have this limitation, even if the impositive power of the Basin Authorities is, at present, not so clear. The first scenario simulations showed in the Tevere basin a very relevant impact of the agricultural diffuse pollution for the nutrients and of the civil not treated discharges for the organic pollution. The effects of treated civil and industrial discharges seem to be less significant, making useful a further reduction only in a subsequent phase of intervention. So it is very important that the Basin Authority could have the power to impose non structural limitations to all the kinds of productive and civil uses of the territory.

5 Urban Wastewater Treatment Plants: Process Schemes Mainly in Use in Italy

Most of the civil wastewater treatment plants presently working in Italy are designed to satisfy the acceptability limits fixed by the table A of the law 319/1976. This is because almost all the Regions drew inspiration from that law in the definition of their original Regional Laws on the civil water pollution control. The law 319/1976 has relatively large limits for organic pollution (BOD $\leq$ 40 mg/l; COD $\leq$ 160 mg/l) and nutrients pollution (N-$NH_4^+ \leq$ 15 mg/l; N-$NO_3^- \leq$ 20 mg/l; N-$NO_2^- \leq$ 0.6 mg/l, $P_{tot} \leq$ 10 mg/l), with a much more strict limit for the nutrients in case of discharge into 10 km from lakes ($N_{tot} \leq$ 10 mg/l, $P_{tot} \leq$ 0,5 mg/l). The limit for suspended solids is fixed in 80 mg/l, while for the bacterial presence a limit is fixed only in cases of specific hygienic requirements.

To satisfy these limits, in most cases the plants have an activated sludge secondary phase with oxidation designed to remove only the carbonaceous BOD substrate. By this way the BOD concentration in the effluent can be much less then the limit of 40 mg/l of the Law 319/1976. Consequently, the limit of 25 mg/l prescribed by the 91/271 EEC directive is not a significant restriction, since this result can be reached with the same type of treatments. Possible difficulties to obtain such concentration are usually due to specific problems of the influent, with presence of inhibitors of the bacteria activity or very high variability of the biodegradable substrate presence. Problems of this nature must be solved by a better control of the sewer system.

The ordinary limits for Nitrogen can often be satisfied with a simple nitrification process which converts part of the ammonia nitrogen into nitrate, since the partial reduction of total nitrogen due to the bacteria consumption is often sufficient to reach the values of 15 and 20 mg/l prescribed for ammonia and nitrate nitrogen. There are also several cases of plants that don't have any specific nitrogen removal phase and don't respect the limits prescribed by the 319/1976 law, thanks to larger limits fixed by the regional laws.

Nevertheless, the adoption of an at least partial denitrification always coupled with the nitrification phase is surely advisable, for two kinds of reasons:

- the anoxic denitrification allows a partial BOD removal at expenses of the nitrates produced by the nitrification, diminishing the expenses for the oxygen supply;
- the diminished presence of nitrates in the biomass makes less probable the formation of filamentous bacteria which can get worse the sedimentability of the sludge, and limits the possible denitrification in the final sedimentation tank which can rise the sludge degrading the final effluent characteristics and making the process less stable.

The plants discharging into 10 km from lakes usually have a secondary denitro-nitro activated sludge phase that controls the total nitrogen contents with the complementary effect to significantly reduce the BOD concentration under the prescribed value of 40 mg/l.

The limit for the suspended solids is usually satisfied without tertiary refining phases even for the largest plants, but an insufficient design of the biological reactors and of the final sedimentation tanks can often be responsible of organic or hydraulic overcharges especially in point conditions or, for unitary sewers, during the rainy days.

Such undersizing is no more possible in presence of specific nutrient removal treatments, which require much more prudential conditions in the biological secondary phase.

Specific phosphorous removal phases were recently added to several plants especially when discharging in water receipts at risk of eutrophication. The most diffused technique is the simultaneous precipitation by chemicals dosing, which allows minimum phosphorous concentrations at the discharge of about 1 mg/l. The large diffusion is due to the very low construction costs, which are practically connected with the sole oversizing of the sludge treatment phases required by the increment of the sludge production.

On the other hand, the phosphorous removal by simultaneous precipitation involves relevant running expenses connected with the use of chemicals and the incremented sludge production. As a valid alternative, various biological phosphorous removal processes are used with increasing frequency. These processes are based on a sequence of anaerobic, anoxic and aerobic phases that allows an incremented phosphorous accumulation in the body of the bacteria, which are then removed with the excess sludge. A similar technique can also be done as a side-stream process along the secondary sludge recycle line.

The biological phosphorous removal usually allows phosphorous concentrations in the effluent of about $1 \div 1{,}5$ mg/l, which is not sufficient to guarantee the limit of 0,5 mg/l requested for the discharge into lakes by the 319/1976 law or the limit of 1 mg/l requested by the 91/271/EEC Directive for plants of more then 100 000 p.e. in sensitive areas. Nevertheless, it can be easily completed with a post-precipitation process which, coupled with a biological phosphorous removal phase, will require a much less chemicals consumption and sludge production, easily obtaining values of total phosphorous concentration at the discharge less then 0,5 mg/l.

6 Possible Evolution and Upgrading Strategies

The directive 91/271 EEC, although not still adopted in Italy, represents an important reference of overcoming of the discharge acceptability limits of the table A of the law 319/1976. A tendency to a further restriction is showed by the recent update of the Lombardy Water Reclamation Plan, which, like other recent Regional Plans, adopts the limits of the 91/271 directive even for the mean period planning [7] and, depending on the pollutants balance in the various regional water receipts, even stricter limits in the long period planning for the largest plants in particularly compromised areas.

To reduce the concentration of the various pollutants (mainly the BOD, COD, N, P and suspended solids for the urban discharges) several ways can be suggested, with particular reference to the upgrading of the existing plants, which represent a common problem with various aspects of difficult solution. A particularly important aspect is the increasing of the stability of the whole process, which can be obtained with several expedients and oversizing criteria that result in a global cost-effectiveness of the plant managing.

By this point of view, large design parameters for the biological reactors and, particularly for the sedimentation tanks are particularly useful to increase the stability and reliability of the process.

The adoption of tertiary phases, and particularly the final filtration of the effluent, is a process which allows a significant decrease of suspended solids, BOD, COD and phosphorous in the effluent, giving also a much more stability and reliability of these parameters. So the adoption of this process is particularly suitable for the large plant, and would be always provided in these cases.

The denitrification would always be coupled with the nitrification, with the most diffused pre-denitrification - nitrification or even with the simultaneous process, that in some cases could be used to upgrade existing plants reusing the existing nitrification tanks [8].

The increased knowledge of the biological phosphorous removal process makes it the favourite technique to remove this nutrient when its control is required, eventually coupled with a post-precipitation to obtain a further reduction of the concentration in the effluent. However, it is important to note that the normative limitation of the phosphate in the detergents has caused a significant reduction of the phosphorous presence in the wastewater, making possible, in many cases, the respect of the ordinary limits without specific treatments, and the respect of the lower limits for sensitive areas with the sole biological phosphorous removal treatments.

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SEDIMENT OXYGEN DEMAND MODELING IN DISSOLVED OXYGEN BALANCE

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Abstract

Dissolved oxygen (DO) is considered a comprehensive parameter of water quality from the point of view of conventional pollution, so that remarkable modeling effort has been addressed to describe and quantify DO balance components, i.e. sources and sinks.
The oxygen demand exerted by bed sediments of rivers, lakes and estuaries (SOD), which is due to the oxidation of settled organic matter, could be of considerable importance; furthermore, SOD available modeling frameworks remain far from a complete understanding of complex phenomena involved.
The paper deals with recent efforts in SOD modeling, starting from empirical relationships up to diagenesis and boundary layer model; finally, the effects of SOD variations on dissolved oxygen levels in a river are assessed for a real case.

1 1 Foreword

Historically, dissolved oxygen (DO) analysis has been the first research area in water quality modeling; modeling approach starts from the analysis of the main components of DO mass balance, i.e. sources and sinks, such as atmospheric reaeration, oxidation of carbonaceous and nitrogenous waste material, photosynthetic oxygen production and respiration of aquatic plants and sediments oxygen demand (SOD). Each one of these phenomena can be expressed through a different kinetic equation.
Generally speaking, sediment oxygen demand is due to the decomposition of organic matter in bottom sediments of rivers, lakes and estuaries, which produces CH_4, CO_2 and H_2S to being subsequently oxidized, resulting in a consumption of dissolved oxygen formerly present in the overlying water column; these benthic deposits could derive both from point and non-point, i.e. distributed sources, which contain high concentrations of organic particulates; among the former, the most remarkable are raw sewage or combined sewer overflows (CSO), while among the latter, should be considered allochthonous particulates such as leaf litter, plants roots, eroded organic-rich soils and, in highly productive environments as eutrophic water

bodies, photosynthetically produced plant matter. Furthermore, some benthic organisms other than common bacteria, such as the attached, filamentous organism called Sphaerolitus or the freshwater mollusks called zebra mussels, could be responsable of a remarkable SOD.
In shallow and speed streams with sandy and gravelly bed, which have low affinity for sorption, fine organic particulates tend to remain suspended, thus organic sediments fraction is low and sediment oxygen demand is negligible. On the contrary, if bed shear stress drops below a threshold value, which could be related to a flow velocity of 0.30 m/s, fine organic particulates and other finer particles settle to the bottom, increasing the organic content of bed sediments. In some rivers and estuaries, settling phenomena could occur only during summer and autumn with low water flowrate, while for high flowrate bed could be partially resuspended.
However, when settling phenomena are present, the oxygen demand exerted by bed sediments could be of considerable importance and could greatly affect the dissolved oxygen levels in the water column.
Nevertheless, SOD available modeling frameworks remain far from a complete understanding of complex chemical, biological and physical phenomena involved and so are unable to provide an adequate quantitative assessment of resulting oxygen demand exerted; particularly, while in water quality models it is possible to describe and to quantify particulate organic matter flux from water column to bed sediment by settling, so that we can predict how much organic particulate reaches the sediments, the mechanism whereby the sediment organic is converted into oxygen demand remains not clearly defined.
Therefore, in many water quality models SOD is an input parameter rather than a calculated output variable; this approach appears to be poor, especially because the other kinetic processes are modeled and, thus, the other DO balance terms are output variables. Sometimes, in early models application, SOD was estimated by adjusting the SOD rate until the model prediction matched the observed DO levels; this method was flawed because it assumed that the parameters involved in the other kinetic processes were known with confidence.
The first attempts to model SOD assumed linearity and lower SOD in direct proportion to load reduction by treatment; these approaches were usually justified under the assumption that a sound understanding of the process was not necessary in rough assessment of the effects of primary and secondary treatment [1]. In last years, also for the increased treatment level, several models has been proposed in order to gain insight into key mechanisms of SOD formation.
The paper deals with recent efforts in SOD modeling; thus, starting from empirical relationships by Fair and Gardiner, advanced models, such as the diagenesis model by Di Toro and the boundary layer model by Nakamura and Stefan, are described and discussed.
Furthermore, the problems related to in-situ SOD measurements are approached.
Finally, the effects of SOD variations on dissolved oxygen levels in a river has been assessed, particularly, this analysis is performed for EPA WASP 4.32 model, which had been formerly calibrated and verified for a river reach downstream of a wastewater treatment plant without nitrification.

2 Review of Available Models

Several models have been proposed in order to obtain a prediction of SOD value; in this section they are described and discussed with their starting assumptions and key shortcomings in order to gain insight into SOD formation mechanisms and to show possible direction for further researches.

2.1 Fair and Gardiner Empiric Equation

Some empirical approaches have tried to point out the parameters affecting SOD values; first at all, Fair [2] examined SOD variation in laboratory reactors as function of sediment depth and time, using artificial sediment composed by a mixing of sewage sludge, sand and diatomaceous earth; particularly, they found a one-half power regression relationship between SOD, in g $O_2/m^2 \times day$, and the initial areal volatile solids concentrations VS, in kg/m^2; then, data field were fitted to a square-root law as:

$$SOD = a_1 \cdot \sqrt{VS} \tag{1a}$$

where a_1 is a time constant.
In a similar way, Gardiner [3] observed a square root dependency between SOD and surface sediment COD as:

$$SOD = b_1 \cdot \sqrt{COD} \tag{1b}$$

where b_1 is a constant.
Both the approaches point out a square-root relationship between SOD and organic matter sediment concentration, but their critical point pertains to the definition of sampling depth where VS or COD should be measured.

2.2 Electron Acceptors Model and Bouldin Model

These models focuse on transport and transformation of electron acceptors, such as O_2 and NO_3, in the pore water; the simplest model of this group assumes that oxygen consumption is zero-order and constant along the depth z, below the water-sediment interface. Thus, the one-dimensional mass balance equation for DO in the pore water, $O_2(z)$ is [4]:

$$-D_{O2} \cdot \frac{d^2[O_2(z)]}{d^2z} = R(O_2) \tag{2}$$

where D_{O2} is the diffusion coefficient for DO and $R(O2)$ is the zero-order consumption rate of oxygen.
The solution could be attained through two integrations, reminding that DO concentration is zero at the depth of aerobic zone L_{O2} and the DO flux downward is zero as well. The DO flux to the sediments is obtained as the slope of DO profile just below the water-sediment interface at z=0:

$$SOD = -D_{O2} \cdot \left.\frac{dO_2(z)}{dz}\right|_{z=0} \tag{3}$$

Thus, the solution is:

$$SOD = \sqrt{2 \cdot D_{O2} \cdot R(O_2) \cdot O_2(0)} \tag{4}$$

If one assumes that VS is proportional to $R(O_2)$, equation (4) gives the expected square-root dependency; however, the shortcoming of this model is that $R(O_2)$ is a unmeasurable quantity.

2.3 Walker and Snodgrass Model

Walker and Snodgrass [5] have proposed a model which assumes two components for SOD, biological and chemical, respectively. Active sediments are schematized as two superimposed layers; upper layer is aerobic and dominated by aerobic heterotrophic bacteria using organic matter as an energy source for growth; their oxygen uptake is called biological sediment oxygen demand (BSOD). Below this there is an anoxic-anaerobic zone where organic matter is decomposed by anaerobic bacteria resulting in the production of reduced substances such as CH_4, NH_3, H_2S, N_2 and various reduced metal ions; these substances diffuse upward into the aerobic layer to be oxidized, consuming an oxygen amount termed chemical sediment oxygen demand (CSOD).
Walker and Snodgrass assume that the organic matter oxidation rate in the aerobic zone controls BSOD develop and that oxygen dependency can be expressed by a Monod kinetic formulation, while, for CSOD, oxygen consumption is mass transport limited and, thus, could be described by Fick first law for diffusional transport. Therefore, mass balance for oxygen in water column overlying sediment is:

$$\frac{\partial(V \cdot O_2)}{\partial t} = -\mu \cdot \frac{O_2}{K_{O2} \cdot O_2} \cdot V_S - k_c^{\cdot} \cdot A_S \cdot \left.\frac{\partial O_2}{\partial z}\right|_{swi} \qquad (5)$$

where V is the water column, in m³, O_2 is oxygen concentration in the water, in g/m³, μ is the maximum aerobic oxidation rate, in g/m³xday, K_{O2} is the half-saturation constant, in g/m³, V_S is the aerobic volume in the sediments, in m³, $k_c^{'}$ is diffusivity coefficient of oxygen penetration, in m²xday, A_S is the cross-sectional area of water-sediment interface, in m², z is the depth in sediments below the water-sediment interface, in m, while swi term means that mass balance is written across water-sediment interface. It should be noted that in (5), the first term pertains to BSOD, while the second one to the CSOD.
If oxygen partial derivative across water-sediment interface could be approximated at finite difference and oxygen sediment concentration is zero:

$$\frac{\partial O_2}{\partial z} \cong \frac{O_{2\,water} - O_{2\,sediment}}{\Delta z} \qquad (6a)$$

and

$$O_{2\,sediment} = 0 \qquad (6b)$$

Then, let V be independent of time, divide both sides of (5) by A_S and let:

$$-\frac{V}{A_S} \cdot \frac{dO_2}{dt} = SOD \qquad (7)$$

Then, assume that Δz and the ratio V_S/A_S are costant over time and let:

$$\mu_b = \mu \cdot \frac{V_S}{A_S} \qquad (8a)$$

and

$$k_c = \frac{k_c'}{\Delta z} \tag{8b}$$

where μ_b, the BSOD coefficient, has a units of a flux, while the CSOD one, k_c, is a mass-transfer coefficient, in m/days; both are temperature-dependent. Finally, model for SOD is:

$$SOD = \mu_b \cdot \frac{O_2}{K_{O2} \cdot O_2} + k_c \cdot O_2 \tag{9}$$

Walker and Snodgrass have calibrated their model using laboratory data for sediments from 4 lakes and the model has shown an excellent agreement with the laboratory data; then, the calibrated model generally agreed with in-situ measurements made in one of the 4 lakes.
Finally, they have obtained also two relationships which express temperature dependency for μ_b and k_c coefficients.

2.4 Diagenesis Model

Di Toro [6] has proposed a comprehensive SOD modeling framework which is able to explain and exhibit in mechanistic and analytical fashion the observed square-root dependency previously described.
Key point is the flux of particulate organic carbon to the sediments and its decomposition or diagenesis which produces a flux to being modeled of some reduced species, such as dissolved methane, ammonium and H_2S; thus, respect to Bouldin model, transport and transformation of electron donors rather than electron acceptors are considered.
The framework starts from the assumption that bed sediment could be divided into two layers, where the reactions resulting ultimately in SOD occur; the former is aerobic and oxidation processes take place, while the latter, underlain the former, is anaerobic, with reduction reactions. The considered reactions concern with particulate carbon organic and particulate nitrogen organic settled to sediments. In the anaerobic layer, organic carbon is decomposed to yield dissolved methane CH_4, which diffuses upward to the aerobic zone where it is oxidized, resulting in a carbonaceous sediment oxygen demand (CSOD); in the same way, in the anaerobic layer, ammonification reaction of organic nitrogen produces ammonium that is, then, nitrified in the aerobic layer to result in a nitrogeneous sediment oxygen demand (NSOD), while ammonium that is not converted to nitrate diffuses in the water column; however, part of nitrate is denitrified to form nitrogen gas using as carbon source the methane, decreasing the final CSOD.
Particularly, according to Di Toro framework, if dissolved methane concentration in the anaerobic layer never exceeds saturation, the relationship between CSOD and organic carbon flux J_C is linear; otherwise, if saturation value is exceeded, the analytical solution of model, if methane is completely oxidized in the aerobic zone, is:

$$CSOD_{max} = \sqrt{2 \cdot \kappa_D \cdot c_{sat} \cdot J_C} \tag{10}$$

where c_{sat} is the saturation concentration of dissolved methane, J_C is the organic carbon flux from water column by settling and κ_D is a mass-transfer coefficient for dissolved methane, equal to D_{CH4}/H, where D_{CH4} is the diffusion coefficient, in m²/days, and H is the thickness of the active sediment layer. Equation (10) holds if dissolved methane is completely oxidized, but in reality in the aerobic layer a competition exists between oxidation reaction and diffusion transport, therefore, if the former is much slower than the latter, much of methane would merely pass through the aerobic zone, resulting in a CSOD decrease respect to (10) equation.
Therefore, final CSOD equation is:

$$\mathrm{CSOD} = \sqrt{2 \cdot \kappa_D \cdot c_s \cdot J_C} \cdot \left\{1 - \operatorname{sech}\left[\kappa_C \cdot \frac{O_2(0)}{\mathrm{CSOD}}\right]\right\} \qquad (11)$$

where $O_2(0)$ is the oxygen concentration at the water-sediment interface and κ_C is equal to:

$$\kappa_C = \sqrt{k_{CH4} \cdot \frac{D_{O2}^2}{D_{CH4}}} \qquad (12)$$

where k_{CH4} is the decomposition rate of dissolved methane in the aerobic layer, in 1/days, and D_{O2} is oxygen diffusion coefficient.

In effect, 1-sech term accounts for the outlined competition as well as the shut down of CSOD when oxygen in the overlying water column gets low.

Using a similar analysis, Di Toro model also evaluates the effect of nitrification on SOD; thus, final complete expression of SOD is:

$$\mathrm{SOD} = \sqrt{2 \cdot \kappa_D \cdot c_{sat} \cdot J_C} \cdot \left\{1 - \operatorname{sech}\left[\kappa_C \cdot \frac{O_2(0)}{\mathrm{SOD}}\right]\right\} + \frac{a_N}{a_R} \cdot J_C \cdot \left\{1 - \operatorname{sech}\left[\kappa_N \cdot \frac{O_2(0)}{\mathrm{SOD}}\right]\right\} \qquad (13)$$

where κ_N is:

$$\kappa_N = \sqrt{k_N \cdot \frac{D_{O2}^2}{D_N}} \qquad (14)$$

where k_N is oxidation rate of ammonium to nitrogen gas, in 1/days, and D_N is ammonium diffusion coefficient in water.

Inspection of (13) shows, first at all, that the conversion of organic carbon flux into nitrogenous oxygen demand, i.e. $(a_N/a_R) \times J_C$, has not a square-root dependency from J_C because of lack of gas formation in the anaerobic layer; then, the hyperbolic secant term in NSOD expression has the same meaning as for CSOD.

2.5 Numerical Models

Diagenesis processes can be modeled also through mass balance equations for organic carbon and for ammonium; then, these equation could be solved applying numerical solution techniques, which offer greater flexibility and broader application than analytical methods [1]. For example, ammonium diagenesis could be modeled representing the active sediments as two well-mixed layers; mass balance equations could be written for organic carbon flux from column water to sediment and for ammonium in the anaerobic and aerobic zones. In these equations diffusion and decomposition terms are present.

These equations can be solved numerically to simulate the concentrations at steady-state and in time variable conditions.

In deeper lakes and estuaries with relatively low flows should be considered, in mass balance, also the laminar boundary layer near the water-sediment interface, which could serve as a compartment where additional oxidation could take place; thus, a mass-balance equation for ammonium in this compartment should be added. However, this analysis has its shortcoming in the need to define boundary layer thickness, which is the a key point of next model reviewed.

2.6 Boundary Layer Model

Recently, Nakamura and Stefan [7] [8] [9] have proposed a model that relates SOD to the flow velocity over the sediments; they have started from Walker and Snodgrass model, i.e. equation (9), to establish a quantitative relationship between SOD and the velocity and the dissolved oxygen concentration in the bulk water. Particularly, they have applied the analysis for momentum and heat transfer made by Prandtl, von Karman and Deissler to mass, i.e. dissolved oxygen, transfer in the boundary layer near the water-sediment interface.
The effect of velocity is attributed to the following two reason; flow velocity increases diffusion coefficient in the boundary layer and decreases boundary layer thickness and, hence, increases the DO gradient.
According to this model, at very low flow velocities, transport through the diffusive boundary layer is the limiting factor of SOD, which could be expressed as a linear increasing function of velocity. On the contrary, when flow velocities are increased, transport through the boundary layer is so fast that SOD becomes independent from velocity, since the reactions in the bed sediments become rate-limiting. In this case, SOD is not affected by velocity but by biological and chemical oxygen consumption, apparent diffusion coefficient in the sediment, and the DO concentration. At intermediate velocity, SOD is an increasing function of velocity and also dependent on sediment parameters.
The model also suggests that SOD is an increasing function of DO concentration in the water column overlying the sediment; particularly, the upper bound for SOD is the rate of supply of the oxygen demanding material to the sediment surface.
The velocity dependence of SOD through the boundary layer thickness agrees with available data field and the predicted profiles of DO concentration in the boundary layer and in the sediment reproduce some observed profile using microelectrodes [10].

3 Assessment of SOD Variations on DO Level in a River

As previously outlined, the effects of SOD on dissolved oxygen levels in a river could be remarkable downstream a point discharge, especially when flow velocity is low; generally speaking, in-situ measurements provide the value of SOD exerted, which then could be used an overall dissolved oxygen analysis for the stream to being studied. This analysis is often performed using a water quality model, which is an useful tool in the management context because it provides system response under different hydrodynamic, environmental and pollutants loading conditions; thus, the model offers a prediction of DO levels consequent to these river conditions.
The uncertainties in SOD modeling pointed out in the foregoing analysis suggest to pay attention to SOD variations and to their effects on DO concentration; thus, these effects have been assessed with USEPA WASP 4.32 model, which had been formerly calibrated and verified for a 12.5 km river reach downstream of a wastewater treatment plant without nitrification [11] [12].
Therefore, SOD variation effect on DO levels has been assessed through a model perturbation; generally speaking, this method is used to assess the magnitude of change in model outputs resulting from a variation in model input parameter; normally, the sensitivity to an input parameter is examined perturbing only one parameter, while all other ones remain constant [13]. Particularly, SOD values has been varied within a literature range suggested for outfall vicinity [1] [14]. Simulations with maximum, minimum and mean SOD values were performed and their results put in comparison with calibration conditions. It should be noted that calibration conditions correspond to absence of SOD, because this process had been formerly found to be negligible in the river.

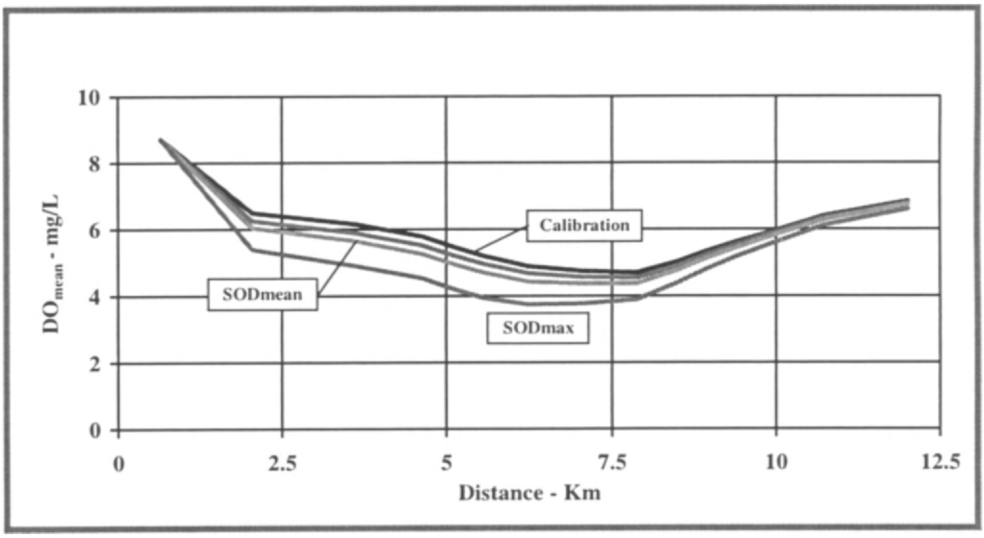

Figure 1: *DO_{mean} Distribution in the River*

In each simulation, it was assumed that SOD follows a step function with the distance from the point of discharge; thus, SOD has high values near the outfall and, then, decreasing ones up to zero in the downstream reaches; particularly, SOD was set always equal to zero in about half of 12.5 km considered. Figg.1/2 show, respectively, DO_{mean} and DO_{min} daily values along the river in the 4 conditions being considered.

It should be pointed out that, for DO_{mean}, SOD variation results in a mean decrease of 2.91%, 6.06% and 15.20% for minimum, mean and maximum SOD values, respectively; then, for DO_{min}, SOD variation produces a mean decrease of 5.77%, 12.08% and 30.33% for minimum, mean and maximum SOD values, respectively. Particularly, near the outfall, it could be observed a maximum DO_{mean} reduction of 4.82%, 9.83% and 24.47% for the three SOD values considered, while maximum DO_{min} reduction is of 10.73%, 22.44% and 56.29%, respectively.

Thus, the effect of SOD on river DO levels appears to be often remarkable; in fact, near the outfall, DO levels are greatly affected by SOD presence, especially DO_{min} values, which are, generally, those of greater concern in waste load allocation studies and in risk assessment problems for polluted aquatic ecosystems.

Finally, it should be noted that decrease percentages point out model linearity respect to SOD input values, which is inherent to the modeling framework, i.e. WASP, considered.

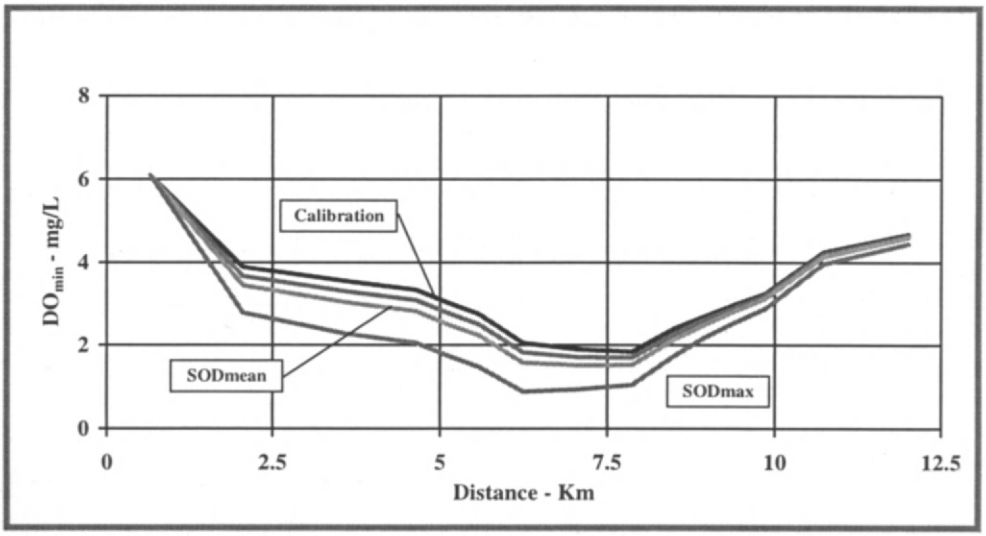

Figure 2: *DO_{min} Distribution in the River*

4 Conclusions

Sediment oxygen demand (SOD) could represent a remarkable consumption process, i.e. sink, in dissolved oxygen (DO) balance for a water body. SOD exerted is mainly due to the decomposition of organic matter settled in bottom sediments; this process is quite complex and is not yet well defined in each intermediate step; thus, modeling efforts to obtain a quantitative and predictive assessment of SOD values are subjected to a rapid and continuous evolution.

The paper has been addressed to show most relevant issues in SOD modeling and to assess SOD variation effect on DO balance; thus, SOD modeling evolution has been outlined pointing out possible direction for further researches, which should be addressed to a strong link between the traditional chemical and biochemical approach and hydrodynamic concepts.

Furthermore, SOD variation effects on DO level for a river have been assessed, in order to points out SOD relevance among the other processes involved in dissolved oxygen balance; the effects predicted appears to be relevant, especially near the point of discharge and for DO_{min} levels, which are, generally speaking, those critical in risk assessment studies for aquatic ecosystems.

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THE 3rd STAGE OF PURIFYING POLLUTED WATER BY VOLCANIC SLAG METHOD

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Abstract

The traditional materials such as quartz sand, coke and others ,which are being used in Russia, are in use for purifying polluted water completely, in large cities of Mongolia. The level of purification by these materials is not satisfactory, the sewage from these plants is soiling the water reserve and grazing land.
The above mentioned materials are seldom used in our land and employ its become heavy.
The research results on the volcanic slag, from the 10 separate deposits of Mongolia are showing that some of the volcanic rocks, especially volcanic slag are satisfying the technical requirements of filter materials such as physical, mechanical and chemical properties, which are required for purifying the polluted water completely.
In most of the cases the volcanic slag, which was scattered on the territory of Mongolia has a glasses and amorphous structure, that has a high mechanical strength, hardness and water proof.
Our result of using volcanic slag in the third stage of purifying polluted water showing that it has more capacity than the traditional filter materials by filtering ability in the filter period. This connects with its internal structure and specific surface.
Many results of research have confirmed that the purification level is more than 98% if the granulate metrical aggregates and thickness of filtering layer are chosen correctly and the volcanic slag is used as a filter in the third stage of water purification. It is creates the fertile condition for increasing the clean bacteria.

1 Introduction

Although there are 3800 rivers covering a length of 67000 km, 3500 lakes, 7000 springs ,120 mineral water spa's used for health giving properties and also 187 glaciers covering 500 sq. km, Mongolia is considered to be one of the 60 countries in the world with least water reserves. [1].

Out of the total water reserves about 34.6 cu km. are used each year. 12.6 cu Km. is taken from underground reserves. There are three main catchment areas in Mongolia, the Arctic and Pacific basins and the much larger central Asian basin, which has no outlet to the sea. 73% of the river water that flows from the Khentil and Hangai mountain flows into the Arctic and Pacific Oceans and the remaining 27% is absorbed into the central Asian basin.
Although the water reserves are sufficient in the Northern part of Mongolia, there is no fresh surface water in the Gobi and steppe zones, which occupy 69.1% of the territory and these areas are therefore supplied with essential requirements from underground resources. In most of the cases the underground resources originating from the continental salty zone, contain dissolved minerals that make it hard, and not suitable for use, [1], and [2].
On an average 312.8 million cu.m of water is used to satisfy domestic and industrial demand each year. Over 255.6 million cu. m of water is polluted by 526 t of 7200 different kinds of chemical substances, which originate from about 1000 industrial enterprises, [2]. This pollution finds its way into 50% of water purification plants, which cannot treat this uncontrolled waste. A large contribution to the pollution is from agricultural sources, particularly cow, pig and poultry farms, as well as industrial sources.
For example about 0.2 to 0.3 mg/lt. of nitrogen was contained in the water in the bend of the "Tuul" river flowing round the "Uu" area to the west of Ulaanbaatar. This pollution component increases by 6 to 17.5 times by the time the river reaches the lower slopes of the Songino Mountain, on the outer edge of U.B. This is strong evidence that the water purification plants in the area are unable to cope with this level of pollution.
Researches have indicated that there is the possibility of using new materials [4], [5], in water purification and that it can decrease the pollution in the water at a cost reduction factor of between 2 to 4 times. This would allow the safe reuse of all water now being polluted.
Our research [3], [5], [6] as well as overseas research has confirmed that the natural and artificial materials such as zeolite, crushed granite, claydite, swelling prelate, and polistirol, are more effective than the traditional materials in water purification. But the above mentioned material costs are expensive by Mongolian standards.

2 Substantiation

Geological investigation has determined that 18,724 million cu. m of volcanic slag is available in the country in about 30 separate deposits. This material has not been researched as a water filter media, although it is used as the main raw material in the technology of low quality binding materials, and light weight concrete, [7], [8]
Our research on the volcanic slag, shows that it doesn't get soft when it is wet and has high mechanical strength and chemical resistance.
The volcanic slag belong to alkali-rock (by the classification of chemical composition) as of its silicon dioxide contents are 47.2 ...51.6 % (see Table 1). Most of volcanic slogs contain glasses and amorphous phases, which have only short-range atomic order and their setting up, are 68.0... 94.94% in it.
The conclusion on it that the volcanic slag extracted from many separate deposits of the country has high hardness, waterproof and high mechanical strength. Also its crash ability is 0,95...4.83% and attrition value 0.49 ...1.05% and it shows that it is a highly- qualified filter material (See Table 2).

Table 1. *The Chemical Composition of Volcanic Slag*

N°	Name of the deposits	The chemical contents, %							
		Ignition loss	SiO_2	Al_2O_3	CaO	MgO	SO_2	R_2O	Fe_2O_3
1	Taatsin gol	0.69	51.6	17.9	5.09	9.17	0.32	1.4	13.83
2	Tsaan-uul	2.14	50.7	19.1	5.82	6.28	0.23	4.0	11.13
3	Dosh tolgoi	0.78	48.3	21.2	5.82	7.20	0.36	6.0	10.36
4	Bayantsagaan	2.7	48.1	15.5	8.31	8.4	0.45	3.2	13.34
5	Khoh burd	1.67	47.2	26.6	7.26	6.2	0.21	4.6	6.26
6	Bosgiin togoo	1.63	51.0	23.2	6.85	6.9	0.19	1.5	8.73
7	Khurmen bulag	2.8	49.8	28.45	7.8	6.4	-	1.8	11.0
8	Khurmen Uul	2.9	53.0	19.8	8.45	7.9	0.16	0.59	7.2
9	Ikh Dosh	1.43	49.3	21.0	6.52	8.64	-	3.20	9.1
10	Tsorj tolgoi	1.23	48.9	20.4	5.63	5.85	0.29	4.1	13.6

Table 2. *The Compared Results of Physical and Mechanical Characters of Volcanic Slag*

N^0	Index	Filter materials					
		Volcanic slag(the average)	Zeolite	Quartz sand(Russian)	Anthracite	Carbonated coal AG-3	GOST-2180-82 (standard of, Russian)
1	Crash ability, %	0.95...4.83	4.45	0.5	-	11	4
2	Attrition in water,%	0.49...1.05	11.34	4	5	21	0.5
3	Emptiness, %	31.6...51.2	-	88.4	53.8	62.7	-
4	Porosity,%	41.9...51.2	-	29...34	50...56	72.5....75.5	-
5	Absorption of water,%	26.0...37	-	-	-	-	-
6	Strength in a cylinder, mPa	1.52...1.96	-	-	-	-	-
7	Level of clean,%	98	98.5	96.2	98.5	96.7	-
8	Potential of working, mg/lt.	14...22	8...10	6...8	10...14	28...34	-

Although it is relatively more than the traditional and other filter materials on the basis of the indices of the dry remnant is 12.9 ... 12.0 mg/it. And oxide ability is 1.7 ... 4.1mg/lt. In acid medium it is in the limit of a standard.

The specific surface of the volcanic slag is 60... 290 cm^2/cm^3, air content of aggregates are 31.6 ... 51.2% depending on the granule metric composition. The air content and water absorb in volume of the volcanic slag are the same by quantity (26.9 ... 37%).

It shows that all holes contained in the volume of the volcanic slag are basically open and it results the volcanic slag to be the highly absorbable material.

Side by this, it filters and accumulates the suspended matters to the surface; in other words, it has the high quality of purification. Because the volcanic slag has a rough and adhesive surface, which is more than other materials by the quantity.

3 Experimental

The suspended matter 's contains are reduces by 88.1 ... 98.1%, and the oxygen for biological demands are reduce also by 84.1 ... 93.6%, when the volcanic slag is used for quickness filtering layer, after 1-st and 2-nd stage of purifying domestic sewage (see Figure 1).

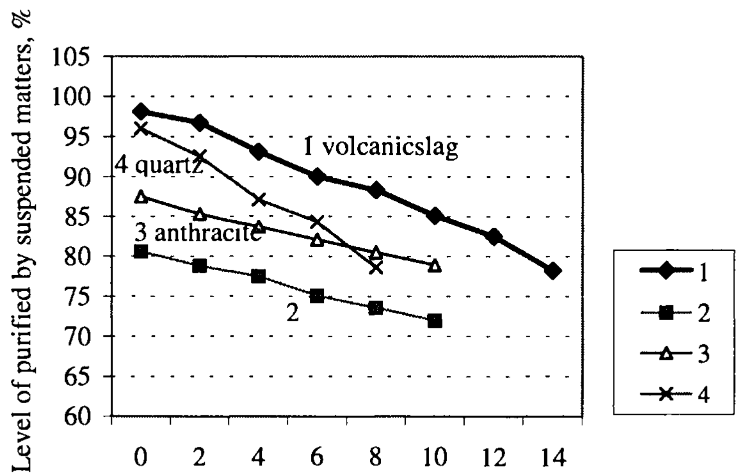

Figure 1: *The Level of Purified by Suspended Matters versus Filtering Time*

A content of the suspended matters were 41.1mg/lt., and the oxygen for biological demands (OFBD) were 38.6 mg/lt., in a sewage before it came to the volcanic slag filter and its content reduced as 0.8 ... 4.8 mg/it for the suspended matters and 1.6 ... 6.4 mg/lt. for the OFBD in a sewage after the purification its (see Figure 2).

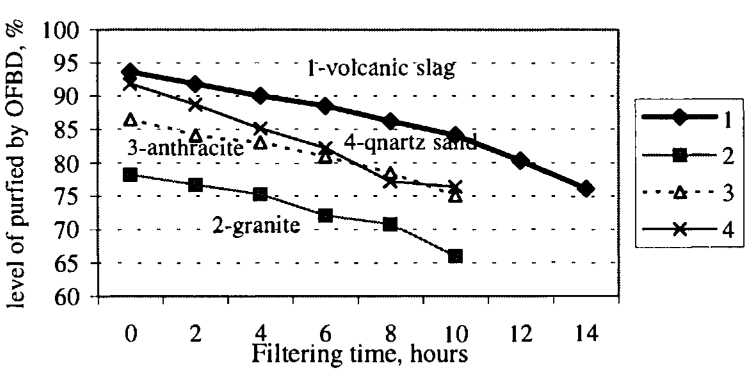

Figure 2: *The Level of Purification by Oxygen for Biological Demands versus Filtering Time*

The purifying level was stable after 14 hours working of the volcanic slag filter with 1.2m high filter-level, which contents are granular aggregates with 1.5mm by equivalence diameter. The speed of sewage was 15 m/h.

Many results of research have confirmed that the purification level shall be over 98% if the granulate metrical aggregates and thickness of filtering layer are chosen correctly when the volcanic slag is used as a filter in the 3-rd stage of purifying polluted water.

In the 3-rd stage of purifying polluted water, the purifying level is high when the volcanic slag is used as the filter material and it connects the below mentioned 3 specificity: 1.When the polluted water leaks out of the filter layer, which has much specific surface, it passes a long way and suspended matters adhere to surface by little. 2.The volcanic slag purifies by accumulating the suspended matters owing to a lot of open holes, which result the increase of its absorb ability. 3.The suspended matters are filtered in the way of sticking on the rough surface with acute angles and edges.

4 Conclusion

(1) The volcanic slag that is available in abundance in Mongolia satisfies the requirements of the filter material used for purifying polluted water completely by the physical and mechanical qualities, chemical resistance and other indices.

(2) The volcanic slag has more capacity than the traditional filter materials by its filtering and filter period.

(3) The specific surface and mechanical quality of the filter layer made of volcanic slag increases, as the granulate- metrical aggregates became smaller. Especially, the purifying level is high when the granulate-metrical aggregates (0.315...5.0 mm) and thickness of filtering layer are chosen correctly.

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WATER TREATMENT IN REMOTE AND RURAL AREAS: A CONCEPTUAL SCREENING PROTOCOL FOR APPROPRIATE POU/POE TECHNOLOGIES

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Abstract

Small communities and individual dwellers in rural areas face the burden of obtaining safe drinking water supplies with limited financial and technical resources. Novel applications of proven drinking water treatment technologies at the point-of-use/point-of-entry (POU/POE) are often seen as an effective and economical solution to production of safe drinking water in rural areas. A brief review of the different technologies is here presented, with respect to maintenance requirements and costs. A conceptual screening protocol for the selection of appropriate technologies is then proposed, which incorporates the site specific factors and constraints that may affect the decision process.

1 Introduction

Small rural communities and owners of private wells do not possess the resources and expertise to respond quickly and efficiently to contamination. Although simple water treatment technologies [1] such as slow sand filtration [2] with chlorination [3] could reliably provide safe drinking water for small communities in rural areas, the utilization of proven water treatment technologies at the point-of-use/point-of-entry (POU/POE) offers a potentially viable and cost effective method of reduction of chemical contaminants to acceptable levels in drinking water. POU/POE have been traditionally used for non-health related water impurities such as taste, odor, color, turbidity, iron, hardness, etc. With the detection of toxins and carcinogens in public water supplies and individual wells, new technologies and applications have been developed.

Furthermore, the treatment of drinking water supplies poses different problems depending on the size of the served population, raw water characteristics, and site specific factors. Moreover, the decision process is affected by time constraints, often due to emergencies and contingencies imposing immediate responses, and cannot rely on adequate human and technical resources to investigate in detail the available treatment alternatives. It results then apparent the need for a screening tool to facilitate this decision process.

Following a brief review of the available technologies for drinking water treatment in rural and remote areas and on point-of-use/point-of-entry units, with references to the maintenance requirements and the costs for the different POU/POE units, a conceptual screening protocol for the selection of appropriate water treatment technologies is presented.

2 Point-of-Use and Point-of-Entry Devices

A POU treatment device consists of equipment applied to selected taps used for the purpose of reducing contaminants in water at each tap. POU treatment offers ease of installation, treats only the water that is used for consumption, simplifies operation and maintenance, and generally has lower capital costs. These systems are usually placed in the following places at the sink [4]:

- *Counter top:* a counter top device normally fits through a connection to the faucet on the sink and rests on the counter or in the sink;
- *Faucet mounted:* a faucet mounted filter is attached directly to the end of the faucet;
- *Under sink cold tap:* the device is fitted onto the cold water lines and treats all the cold water that flows through the faucet;
- *Under the sink line bypass:* the device taps onto the cold water line, and after flowing through the lines to a reservoir, exits through a tap attached to the sink.

A POE treatment device consists of equipment applied to water entering a house or building for the purpose of reducing contaminants distributed throughout the house or building, usually placed where the household water enters the house (but normally after the outside outlets). POE treatment would be necessary where exposure to the drinking water contaminant by pathways other than consumption is of concern. To be effective for the homeowner, POU/POE treatment should work with minimal attention, be relatively inexpensive, and be effective for contaminant removal [5].

2.1 Common Technologies and Maintenance Requirements

Currently, POU/POE treatment is used to control a wide variety of contaminants in drinking water treatment [6], using the same technologies used in large-scale water treatment plants. POU/POE may me designed to reduce levels of organic contaminants, control turbidity, fluoride [7], iron, radium, chloride, arsenic [7], nitrate [8], ammonia, microorganisms including cysts, and many other contaminants. Aesthetic parameters such as taste, odor, or color could also be improved with POU/POE treatment. Table 1 present POU/POE common technologies, target contaminants potentially removed, and usual placement of the units [9]. The most common technologies applied for POU/POE treatment are briefly reviewed in the following sections.

2.1.1 Particulate Filters

Particulate filters for turbidity removal for POU applications usually consists of a prefilter and a filter cartridge. Various materials are used from different manufactures for the cartridges, including polypropylene, structured carbon, ceramic, pressed carbon, and cotton. Particulate filters at the POU are replaced when the observed flow of produced water is too low (i.e., excessive headlosses) or when the removal efficiency is not acceptable. The POE units, instead, are backwashed when the above mentioned criteria are violated. POE devices are usually required to achieve the required treatment efficiency [10].

Table 1: *Common Technologies, Target Contaminants, and Placement for POU/POE Devices.*

Technology	Target Contaminant	Normal Placement
Particulate Filters	Turbidity removal	POE All POU placements
Activated Carbon Adsorption Filters	Radon Organic contaminants	POE All POU placements
Reverse Osmosis	Inorganic contaminants (nitrates, lead, copper) Total organic carbon Volatile organic chemicals Low molecular weight organic compounds	Countertop Undersink line bypass
Ion Exchange Columns	Inorganic contaminants (radium and barium with cation resins; nitrates and arsenates with anion resins)	POE All POU placements
Distillation Systems	Inorganic contaminants	Countertop
Oxide Adsorbents (Activated Alumina, Iron Oxide Coated Sand)	Fluoride, arsenic	POE All POU placements

2.1.2 Activated Carbon Adsorption Filters

The carbon replacement rate is dependent on many factors including the level of contamination, water temperature, pH, chemical makeup of the water, and water usage Breakthrough of the contaminant is the main criteria used to identify the replacements time of the adsorption media from these systems. Some units have a shutoff devise that indicate the throughput volume. The units are often certified by the United States National Sanitation Foundation (USNSF) with a 100% safety factor when replacement is based on throughput volume (i.e., the certified capacity should actually be half of the actual capacity) [11]. Research has confirmed that bacteria can proliferate on both silver- and non-silver-containing activated carbon filters: even those devices with special features, such as silver or compressed carbon with a very small pore size, are susceptible to bacterial growth, even when used with chlorinated, treated tap water [12].

2.1.3 RO Systems

Reverse osmosis is a viable treatment method for reducing the level of several inorganic contaminants, such as nitrates, arsenates, fluoride, lead, and copper. Contaminant removal, however, depends on the type of membrane: thin film composite membranes are more effective than cellulose acetate membranes. Membrane fouling and deterioration will require replacement of the filters an the RO modules. Assuming proper maintenance of the pre-filters, a cellulose acetate module will normally be replaced after 18 to 24 months of service, while a polyamide module after 24 to 48 months. The GAC and particulate prefilters are normally replaced every 6 to 12 months.

2.1.4 Ion Exchange Systems

Ion exchange resins consists of two main types, i.e., cation exchange resins, that exchange positively charged ions, such as sodium, for calcium, and anion exchange resins, that exchange negatively charged ions, such as chloride, for arsenic. Resins are usually made from the polystyrene polymer backbone and differ only by their specific functional groups. The ion exchange systems are usually regenerated with sodium chloride. The strength of the solution depends on the strength of the adsorption bond. Usually, 0.1 N NaCl is effective in removing even strongly adsorbed anions.

2.1.5 Oxide Adsorbents Packed Bed Filters

Oxide adsorbents such as activated alumina and iron oxide coated sand are effective in removing inorganic anions and [13], and are usually regenerated with various strength of sodium hydroxide solutions. The pH of the media must be neutralized after regeneration.

2.1.6 Distillation Systems

Distillation has been known to be effective in producing contaminant-free water. Higher operation expenses are required for this type of units due to the energy input for distillation. Maintenance is required due to scaling.

2.1.7 Halogenated Resins

Halogenated ion exchange resins have been developed for water disinfection in which an halogen, i.e., chlorine, bromine, and iodine, is exchanged with an ion in solution [14]. They don't require electrical connections (unless monitoring devices are present), are easy to install and service, have minimal space requirements, and can be integrated with other POU technologies.

2.1.8 Disinfection Devices: UV, Ozone, and Iodine Systems

Disinfection packages relying on ultraviolet [15], ozone [16], and iodine [12] technologies are available for POU/POE applications. UV devices are potentially effective and have the advantage that they do not leave any residual taste or chemicals that can react with other substances in the water. In order to ensure the quality of the water a fail-save device measuring the UV intensity farthest from the source is necessary.

The household-type ozonation units consist of a large box with a hose emanating from it that bubbles ozone into a container of water using only a timer as a control. The disinfection efficiency decreases when the relative humidity increases, due to lower ozone production.

Iodine is the only solid halogen at room temperature and is an effective disinfectant over a wide pH range. It is easy to maintain a residual in the water because iodine does not react with nitrogen-containing substances or organic compounds. Because of its toxicity, use of iodine for disinfecting drinking water should be reserved for emergencies or occasional use [12].

2.2 Indicative Costs

Cost of drinking water treatment increases with decreasing the size of the served community. Economies of scale make the construction of central treatment plants for small water systems difficult. Recent publications [6] provide information on costs for POU/POE systems. Capital, operation, and maintenance costs should all be evaluated, since each cost could be critical in the selection process. For instance, systems that require significant energy input may result non economical due to high operation costs. Monitoring costs should also be considered. Table 2 provides indicative cost ranges for the installation of several POU treatment devices.

Table 2: *Cost Ranges for Common POU/POE Devices*

Technology		**Cost Range (US $)**
Particulate Filters		20-100
Adsorption Filters		
	POU	50-300
		(20 for replacement)
	POE	800-1000
		(200-400 for replacement)
Reverse Osmosis		
	Counter Top	100-300
	Under the sink cellulose acetate	300-600
		(50-60 for replacement)
	Under the sink thin film composite membrane	400-800
		(100 for replacement)
Ion Exchange Columns		300-2000
Distillation Systems		200-600
Ultraviolet Units		300-700

3 Conceptual Protocol for Screening the Alternatives

Identifying appropriate POU/POE technologies for drinking water treatment in rural areas is a process driven by technical, regulatory, and economical factors, including:

- Required production rate;
- Raw water characteristics;
- Operation and maintenance requirements;
- Site accessibility;
- Capital and maintenance costs;
- Expected duration of operation.

The variety of available treatment alternatives briefly reviewed in the previous sections proves that identifying the necessary flow rate, the raw and product water characteristics, and the appropriate treatment alternative are three phases that should be integrated, in order to reduce the burden of the decision process, by screening the different alternatives and discarding those that are not appropriate.

Conceptually, this screening protocol adopts an integrated approach articulated in three phases. One phase would aim at identifying the general and specific factors affecting supply quantification, characterization, and selection of treatment alternatives. A second phase would aim at identifying specific priorities at the site of interest. A third phase would aim at discarding the alternatives which are not compatible with the site characteristics and priorities.

The interrelated character of these three phases requires several iterations before identifying the most significant conclusions of the decision process. It should be noted that the phases are not sequential, but rather each one could be set as the starting step of this iterative screening protocol depending on site specific considerations.

To facilitate the phase aiming at identifying the general and specific factors affecting supply quantification, characterization, and selection of treatment alternatives Table 3 has been developed, which lists the general and site specific factors affecting the selection process. Table 3 represents a general case and, depending on site specific considerations, it could be simplified. It should be noted that many of the general and specific factors identified in Table 3 have an impact on more than one category.

Table 3: *Synoptic Identification of Factors Affecting Raw Water Quantity, Characteristics and the Selection of Treatment Technologies.*

Categories	General Factors	Specific Factors
Raw Water Quantity	• Climatic and hydrogeological • Resource management • Short and long term variation • Permeability of soil • Flow patterns	◊ Quantity and intensity of precipitation, nature of soils ◊ Seasonal climatic variation ◊ Degree of stabilization of wastes ◊ Landfill management
Raw water Characteristics	• Climatic factors • Presence of organic and inorganic compounds • Seasonal variability • Attenuation phenomena	◊ Infiltration rates, contact time ◊ Hydrolysis, soil adsorption, biological reaction, ion exchange reactions, , speciation, dissolution, red-ox reactions, dilution, filtration and precipitation ◊ Waste disposal and management practices
Selection of Technologies	• Contaminant characteristics • Time constraints • Proximity to water treatment plant • Production rate and treatment goals • Time dependence of raw water flow rate • Operation and maintenance requirements • Flexibility • Initial toxicity • Expected duration of service • Necessity for hydraulic equalization	◊ Suitability of each technology ◊ Compliance with regulation ◊ Continuous vs. batch reactors ◊ Short and long term variations ◊ Active vs. passive systems ◊ Metals, organics ◊ Regulations, best available technologies ◊ Annual costs ◊ Site specific exigencies ◊ High loading peaks, strong climatic dependency

The second phase, aiming at identifying specific priorities at the site of interest, could be implemented by answering the following questions:

- Are there constraints that impose to adopt an immediate response action, e.g., compliance with regulator's deadlines or excessive health risk?
- What annual costs would be affordable?
- Is it possible to afford a treatability study?
- Is it economical to control the cause of contamination of the water supply?

- Are chemical constituents and parameters impairing the suitability of some of the treatments?
- Is it necessary to rely on more than one technology?

The following guidelines [17] should also be considered when selecting technologies for water treatment in rural areas:

- Hydraulic devices that use gravity for mixing, flocculation, and rate control are preferred over motor-driven equipment;
- Mechanization and automation are appropriate only where operations are not readily done manually or where they would greatly improve reliability;
- Indigenous material should be used to reduce costs, to bolster the local economy, and to expand industrial development [18];
- Innovative application of proven technologies is better than application of new technologies.

4 Conclusions and Recommendations

Numerous POU/POE systems are available as appropriate technologies for drinking water treatment in remote and rural areas. Selection of the alternative systems is based on many general and site specific factors.

The proposed protocol for screening alternative POU/POE technologies adopts an integrated approach articulated in three phases. One phase aims at identifying the general and specific factors affecting quantity, treatment goals, and selection of the alternative treatment technologies. A second phase aims at identifying specific priorities at the site of interest. A third phase aims at discarding the alternatives which are not compatible with the site exigencies and priorities. The interrelated character of these three phases requires several iterations before the most significant conclusions of the decision process are identified. The following observations and recommendations should also be considered when assessing the viability of POU/POE drinking water treatment technologies:

- In areas where centralized treatment is not feasible (i.e., when each home has a private well or when the cost of a central treatment plant would be prohibited to end-users), POU/POE treatment techniques may be a viable alternative;
- Use of proven technologies at the POU/POE is effective for reducing contaminants from drinking water supplies. Specifically, reverse osmosis, ion exchange, metal oxide adsorbents, and distillation are more effective for inorganic reduction, while granular activated carbon is more effective for organic contaminant reduction;
- Costs for small communities appear to be attractive particularly if these devices can be leased to the community avoiding up front costs;
- Choosing POU or POE units depends on site specific factors and on the risk associated to exposure through pathway different from consumption;
- POU/POE treatment may increase the amount of monitoring required and the amount of education that a water utility must provide to its customers;
- Because control and monitoring of POU/POE are the key factors to protecting public health, these systems should not be allowed to evolve without regulation;
- The public should be informed about the correct application of devices, and the industry should be aware of the potential problems with POU/POE treatment devices;
- POU/POE treatment devices could cause problems with the microbiological quality of the water. Specifically, when using activated carbon POU/POE filters, a short flushing time of about 30 s is recommended after quiescent periods.
- POU/POE treatment does not alleviate the liability of a water utility to provide safe drinking water to its customers;
- Mechanical equipment should be limited as much as possible to that produced locally;

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DECHLORINATION OF POLYCHLORINATED BIPHENYLS IN NON-POLAR MEDIA

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Abstract

The paper deals with the application of the KPEG technology to the treatment of both dielectric and lube used oils is reported. The experimental results, achieved by using the two class of oils, are compared in order to evaluate the reduced efficiency of the process when lube oils are treated.
The kinetic of the PCBs removal reaction from a mineral oil was determined; the reaction resulted first order relatively to each congener concentration and first order relatively to the polyethylene glycol alkoxide concentration. The calculated kinetic constants for the considered congeners, have showed an exponential correlation with their gas-chromatographic relative retention time.
From the kinetic results it is confirmed that the slightly chlorinated PCB are more hardly removed, whereas the more chlorinated PCBs are those more easily eliminated.; the kinetics of PCBs removal seems to be strongly affected by their structural conformation and not only by the chlorine content.

1 Introduction

Polychlorinated biphenyls or "PCBs" were widely used, until some years ago, both in industrial and civil applications. This was mainly due to their advantageous characteristics: heat stability, low volatility, good viscosity characteristics in a wide operational temperatures range, excellent dielectric properties, resistance to oxidation, reduction and chemical agents.
The extremely high toxicity of this class of compounds is due to its high stability to chemical agents, which makes itself resistant to degradation, leading to bioaccumulation in the living organisms [1,2].
Because of their environmental resistance, PCBs are considered one of the most dangerous pollutants [3] and their manufacture or use has been banned in the United States since 1976. The European Union has recently made it compulsory to decontaminate all apparatuses containing PCBs not later than 1st of January 2005. Consequently many investigations were made for PCBs removal and destruction from contaminated products (mainly dielectric oils), and numerous processes have been developed [4,5].

Incineration is the main technology utilised for PCBs-contaminated hydrocarbons. This is a destructive treatment for both PCBs and PCBs-contaminated products [6]: currently are available highly efficient incineration processes to convert PCBs to HCl, CO_2 and H_2O, and to minimise the formation of toxic compounds like dioxins. However, application of high temperature incineration is limited to pure PCBs mixtures and hydrocarbons containing very high concentrations of PCBs, due to expensiveness of this technology, to the problems with handling and transporting contaminated material and to the destruction of reusable material.
On the contrary, the selective destruction or removal of PCBs [7-11] has become more important in the last years, due to the improved interest in recovery of reusable materials, and to the necessity to treat contaminated products containing low concentrations of PCBs. Several selective destruction technologies are today available, based on chemical dechlorinations, photochemical degradations, biological treatments and electrochemical processes.
Among current non-destructive industrial scale decontamination processes those based on the reaction of PCBs with PEG alkoxide, appear at the moment the most suitable ones. The "NaPEG" technology patented by Pytlewsky et al., demonstated that PCBs can be rapidly and completely decomposed by the use of molten sodium metal dispersed in polyethylenglicols[12-13]. However, the use of metallic sodium requires special handling, and trace amounts of water must be eliminated to minimize dangerous side reactions. By substitution of metallic sodium with potassium hydroxide the so-called KPEG technology has been developed by several companies, assuring a more safe system, still effective and tolerant of water and other contaminants [14].
Up to now, this technology has been successfully applied to the PCBs decontamination of dielectric oils. However the extension of these methods to the treatment of lube used oils accidentally contaminated by PCBs was not yet attempted but interesting. In fact, if the content of PCBs in these latter oils overcomes 25 ppm, according to the Italian clean-up policy the oils have to be considered as toxic wastes, cannot be regenerated and their compulsory destruction is expensive and environmentally dangerous.
The application of the "KPEG" processes for the decontamination of lube used oils is more difficult than for dielectric oils, because of various additives of the lube used oils like as detergent, antioxidant and emulsifying agents aside the presence of water up to 10% wt which has to be preliminarily eliminated. All these additives can interact with the kinetics of the PCB decontamination reactions by reducing the yields of the treatment.
In this work an experimental study on the application of the KPEG technology to the treatment of both dielectric and lube used oils is reported. The experimental results, achieved by using the two classes of oils, are compared in order to evaluate the reduced efficiency of the process when lube oils are treated.

2 Experimental Procedure

The experimental work deals with the removal of polychlorinated biphenyls from dielectric and lube used oils reported in Table 1 by using polyethylene glycol alkoxide, as reagent.

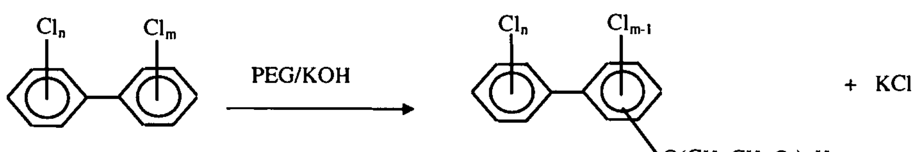
Table 1: *Characteristics of Oils Used in the Dechlorination Reactions*

Oil sample	Oil type	PCB content (ppm)	Water content (% wt)
T	Dielectric	1380	<1
L	Lube	2700	8
U	Lube	2500	11

The experimental runs were carried out in a thermostated glass vessel 300 cm^3 in capacity, fitted with a magnetic stirrer. The experimental procedure was as follows: the contaminated oil was heated in the reaction vessel up to the fixed temperature under stirring. After the addition of the KOH-PEG mixture, previously prepared by dissoluting KOH in PEG at 70°C, the run started.
In case of a water content of the contaminated oil higher than 0.1%, an evaporation under reduced pressure (500 mm Hg) was operated before the treatment. The elimination of water was shown by a sharp rise in temperature over 100°C.
All the runs were operated in batch mode and had a duration time between 2.5 hours and 5 hours. Throughout each run liquid samples of about 5 cm^3 were withdrawn at fixed time interval from the reactors in order to determine the residual PCBs content in the oil. All the samples were decanted for some hours to separate the glycolic and oil phases, i.e. the heavy and light phase respectively. When lube oils were treated, the separation was accomplished by the use of a centrifuge.
The PCBs content in the reaction products was determined using gas-chromatography. Sample clean-up and preparation and GLC analysis were carried out according to the most applied analytical procedures. A Fison 800 gas chromatography was used, fitted with a split/splitless injector, an ECD detector and a 30 m × 0.32 mm ID capillary column. The film thickness was 0.25 mm (SE-30). The main parameters used were the following: nitrogen as carrier gas and as make-up gas respectively with a flow rate of 1.5 ml/min and 30 ml/min; injection temperature 280°C; detector temperature 310 °C. Temperature program: 110 °C for 1 minute; 110 to 160 °C at 15 °C/min; 160-270 °C at 5 °C/min; 270 °C for 4 minutes; 270-300 °C at 20 °C/min; 300 °C for 10 minutes. Isooctane supplied by Aldrich was used as solvent.
The water content in the oil was determined using the ASTM D 95-70 method. Polyethylenglycol 400 (PM 400) technical grade (Enichem) and KOH 97% (Backer reagent grade) were used as reagents.
In order to study the influence of the PEG/oil and KOH/PEG ratios on the reaction grade, experimental runs were carried out on both the mineral oils by varying the KOH/PEG molar ratio from 0.5 to 2.0, and the PEG/oil weight ratio from 0.1 to 0.5.
Runs were also performed at different temperatures (100, 110, 120 °C) in order to evaluate the kinetic of the reaction.

3 Results and Discussion

PCBs removal in a non-polar medium, using KPEG as dechlorinating agent, involves the nucleophilic aromatic substitution of chlorides of the PCBs by the polyethylene glycol alkoxide, so giving an aryl polyethylenglycolate and KCl [14]:



In the studied two-phases system, the displacement of a chloride ion from the chlorinated substrate should be rapid only if the glicol alkoxide reagent and the PCB are in the same phase.
The PEG/oil and KOH/PEG ratios play an important role on the efficiency of the proposed treatment for the PCBs removal. In case of lube oils, on increasing the PEG/oil ratio between 0.1 and 0.5 an almost linear increasing of the PCB elimination rate occurs, as shown in Fig. 1.

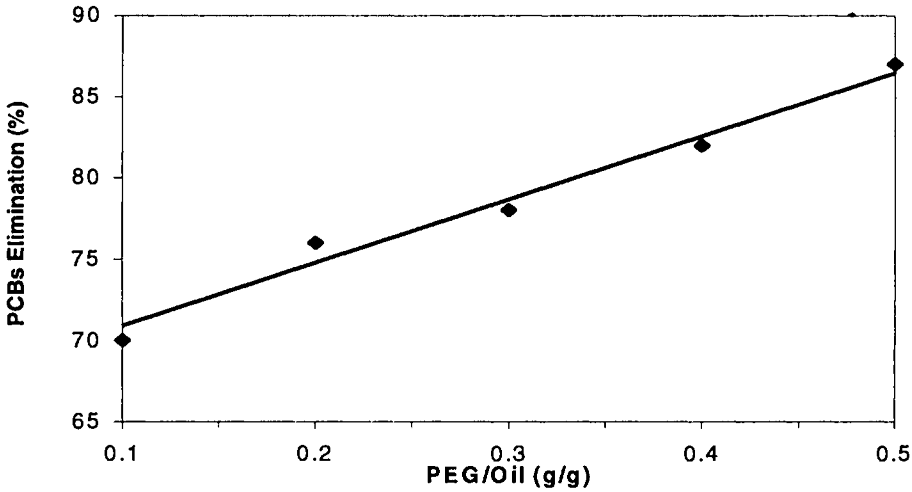


Figure 1: *Influence of the PEG/Oil Ratio on the Elimination of PCBs.*

The influence of the KOH/PEG ratio on the efficiency of the disposal treatment is shown in Fig. 2.

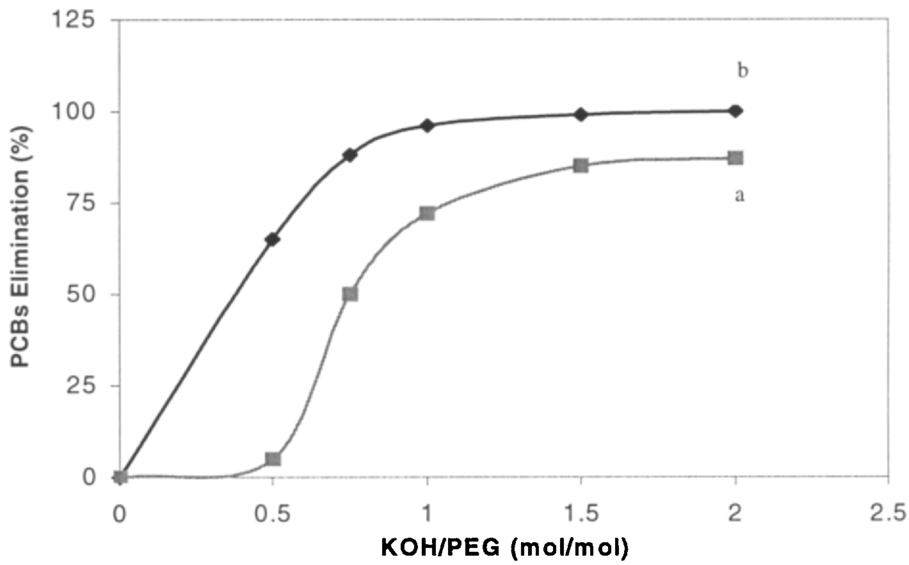


Figure 2: *Influence of KOH/PEG Ratio on the Elimination Grade of PCBs from Lube Oil (a) and Dielectric Oil (b) after a 5 Hours Treatment.*

The removal of PCBs strongly increases as well as the KOH/PEG ratio increases up to the stoichiometric value. For higher ratio values a slightly improving of the treatment occurs. Therefore for a high elimination grade of PCBs, the KOH/PEG ratio has to overcome the stoichiometric value (equal to 1), as previously reported by Brunelle et.al [14].
The low efficiency of the treatment observed in the case of lube oils (see Fig. 2) is mainly due to the additives normally present in these oils, like as polyphosphates, sulfur compounds, etc. They may react with KOH, thus lowering the concentration of the nuclephilic agent of the reaction.

However the most remarkable effect on the PCBs reaction grade is due to the different nature of PCBs. In fact, by comparing the performances of runs carried out on the two different lube oils at the same operating conditions (KOH/PEG molar ratio: 2.0; PEG/oil weight ratio: 0.2; temperature: 110°C) a significant difference between the final contents of PCBs can be observed. After a reaction time of 5 hours, for lube oil L an elimination of 87 % of PCB was obtained, whereas the PCBs elimination was equal to 76 % when reaction was performed on lube oil U. As shown by the chromatographic analyses of the chlorinated compounds in the original oils reported in Fig. 3, the PCBs present in the oil L consisted mainly of highly chlorinated molecules (penta-heptachlorobiphenyls), while less chlorinated PCBs (tri-pentachlorobiphenyls) were detected in the oil U.

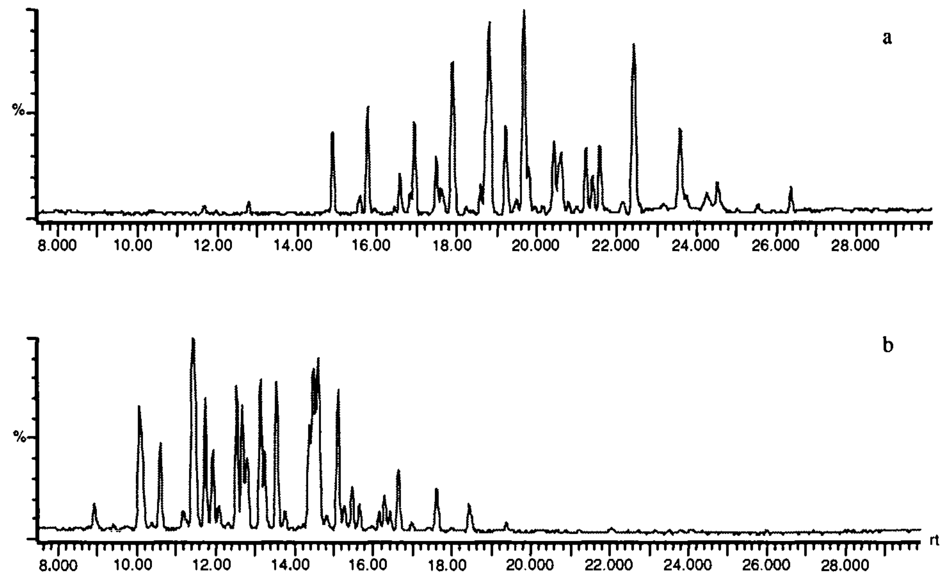


Figure 3: *Difference between PCBs Contained in Oil L (a) and in Oil U (b)*

Therefore by means of the proposed process the highly chlorinated biphenils are more quickly eliminated from the oil than the slightly chlorinated ones. Such a behavior of the reaction system is evident by observing the trend of disappearance of various PCBs during a typical run by using dielectric oil (see Figure 4).

As long as the treatment carries-on, the more chlorinated PCBs disappear and the residual amount of PCBs is increasingly less chlorinated. In particular, the highly chlorinated PCBs, with a retention time in the GLC column longer than 16 minutes, are removed from the oil after a run-time of 15 minutes, whereas the slightly chlorinated PCBs, whose retention time is shorter than 13 minutes, disappear at a very slow rate.

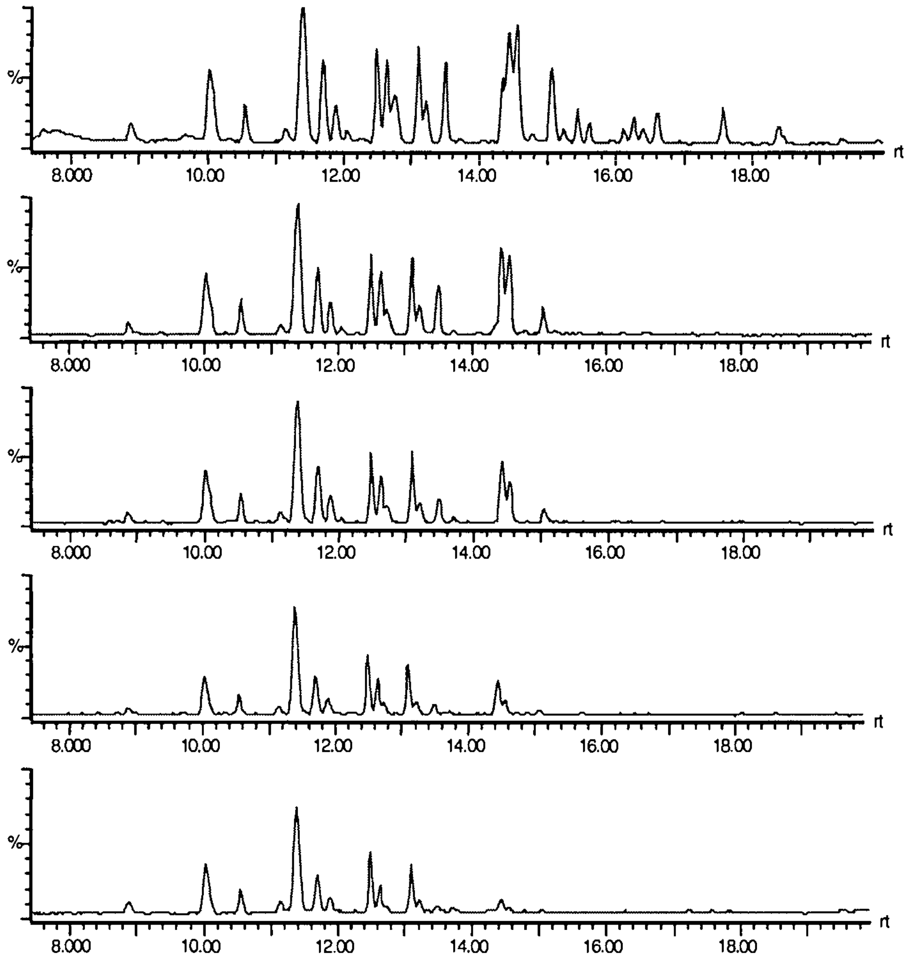


Figure 4: *Trend of Disappearance of PCBs at Different Values of Run Time for a Typical Run Conducted at PEG/Oil Weight Ratio = 0.2 and KOH/PEG Molar Ratio = 1.0; T = 110 °C Run Time: (a) t = 0 min; (b) t = 0.25 h; (c) t = 2.5 h; (d) t =4 h; (e) t = 5h.*

In order to study the influence of the chlorine content on the PCBs removal rate a number of identified PCB congeners were considered. The kinetic of singles PCBs disappearance was investigated by the reduction of the gas-chromatographic response area of their peaks. Thus, a number of gas-chromatographic peaks corresponding to homologous congeners were selected. The main characteristics of each considered peak are reported in Table 3; the response factors for each congener are reported in literature; for peaks corresponding to two congeners having the same relative retention time the response factor was assumed as the mean value of the response factors reported in literature for such congeners [15].

Table 3. Characteristics of the Considered GLC Peaks

Congener number	IUPAC name	Chlorine atoms	Relative retention time
28	2,4,4'-trichlorobiphenyl	3	0.384
52	2,2',5,5'-tetrachlorobiphenyl	4	0.434
90; 101	2,2',3,4',5 and 2,2',4,5,5'-pentachlorobiphenyl	5	0.554
132; 153	2,2',3,3',4,6' and 2,2',4,4',5,5'-hexachlorobiphenyl	6	0.670
138; 160	2,2',3,4,4',5' and 2,3,3',4,5,6-hexachlorobiphenyl	6	0.705
187	2,2',3,4',5,5',6-heptachlorobiphenyl	7	0.7292

The kinetic of removal of the selected PCB congeners were determined, evaluating the decreasing with time of the correspondent peak area. Runs were carried out by using dielectric oil, at KOH/PEG molar ratio of 0.85 and PEG/oil weight ratio of 0.2; the reaction temperatures were 100, 110 and 120 °C. Table 4 reports as example the gas-chromatographic areas values measured at different times for run performed at 100 °C.

Table 4. GLC Areas Measured for Selected Congeners During Run Performed at 100 °C

Congener number	Peak area response after (min)						
	0	15	45	60	150	240	300
28	18731	17818	17590	17161	16780	15379	12454
52	14473	14299	13200	12938	11393	11274	9544
90; 101	49910	41688	22202	19110	5698	2638	n.d
132; 153	121537	78274	26055	14714	n.d	n.d	n.d
138; 160	124488	43445	8332	4269	n.d	n.d	n.d
187	78645	8167	1150	n.d	n.d	n.d	n.d

n.d.: not detectable by GLC

When the kinetic of the heterogeneous reaction is expressed in terms of pseudo-homogeneous rate, for each congener the form of the kinetic expression that better fits the experimental data is:

$$r = -\frac{d[PCB_{cong}]}{dt} = -k_{cong}[PCB_{cong}] \qquad (1)$$

Then the kinetic of PCB removal results of first order regarding to each congeners.
The dependence of the kinetic constant from the chlorine content was analysed. From the k_{cong} calculated for the hexachlorinated homologous (132-153 and 138-160) the starting hypothesis about a correlation between the number of chlorine atoms and k_{cong} was not verified. On the contrary was found that the reaction kinetic constants increase exponentially with the relative retention time (RRT) for each reaction temperature, as is shown in Fig. 5.
The exponential correlation between the k_{cong} and relative retention times, as reported in Fig. 5, was found only for the selected congeners giving rise to the six considered chromatographic peaks.

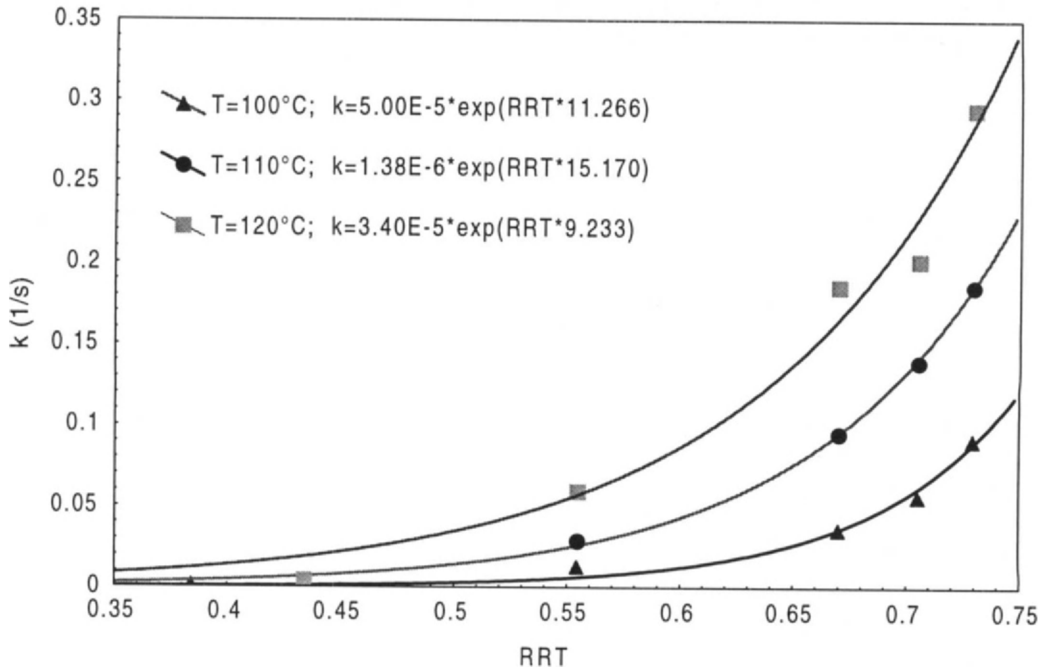


Figure 5: *Kinetic Constant vs. Relative Retention Time.*

The found correlation between k_{cong} and the relative retention time indicates that the reactivity of each PCB is not only dependent by the number of activated chlorine atoms but also by the PCB structure and conformation: in literature is reported that the general trend is an increase of the relative retention time with chlorine content, but for homologues PCBs the RRT is dependent on structure, increasing when chlorines are placed further from the biphenyl bridge and for these homologues which can more readily assume a planar conformation [15,16].
As reported above and shown in Fig. 1 the studied reaction is first order respect to KPEG concentration.
Therefore the global reaction kinetics for the removal of a PCBs mixtures from a mineral oil could be written as:

$$r = -\frac{d[PCB]}{dt} = -k'(\sum k_{cong}[PCB_{cong}])[KPEG] \qquad (2)$$

4 Conclusion

The so called KPEG process is effective to eliminate PCBs both from dielectric and lube used oils, but a remarkable difference of reactivity occurs in the two cases. In fact, PCBs can be completely removed from the dielectric oils under mild operating conditions, whereas a small fraction of PCBs still remains in the lube oils after the treatment, regardless more severe operating conditions applied. The reduced efficiency of the disposal treatment is probably due to the several additives present in lube oils.
The kinetic of the PCBs removal reaction from a dielectric oil using the KPEG treatment was also determined. The reaction resulted first order relatively to each congener concentration and first order relatively to the polyethylene glycol alkoxide concentration. The calculated kinetic constants for the considered congeners, have showed an exponential correlation with their gas-chromatographic relative retention time.

The removal of PCBs is strongly affected by their structural conformation and not only by the chlorine content; from the kinetic results it is confirmed that the slightly chlorinated PCB are more hardly removed, whereas the more chlorinated PCBs are those more easily eliminated.

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HEAVY METALS PARTITIONING IN WASTE INCINERATION

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Abstract

Over the past years, many efforts have been made towards improving the efficiency of flue gases treatment in waste incineration in order to meet the more and more stringent limits prescribed for emissions of acid gases and toxic organic compounds.
Conversely, less attention has been devoted to the investigation of heavy metals behavior during combustion. Heavy metals can deserve special attention, due to the enrichment phenomena usually observed onto small solid particles.
Heavy metals release due to waste incineration depends not only on the concentrations in the waste itself, but mostly on the physical mechanisms and chemical transformations acting during combustion, which can greatly affect heavy metals partitioning among the different residues. Some highly volatile metals, in spite of their relatively low concentrations in the untreated waste, can therefore be present at very high concentrations (thus showing very high enrichment factors) in fly ash or in flue gas dust.
In the present paper a number of data concerning partitioning of some typical lithophilic and volatile metals as detected in a full-scale Hospital Solid Waste (HSW) incineration plant are presented.

1 Introduction

The tendency of modern waste management is towards the adoption of different technologies for waste treatment and/or disposal (integrated waste management).
Among the various options, waste incineration is expected to be increasingly used as a valid and efficient treatment technology, especially in those countries characterized by high population density and hydrogeological vulnerability, where selecting sites suitable for landfilling may represent a serious issue.
As a matter of fact, waste incineration results in several advantages that can be summarized as follows: *1)* reduction of waste volume and weight is achieved by converting the organic

matter into gaseous end products (CO_2 and H_2O); *2)* reduction of health hazard represented by the presence of toxic organic compounds in the waste is again obtained by transforming them into non-toxic gaseous products; *3)* valorization of the energy content of the waste can be accomplished by recovering steam and/or electric energy.
Over the past years many efforts have been made towards improving the efficiency of flue gases treatment in waste incineration in order to meet the more and more stringent limits prescribed for the emissions of acid gases and toxic organic compounds.
Conversely, less attention has been devoted to the investigation of heavy metals behavior during combustion.
Heavy metals, at trace concentrations, are considered as important nutrients. At higher concentrations, however, heavy metals are characterized by a relevant toxicity relative to biological systems, particularly human beings.
Heavy metals can deserve special attention in waste incineration due to the enrichment phenomena usually observed onto small solid particles, which are not effectively collected by conventional air pollution control (APC) devices and are therefore likely to be emitted into the atmosphere. It must be taken into account that in various emission systems heavy metals can occur at greatly differing individual concentrations and hence each of them can be given a different relevance. On the other hand, heavy metals release from waste incineration plants depends not only on the concentrations in the waste itself, but mostly on the physical mechanisms and chemical transformations acting during combustion, which can greatly affect heavy metals partitioning among the different residues. Some highly volatile metals, in spite of their relatively low concentrations in the untreated waste, can therefore be present at very high concentrations (thus showing very high enrichment factors) in fly ash or in flue gas dust.

2 Heavy Metals Thermal Behavior

Heavy metals are more or less uniformly distributed in the waste being fed to an incineration plant. Their thermal behavior determines their distribution among the solid phases and the flue gas, depending on the chemical and thermal conditions in the combustion chamber.
Several mechanisms may affect heavy metals behavior during combustion. These mechanisms can be grouped in the following transformation categories (see Figure 1) [12]: *1)* vaporization from the bulk of the burning waste; *2)* formation of new species due to reactions with other waste components; *3)* particle entrainment by the flue gases; *4)* vapors condensation on particulate matter; *5)* solid particles coagulation; *6)* wall deposition of vapors and particulate matter; *7)* suspended particles interception by APC devices.
Metals are generally present in wastes as either small mineral inclusions within the organic matrix or elemental species incorporated in the structure of organic compounds. Some metallic compounds are not affected by the combustion conditions, therefore they do not undergo any change in their chemical form during the process. Among such compounds, those associated to larger particles will be removed along with the bottom ash, while the ones associated to smaller particles (particle size usually in the range $1 \div 100\ \mu m$) are transported by the gas stream in its way to the following units. The extent of entrainment is a function of size, shape and density of the ash particles as well as the incinerator operating conditions [1].
Metals or metallic species characterized by a certain volatility under the combustion conditions (i.e. the volatilization temperature is lower than the temperature in the combustion chamber) can vaporize, therefore diffusing into the exhaust gas stream, which then carries them through the incineration system.
Based on their boiling temperature, metals are usually classified as volatile ($T_b < 1500°C$) or lithophilic ($T_b > 1500°C$) metals [11]. Examples of volatile heavy metals are Hg, Cd, Sn, Se, Zn, Pb, As, Sb; examples of lithophilic heavy metals are Cr, Ni and Cu.

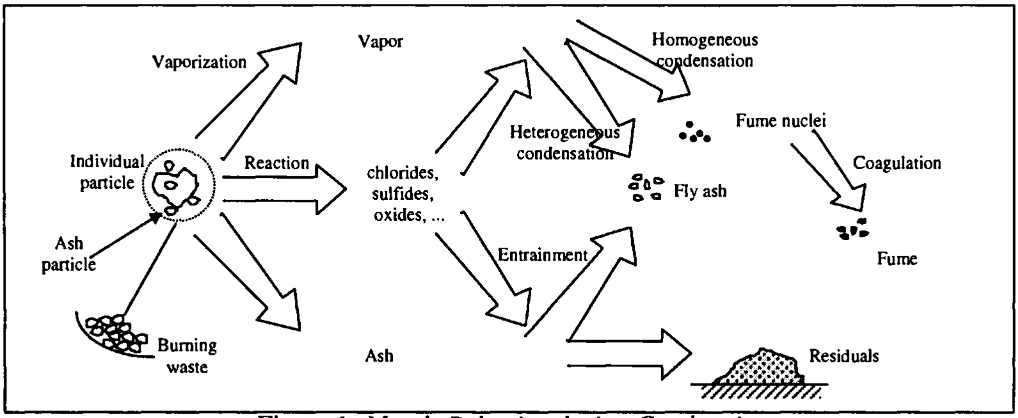

Figure 1: *Metals Behavior during Combustion*

The effect of temperature on vapor pressure of metallic compounds has been identified [4] as playing a critical role in affecting the extent of metal vaporization. An increase in temperature results in an exponential increase in vapor pressure of metallic compounds.

Figure 2 shows the dependence of temperature on vapor pressure for some metallic species (elemental metal, oxides and chlorides).

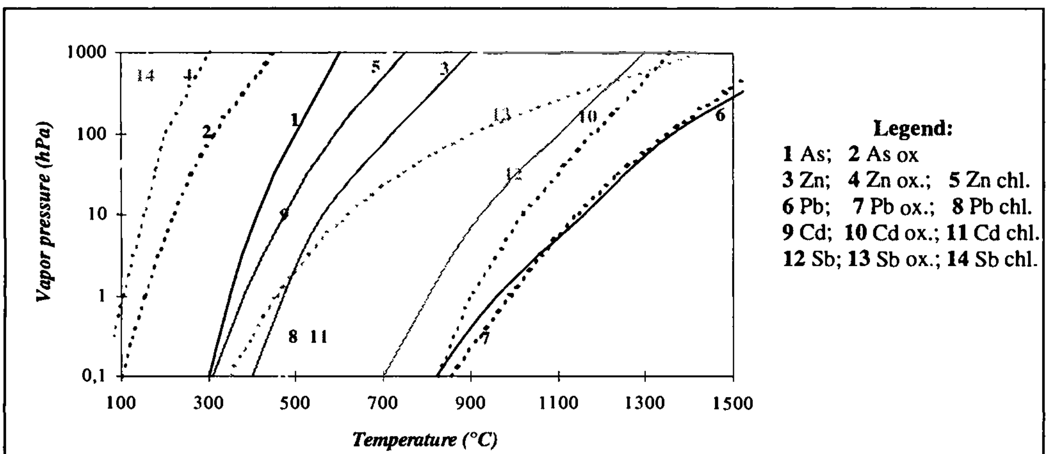

Figure 2: *Vapor Pressures of Some Metallic Species as a Function of Temperature*

As the exhaust gases are cooled, supersaturation pressures may force the vapor phase metals to condense both homogeneously (nucleation) to form new particles, or heterogeneously on the available surfaces. The two mechanisms occur simultaneously, but at different rates depending on the operating conditions.

Nucleation may occur when the partial pressure of the vapor species exceeds a certain critical value; the flue gases become super-saturated as a result of either cooling or formation of a new, less volatile, species [8].

Heterogeneous condensation occurs when surfaces are available and the degree of super-saturation is low. Entrained ash particles or chamber walls may act as condensation sites.

Homogeneous condensation gives particles less than 1 μm in diameter. The dimensions of the particles produced by heterogeneous condensation depend on the nature and dimensions of the entrained ash particles: heterogeneous condensation tends to favor small particles, due to their high specific surface. This is the reason why the smaller particles are usually more

concentrated in heavy metals than the original waste.
The quantities of metals emitted at the stack along with the suspended particles are strictly related to the dimensions of particles resulting from both homogeneous and heterogeneous condensation. Particle size determines the possibility of interception by APC devices. It can be generally stated that stack emissions of metals are reduced when heterogeneous condensation phenomena prevail [1].
Metals species can also undergo some transformations in their chemical form during combustion. It is well known that metal-containing materials can react in the combustion chamber according basically to two main categories of reactions. According to the first kind of reactions, the reactive elements released during organic compounds combustion combine with metals. These reactive elements are generally chlorine and sulfur. Organically-bound chlorine (mainly contained in plastics) is directly converted into HCl during the combustion process. Organic chlorides, which are thermally stable, at high temperatures form HCl due to hydrolysis reactions. The presence of these gaseous compounds, as well as of the chlorides of alkaline elements, cause the formation of heavy metals chlorides, which generally have a higher volatility than the corresponding oxides or elemental metals.
Another kind of reaction having the potential to form volatile species is the possibility of ion exchange reactions between inorganic salts - like chlorides - and heavy metals (especially Zn) sulfates; these reactions are responsible for the formation of chlorides of heavy metals (which are generally highly volatile [1], [9], [11], [12]) and sulfates (which are generally almost immobile):

$$2\,NaCl + ZnSO_4 \longleftrightarrow ZnCl_2 + Na_2SO_4 \qquad (1)$$

The second category of reactions can be caused by the formation of high temperature, oxygen-depleted zones around the burning waste. These conditions may form locally almost in all waste combustion systems though they are actually operated with high excess air values. In this case the reactions basically involve the reduction of metal oxides, and the newly formed reduced compounds often volatilize more readily than the original species. Once vapors diffuse away from the waste and encounter lower temperatures and higher oxygen concentrations, the reduced species undergo secondary reactions which convert back to the original, less volatile forms and therefore condense (either homogeneously or heterogeneously).

3 Materials and Methods

The investigated HSW incineration plant consists of two parallel lines of 60 t/d waste each equipped with the following main units:

- a rotary kiln combustion chamber being operated at a temperature of 1000°C;
- a post-combustion chamber being operated at 950°C;
- a boiler for exhaust gas cooling;
- a selective non-catalytic NO_x reduction by means of ammonia addition;
- a dry acid gases neutralization and adsorption section by means of lime and activated carbon addition;
- a fabric filter for particulate matter removal;
- a spray scrubber tower for mercury removal.

In order to investigate heavy metals behavior during combustion and their distribution among the different residues, a sampling campaign was carried out. Over a total period of ten days aliquots of solid and liquid residues were withdrawn every two hours. Heavy metals concentrations in the gases emitted from the stack were also recorded.
The process residues were bottom ash collected at the end section of the combustion chamber,

boiler ash collected from the boiler, fly ash collected from the baghouse, water from the bottom ash quenching section and water coming from the spray scrubber.
The analyses of heavy metals were made by means of an atomic adsorption spectrophotometer with an air-acetylene flame. For the solid residues treatments consisting of sample homogenization and subsequent digestion were previously performed [10].

4 Results and Discussion

In Figure 3 the fluxes of solid materials for the examined incineration plant are shown.

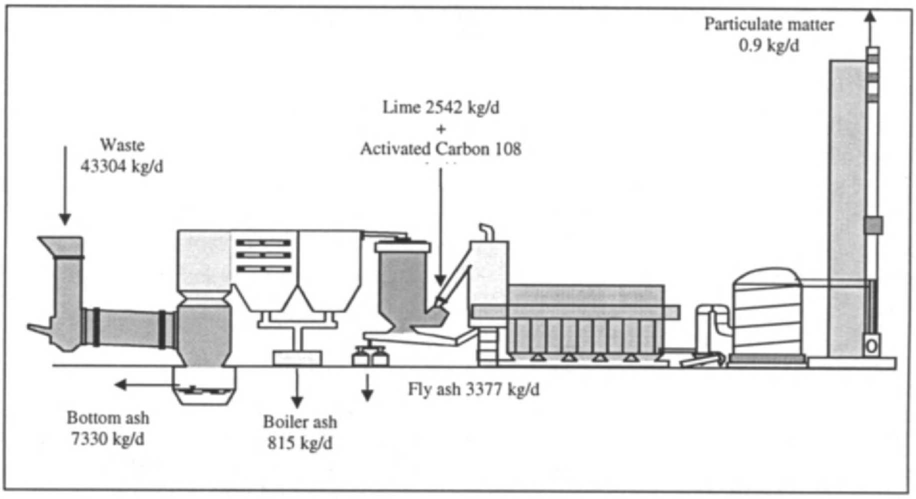

Figure 3: *Solids Mass Fluxes for the HSW Incineration Plant*

In Table 1 the concentrations of some of the analyzed heavy metals in the different residues are shown. The reported data refer to the observed concentration range and to the corresponding mean value and standard deviation.
It can be observed that the measured concentrations are often remarkably different with respect to the corresponding mean value, thus revealing a considerable variability in the residues characteristics. In such cases a statistical analysis could help interpret the distribution of metal concentration in the residues.
As to the values relating to the metals concentrations in the liquid streams, it can be noticed that they are in all cases lower than or around the corresponding detection limit. The only exception is represented by mercury, which revealed measurable concentrations in water coming from the spray scrubber; this is to be ascribed to the condensation phenomena occurring as a result of flue gases washing.
In Figure 4 heavy metals partitioning among the different residues is presented. The investigated heavy metals were chosen based on their toxicity characteristics and their thermal behavior: Cd and Hg are recognized as volatile metals, while Cr and Ni belong to the group of the lithophilic elements.
As far as cadmium is concerned, according to thermodynamic evaluations this element and its oxides are predicted to be preferentially converted into volatile chlorides ($CdCl_{2(g)}$) [16] under the conditions prevailing in the combustion chamber. Cadmium chlorides can subsequently condense onto the surface of solid particles, causing the well known enrichment phenomena on small particles. It was shown [17] that cadmium compounds form condensed particles which are smaller ($0.1 \div 1$ μm) in size than those formed by other metallic species.

Table 1: *Heavy Metals Concentrations in the Different Residue Streams*

Residue stream		Cd (mg/l)	Hg (μg/l)	Cr (mg/l)	Ni (mg/l)
Spray scrubber water	min.	n.d.	2.61	n.d.	n.d.
	max.	n.d.	155.20	n.d.	0.03
	mean	n.d.	22.72	n.d.	0.00
	s.q.m.	n.d.	24.82	n.d.	0.01
		(mg/l)	(μg/l)	(mg/l)	(mg/l)
Bottom ash quenching water	min.	n.d.	n.d.	n.d.	0.02
	max.	n.d.	n.d.	n.d.	0.04
	mean	n.d.	n.d.	n.d.	0.02
	s.q.m.	n.d.	n.d.	n.d.	0.01
		(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Bottom ash	min.	4.97	n.d.	152.83	105.28
	max.	24.31	n.d.	5021.12	9565.56
	mean	10.82	n.d.	684.80	2085.96
	s.q.m.	2.80	n.d.	943.80	3112.27
		(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Boiler ash	min.	8.91	n.d.	37.11	80.65
	max.	39.56	0.91	856.36	173.06
	mean	17.04	0.23	274.92	128.51
	s.q.m.	5.80	0.17	100.53	20.46
		(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Fly ash	min.	7.89	18.66	10.31	16.99
	max.	36.73	404.22	33.22	37.52
	mean	21.16	74.43	22.49	32.91
	s.q.m.	6.03	67.78	4.34	3.41
		(mg/Nm^3)	(mg/Nm^3)	(mg/Nm^3)	(mg/Nm^3)
Flue gases	min.	<0.00001	<0.0001	<0.0001	<0.0003
	max.	0.00016	0.0108	0.0034	0.0100
	mean	0.00005	0.0021	0.0007	0.0019
	s.q.m.	0.00005	0.0024	0.0008	0.0022

n.d. - not detectable

In the investigated plant cadmium volatilization appears to occur to a lesser extent than would be anticipated based on thermodynamic evaluations [2], [3], [16]. As a matter of fact, 48% of the cadmium being fed with the waste was found in bottom ash. This may be ascribed to the presence of relevant concentrations of carbonates or sulfates, which can form stable solid compounds, such as $CdCO_{3(s)}$ and $CdSO_{4(s)}$ [15]. Under locally-reducing conditions (due to the presence of oxygen-depleted zones), sulfur can also react to form $CdS_{(s)}$, which is also stable under the combustion chamber conditions.

Anyhow, the absence of cadmium at the stack proves that the volatile compounds leaving the combustion chamber will subsequently condense almost completely as the temperature drops down.

Besides, the fraction of cadmium coming out of the plant along with boiler ash was noticed to be quite small (8% ca.) when compared to the one associated with fly ash (43% ca.); this may be ascribed to the fact that condensation leads to the formation of small solid particles, since cadmium compounds are not highly volatile at the boiler exit temperature.

As far as mercury is concerned, most of its compounds have relatively high vapor pressure values. Mercury compounds can remain in the gaseous phase even at temperatures lower than 180°C. The main volatile species commonly found in the exhaust gases are chlorides ($HgCl_{2(g)}$, $Hg_2Cl_{2(g)}$), elemental mercury ($Hg_{(g)}$) and, to a lesser extent, mercuric oxide ($HgO_{(g)}$) [3], [13], [16].

In the investigated plant almost all the mercury entering the incinerator along with the waste is present in the ash from the baghouse filter; this can be awarded to the following causes: *1)* to its condensation onto the solid particles in the form of chlorides or sulfates (which are indeed highly concentrated in such residues); the chemical species that can be formed are usually $HgCl_{2(c)}$, $Hg_2SO_{4(s)}$, $HgSO_{4(s)}$, $Hg_2Cl_{2(s)}$ [13]; *2)* to the adsorption phenomena onto activated carbon, that are recognized to be basically responsible for metallic mercury removal.

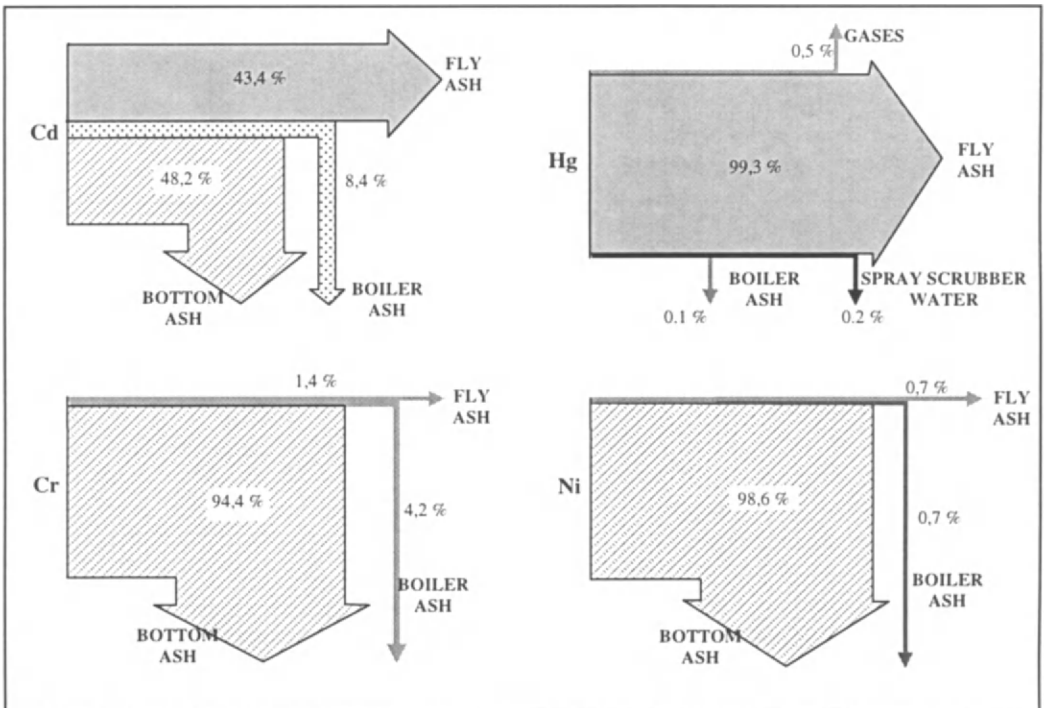

Figure 4: *Heavy Metals Partitioning Among the Different Residues*

Among lithophilic metals, chromium has been shown to thermally behave strictly depending on chlorine concentration: for low chlorine concentrations the prevalent compound is $Cr_2O_{3(s)}$, that is thermally stable at the combustion temperatures [12]; as chlorine content increases, higher amounts of chromium can be converted to volatile chlorides (like $CrO_2Cl_{2(g)}$ or $CrCl_{4(g)}$). It must also be observed that, among those chromium compounds, the chloride $CrO_2Cl_{2(g)}$ contains the highly toxic hexavalent chromium, while the oxide $Cr_2O_{3(s)}$ contains trivalent chromium.

During the experimental campaign carried out at the HSW incineration plant, chromium revealed the strong tendency to form solid species [2], [6] (approximately 94% of chromium was found in bottom ash). Speciation of chromium in the solid residues was also investigated, thus showing that for bottom ash hexavalent chromium represents a negligible fraction (within the range 1/50 ÷ 1/100) of total chromium, so it can be concluded that chromium is essentially present in bottom ash in its reduced form (mainly as trivalent oxide $Cr_2O_{3(s)}$). For boiler ash, the fraction of hexavalent chromium compared to total chromium is higher (approximately 1/10) than for bottom ash, thus indicating a slight volatilization of chromium in its hexavalent state (e.g. $CrO_2Cl_{2(g)}$); the remainder of chromium in the boiler ash can be present either in the trivalent form as solid species entrained by the exhaust gases or in the more uncommon tetravalent or pentavalent form as gaseous species (such as $CrCl_{4(g)}$, $CrO_2OH_{(g)}$, $CrO(OH)_{3(g)}$, $CrO(OH)_{2(g)}$).

As far as nickel is concerned, its solid species are generally thermally stable within a wide range of temperatures [2], [11], [14]: the main nickel compounds are usually represented by $NiCl_{2(s)}$ and $NiO_{(s)}$ (at low and high temperatures respectively). The volatile species that may be formed (e.g. $NiCl_{2(g)}$, $Ni(OH)_{2(g)}$, $NiCl_{(g)}$, $Ni(CO)_{4(g)}$) are generally present only at very

high temperatures (above 1000°C) and at low concentrations.
The characterization of the different residues showed that nickel is present almost totally (99% ca.) in bottom ash; this allowed the existence of significant volatilization or entrainment phenomena to be excluded for the investigated process.

5 Conclusions

The present paper presented a review of the main mechanisms recognized to be affecting heavy metals thermal behavior during combustion.
Partitioning of some heavy metals, as representative of either a lithophilic or a volatile behavior, was calculated based on the analyses conducted on the residues from a HSW incineration plant.
Cadmium showed appreciable concentrations in bottom ash, boiler ash and fly ash. However, the extent of volatilization was lower than would theoretically be predicted based on thermodynamic calculations.
Due to its extreme volatility even at relatively low temperatures, mercury was almost totally found in the ash collected from the baghouse.
As to chromium and nickel, the highest fractions (94% and 99% ca., respectively) of the total amount entering along with the waste were detected, due to their low thermal mobility, in bottom ash. Further analyses for hexavalent chromium content revealed that chromium is almost totally present in bottom ash in its reduced state, while an appreciable fraction in boiler ash is in the form of oxidized chromium.
A better understanding of the mechanisms affecting heavy metals partitioning in waste incineration will be attained by means of some additional experimental campaigns. In particular, a more detailed investigation will be carried out by analyzing the various residues streams (including particulate matter and gaseous phase composition) at the outlet of each plant unit.
This will allow the extent of entrainment phenomena and condensation mechanisms to be more carefully detected and more precisely quantified.

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LONG DURATION COMPRESSIBILITY TESTS ON MSW

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Abstract

The prevision of settlements is a major item in designing a sanitary landfill. In order to have a behaviour significant model, it is also necessary to consider the initial waste composition, the fluids action, and the landfill environmental conditions. This paper gives account of the results of laboratory tests, with the purpose of giving a contribution to the construction of a preliminary behaviour model.

1 Introduction

Municipal solid waste (MSW) is a highly deformable material because of its specific composition and disposal techniques [8] [9] [14]. The great deformations that waste heaps can undergo raise serious problems in terms of functionality and management of the sanitary landfills because they influence the stability in time of the drainage systems, the possibility of reclaiming the landfill area and the evaluation of the available dumping volume. In the design stage of a landfill, it is necessary to have the right tools to make an accurate evaluation of its settlement.
There are no specific models for calculating MSW landfill settlements. The analysis of landfills settlements with classical geotechnical methods has given scattered results.
Some elementary models deriving from Soil Mechanics methods do not seem totally reliable [18] [20] [7] [5] [17] [19].

2 MSW Compressibility

Waste has a highly heterogeneous composition and a great deformability of its solid elements many of which may undergo deep physical and structural changes in time. Fluid pressure, both liquid and gaseous, within waste mass is influenced by these changes and cannot be controlled by means of simple techniques [10] [13]
The compressibility characteristics of a multiphase medium depend on complex mechanisms linked to the effect of external loads on the solid elements. Such mechanisms are regulated by transient regimes between the fluid phases. To study the compressibility of MSW, deformability of the solid phase and the role played by the fluids (liquid and gaseous) are to

be taken into account.

2.1 Solid Phase - Waste Composition

In order to interpret the overall mechanical behaviour, the various materials that form MSW may be divided into three main classes:
Class A: stable inert elements. This category groups materials whose initial composition does not vary in the short term and whose strength and deformability characteristics do not affect the overall behaviour of the landfill. This group includes glass, ceramics, metal elements, masonry debris and natural materials used as daily cover.
Class B: highly deformable elements. Paper, fabric, rubber, plastic sheet , tyres, etc. All these materials undergo settlements and shape changes under load. Most of them tend to dispose themselves so as to acquire structural characteristics of a well-stratified medium and the mechanical behaviour of highly anisotropic material which can be compared to a "reinforced soil".
Class C: readily degradable elements. Waste contains large amounts of organic matters such as vegetables, food waste and the so-called "undersieve" [4]. These materials undergo degradation and transformation processes causing variations in volume and in the rheological features of the waste heap as well as in its average permeability. The duration and evolution of degradation processes cannot be foreseen. Recent experiences showed that, under certain conditions, decay process may be very long as shown by the results of a study on the New York municipal landfill [15].
This classification has allowed the correlation between initial composition of MSW and mechanical properties of waste [11]. The composition of waste in a landfill vary according to many factors, such as climate, people's lifestyle, garbage collection system, pretreatment, etc.. In Figure 1 a large number of data on the composition of MSW from different countries is represented in a triangular diagram. Representative points are clustered in zones according to the geographic origin of MSW.

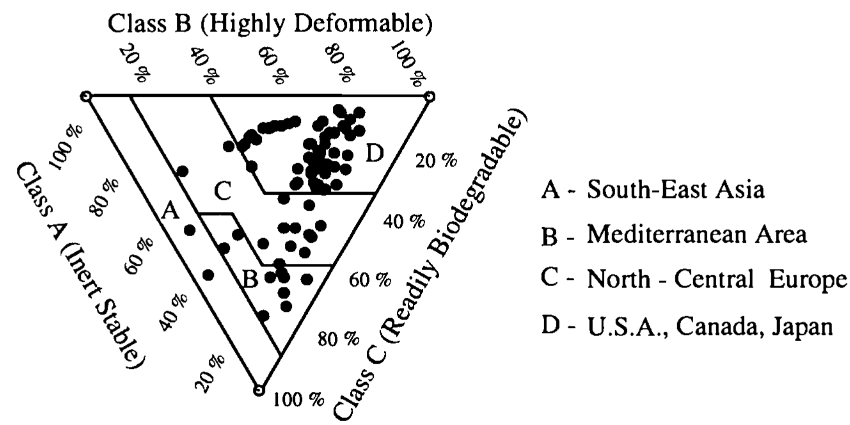

Figure 1: *MSW Classification for Different Geographic Area*

2.2 Fluids Effect

The presence of fluids modifies the properties of solid materials causing a different global rheological behaviour. Some waste components rich in micropores (paper, wood, fabric) can absorb large amounts of fluids which, under loads and/or in time, may cause changes in their physical state and mechanical properties. There is a limit condition corresponding to the maximum amount of fluid that a material can absorb before leachate begins to form [3]. Under such limit condition the "absorbing" elements are generally saturated. Water content is

not constant and varies with stress level, time and decay rate .
Waste compressibility may be interpretated by referring to three different physical states:
a) Totally saturated material. This is the case of landfill bottom layers where circulating leachate is constantly present.
b) Material close to leaching. This is the condition of most waste landfill exposed to rain and running waters.
c) Virtually dry waste. Fluid contents in this waste correspond to natural water contents. This is the case of dumped materials in dry climates or waste which is sheltered from rain and runoff waters.

If a loaded saturated waste sample is taken into consideration, its deformation process is similar to the consolidation in saturated soils. However, if the specific structure of some waste components is considered, two phases of this process may be distinguished: A phase (a) controlling initial settlements and major overall deformations in deformable elements; a second phase (b) which is controlled by the fluids overpressure release in the materials capable of absorbing or trapping fluids. Phase "a" is a relatively short phase because the average permeability of waste is generally high and, therefore, the loads transfer time to the solid skeleton is independent of pore water. Magnitude and duration of phase "b" depend on the amount and type of materials that can capture and keep fluids within their inner structure [20]. Once phases "a" and "b" are over, further deformations will mostly depend on the "creep" of materials forming the solid phase. Owing to the peculiar rheological features of some solid elements (plastic and rubber), "creep" can lead to very large deformations developing over long time; final deformation will depend on the overall arrangement assumed by the "inert stable elements".

In the case of waste close to leaching, the process described for the saturated material is preceded by a transient phase, which generally has short duration and is accompanied by large deformations. During this transient phase, a conspicuous decrease of porosity occurs with no significant variations in water contents; hence conditions close to saturation set in. The substantial difference between initially saturated and unsaturated materials is that a larger amount of fluids accelerate degradation and decay processes in some substances and materials (e.g. paper, cloths etc) [10] [8] [9]. Such trends are substantially in agreement with the remarks made for saturated peaty soils with a strong fibrous component [1] [6]. This confirms that water accelerates the "softening" and degradation process of some materials (mainly paper and textiles).

In the case of waste dumped in a landfill, the model is more complex as it has to take into account the effects of organic matters decay, which is accompanied by gas production. Other factors influencing the model are connected with the characteristics of fluids (leachate and gas) and with the rearrangement of inert materials due to the ravelling of fine materials inside the mass.

3 Deformability of Waste Heap

Deformations resulting from loading depend on how waste constitutive elements arrange themselves to contrast stresses.

In medium- to coarse-grained soils, deformations are essentially associated with slips between grains, which hence rearrange themselves to new equilibrium conditions; volume variations of single elements resulting from loading are virtually negligible. In the case of waste many solid elements can vary in shape and volume both because of a great intrinsic deformability and because of transformation resulting from decay processes. As to the average composition of a waste heap, it is probable that, from the volume point of view, highly deformable and degradable elements prevail. Contact between the so-called "Class A - inert stable elements" is limited to a few points. Under load, the "Class B - highly deformable elements" account for the marked initial decrease in mass volume. In this phase, the inert stable elements undergo major shifts and tend to gradually arrange themselves according to a final pattern. Contact between these elements is prevented by deformable materials and by organic matters. Therefore, deformations in the heap will continue to be conspicuous and to occur over long time because of constant load slow deformations of the "creep" type and of the decomposition of organic matter.

Magnitude and evolution of deformations will depend on nature and amount of materials with a creep behaviour, on stress level and on environmental conditions. At the end of the deformation processes, direct contacts between inert stable elements will be reinstated and the behaviour of the mass would be quite similar to that of a soil.

Thus, it is possible to draw a theoretical compressibility curve by taking into account most of the characteristic phases of the waste heap deformation (Fig. 2) [8]

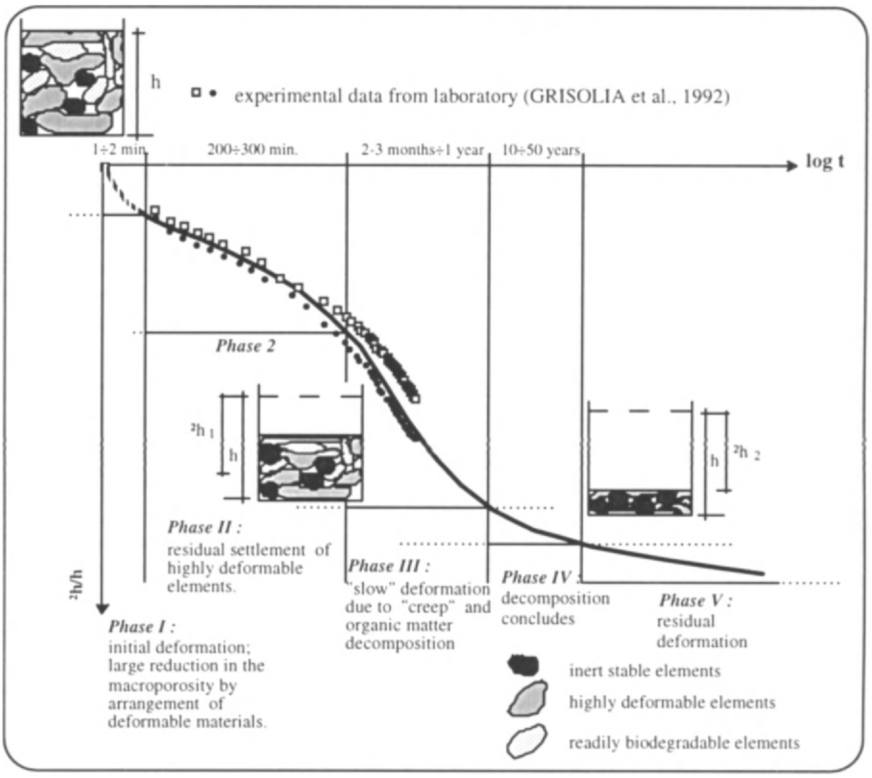

Figure 2: *Deformability Quality Model for MSW*

After the closure of a landfill, there is a rapid primary compression (Phases I and II) followed by secondary compression (Phases III and IV) or creep, which continues at a rate which is roughly proportional to log time. The primary (physical) compression stage occurs rapidly with little or no pore pressure build up and is usually complete within less than a month. Primary compression is relatively large.The amount of immediate settlements strongly depends on initial composition of MSW particularly referred to the kind and status of high deformable elements. The overall behaviour depending on contribution af the single components and by their initial structure.

Secondary compression is also relatively large and is due both to physical creep and to biodegradation. The continuing settlement under selfweight can be extremely high. Surcharge loading on existing landfill will also cause high secondary compression in the form of re-activated physical creep.

The process of decay of organic matter implies a reduction in volume of the waste mass due to the degradation of initially solid materials transformed into liquid and gas. Magnitude and rate of such events depend on the amount and type of organic matter and on the contingent environmental conditions.

The evolution of waste degradation processes can be followed by observing changes in temperature, in leachate chemical and biological properties, in the amount and type of biogas, etc. [12]. Some measurements of long duration settlements under constant load, carried out on a pilot landfill at lab scale, have provided interesting data [2]. The diagram of Figure 3 shows the trend of settlements observed in time. The values of settlements have been correlated with other factors controlled during the tests, such as quantity and ways of water addition and of recirculating leachate, temperature trend, quantity and characters of the produced leachate.

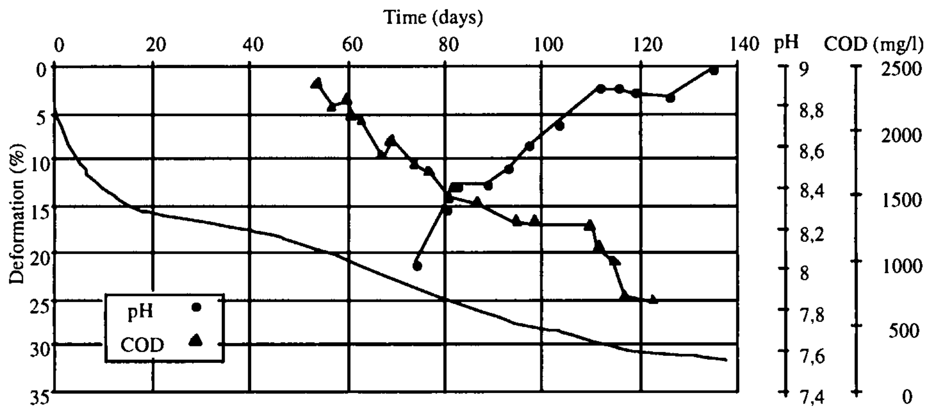

Figure 3: *Typical Settlement vs Time Curves in Oedometric Tests for MSW Samples*

4 Long Duration Laboratory Tests

Deformability laboratory tests were carried out on large size of reconstituted sample of MSW in which the organic matter was previously stabilized so that it is possible to study only the influence of mechanical and creep deformation of MSW whithout the presence of biological decomposition.
The test apparatus was a oedometer cell with 0.28 m in diameter and 0.5 m in height with the possibility of drenage control at the bottom. In Table 1 and 2 the merceological composition of the sample and test conditions are summarized.

Table 1: *Merceological Composition of the Sample*

Class	% by wet weight
Class (A)	30
Metals, Glass, Ceramic, Soil etc.	
Class (B)	30
Paper, Textiles, Plastic, Rubber etc.	
(Class C)	40
Organic (Compost)	

Table 2: *Initial Test Conditions of the Sample*

Property	
Initial Height	0.45 m
Water Content	40 %
Initial Unit Weight	4.9 kN/mc
Compression Load	13 kPa
Compaction Energy	2.528 J/mq

The duration of the test was 651 days, until the rate of settlements was under a fixed values

that is related to a significant rate in an actual landfill (0.01 mm/day).
In Figure 4 is show the strain (•H/Ho) of the sample vs time and the rate of settlement vs time. Published records of field and laboratory measurements of landfill settlement have been reviewed to establish the most useful forms of the equations describing the end of primary and secondary compression and to obtain some typical values of coefficients for this laboratory test.
It must be noted that these values (expecially for actual landfill settlements data) do not represent total settlements, but only relative values with respect to the first reading. For this reason, they are more easily interpreted in terms of settlement rates.

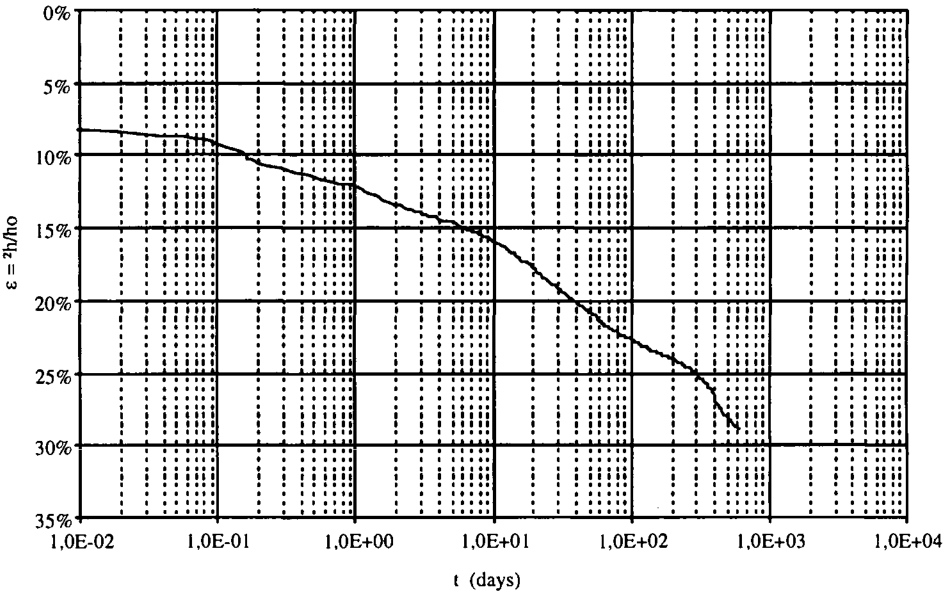

Figure 4: *Results from Laboratory Test*

The measured values of the settlement rate (difference of settlement between consecutive readings divided by the time elapsed between them). The origin of time for each level has been taken as the mid time between start and end of the corresponding construction period (the 'medium fill age', defined by Yen and Scanlon) [19].As expected, the settlement rate decreases with time.
Several authors have tried to interprete measured settlements or settlement rates with some fitting laws.
Sowers [18] adopted for MSW a behaviour similar to secondary consolidation of soils, in which settlement varies linearly with the logarithm of time:

$$\frac{Ss}{H} = C\alpha \, \mathrm{Log} \frac{tf}{ti} \tag{1}$$

where Ss is the secondary compression of a landfill of thickness H over the time interval between ti and tf, and Cα is the coefficient of secondary compression expressed in units of compressive strain per log cycle of time.
The Sowers model implies an inverse law for the settlement rate:

$$v = 0\,434 \;\; H\,C\alpha \frac{1}{t} \tag{2}$$

Equation (2) gives an infinite initial settlement rate, with endless settlement process, resulting in a "final settlement" tending to infinite.

For extimating the final settlement is necessary an integration of equation (3) between a reference time (to = 1gg at the lab scale) and the end of settlements:

$$S = C\alpha \; H \; Log \; (t) \qquad (3)$$

Yen and Scanlon [19] [17] observed the effect of age and fill thickness on the post construction settlement under self-weight of thick sanitary landfills in California. They express settlement rates in terms of settlement per month.
They proposed a logarithmic decrease of the rate:

$$v = a - b \; Log \; t \qquad (4)$$

where a has the meaning of the settlement rate at t = 1.

Yen and Scanlon give values for a and b for different construction times (tc) and landfill heights (H). The residual settlement under self weight can be obtained by integrating the settlement rate over a fixed time span (t1-tf):

$$Sr = (a \; tf - b \; (tf \log(tf) - tf \log(e))) - (a \; t1 - b \; (t1 \log(t1) - t1 \log(e))) \qquad (5)$$

Where "a" and "b" are obtained from experimental data fitting.

Gandolla et al. [7] used an exponential law like in a typical decay process:

$$v = ro \; H \; e^{-kt} \qquad (6)$$

where ro has the meaning of a initial unit rate.
For extimating the final settlement is necessary an integration of equation (6):

$$S = roH/k \; (1 - e^{-kt}) \qquad (7)$$

The final settlement is, for $t = \infty$:

$$Sf = ro \; H/k \qquad (8)$$

The authors developped this formulae fitting settlements observed in laboratory large scale tests.

In order to interpret the presented long duration test, a new law for rate of settlements versus time is proposed:

$$v = a \; t^{-\alpha} \qquad (9)$$

The final settlement is obtained from an integration of equation (9) between a reference time (to = 1gg) and the end of settlements:

$$S = (a/(1-\alpha) \; t^{-\alpha}) - a/(1-\alpha) \qquad (10)$$

In Figure 5, the results of equations (2), (4), (6), (9) have been plotted and compared with measured settlement rate in laboratory scale test.
The equations (2) and (9) fit well measured settlement rates for times over 1 day. For earlier stages the measured settlement rates are larger than that predicted by all equations.
In Table 3 are summarized the predicted settlement for all model and the actual data from labarotary test.

Table 3: *Results of Model Fitting vs Lab Data and Prediction of Settlementt*

Model	Settlement (mm)
Actual Test (between 1 and 651 days)	76.16
Sowers (between 1 and 651 days)	51.44
Yen and Scanlon (between 10 and 651 days)	24.34
Gandolla (t = ∞)	57.35
Proposed model (between 1 and 651 days)	72.36

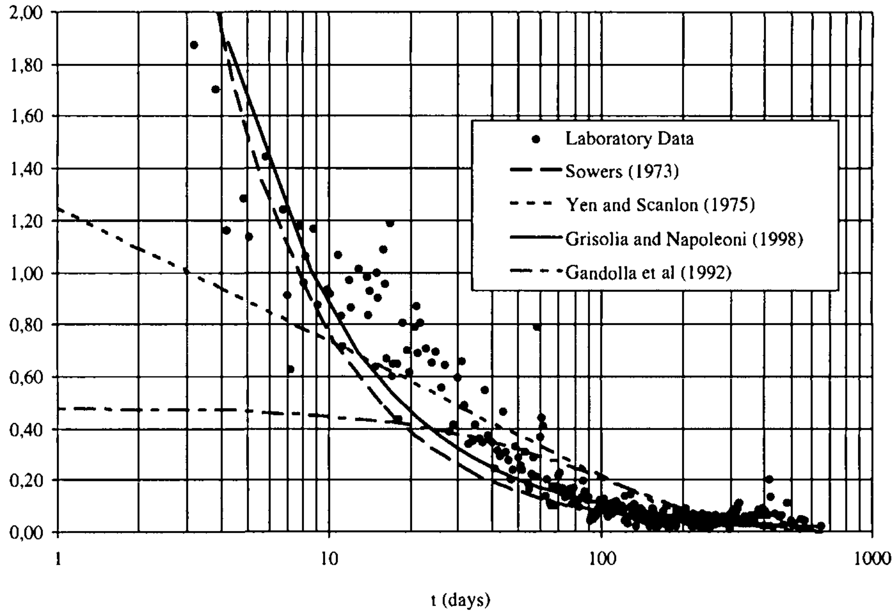

Figure 5: *Laboratory Test Data and Model Prediction*

5 Final Remarks

The possibility of reproducing the processes governing the deformability of a waste body in a simple and significant model is strongly hindered by the extreme complexity of the material and by the inadequacy of currently available experimental techniques.

Compressibility lab tests carried out on reconstituted waste samples made it possible to make only assumptions on the mechanisms governing the various phases of the process under different conditions.

In order to estimate long term settlements, the comparision of the results obtained shows a large scattering between the different prediction models adopted. It confirms that every model must be adapted to the single situation. In particular, it is essential to collect data on initial structural characteristics of materials having a creep behaviour and to study the behaviour of single components making up the waste so as to get useful indications on the bearing of each factor.

At present a monitoring system on the actual MSW landifill is an essential element to interpret and correctly extrapolate lab result.

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NEW TRENDS IN MUNICIPAL SOLID WASTE MANAGEMENT IN ITALY.

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Abstract

In the last twenty years it can observe in Italy a strong quality evolution for Municipal Solid Waste. In particular the collected data outlined a reduction of the moist organic fraction from the 49% (by weight) to the real values, varying in the range from 20 to 25%. It can be noted a strong increase of the packaging material (paper and plastic). The average MSW heating value is increased from 1,500 kcal/kg to a value of about 2,500 kcal/kg.
This evolution, together with some new Laws, make a strong change in the MSW disposal strategies.
The raw refuse composting was neglected while a more and more great attention is given to the materials recovery by source selected collection and to the energy recovery by incineration.

1 1 An Up-to-date Outline of Waste Disposal Solutions

1.1 A Brief History of the Evolution in Waste Disposal Systems

The Italian Republic has a population of 56 million people.
Until 1982, waste management policy in Italy was still regulated by a 1941 law. This law mostly controlled public cleaning services and promoted material recovery and recycling. Waste management policy was mainly suggested by the war economy at that time. Until the early 1950s a recycling plant with manual sorting was operating in Milan, and some composting plants were operating in the north of Italy.
Later, an economic boom reduced the need for material recovery and, due to pressure from hygienists, incineration became the optimal solution for solid waste disposal. This continued until the late 1970s. After incineration stack gases were found to contain dioxin, all construction of new incineration plants was stopped.
In the 1970s attention turned wholly to integral waste recycling plants (plastic, iron, paper pulp, compost, glass, RDF) after the Rome plant had started working (1,000 ton/d capacity).

The failure of this initiative at the end of the '70s, due to the low marketability of the recovered products, brought about serious doubts about the reliability of raw refuse recycling. Sanitary landfilling was then considered with interest, and the issuing of new regulations and guidelines gave impetus to this system. In 1982, the "New Waste Law" came into force and, together with other specific laws, has set up the principle of an integrated system based on waste avoidance, material recovery and recycling, incineration of combustibles with energy recovery and sanitary landfilling of the residues.

1.2 The Present Situation

The disposal criteria adopted in Italy today for MSW compared to those adopted in other countries are shown in Table 1. It can be seen how in Italy, as in almost all the other countries listed, landfills play a very important role. Only Sweden, Denmark and above all Japan mostly use incineration.
It is to be noted that in many countries, and above all in Italy, the use of incineration slowly decreased in the twenty years from 1970 to 1990 due to strong opposition from public opinion and environmentalist movements. In addition, many small plants were shut down when the new law (Law 915/1982) came into force in 1982, prescribing restrictive regulations to control atmospheric pollution and to promote energy recovery.
Recovery/recycling is carried out to a different extent from country to country; however, the data given are not always comparable. In particular, the data of USA and Denmark consider the recovery of quotas of "municipal-like wastes" and dangerous urban refuse not contemplated by other countries.
In any case, as far as E.U. countries are concerned, the quota of materials recovered through separate collection is on average 5-10%. The remaining quotas are mainly due to the production of compost.

Table 1: *MSW Disposal Methods Adopted in Various Countries (Percentage Quantities) [1, Updated]*

Country	Sanitary Landfill	Incineration	Recovery-recycling
Europe:			
Austria	64	20	16
Denmark	31	50	19
Finland	95	2	3
France	55	40	5
Germany	74	24	2
Italy	82	6	12
Holland	51	34	15
Sweden	35	60	5
Great Britain	88	11	1
Other Countries:			
USA	63	16	21
Japan	30	67	3

2 Disposal Strategies for the Near Future

2.1 The Guiding Principles Dictated by the European Union

The strategies in action in the various countries of the E.U. follow a priority scheme defined in a 1991 E.U. directive (directive 91/156/EEC). This scheme is in compliance with the following principles:

1. To give priority to the reduction of refuse at the source and of the chemical hazard of refuse, through appropriate intervention in technological production processes.
2. Secondarily, to favour the recovery and recycling of materials, as well as the use of refuse as a source of energy.
3. Finally, to send to the landfill any residual waste which cannot be more conveniently exploited.

This type of scheme is obviously directing the member states of the E.U. towards "integrated solutions" to the waste problem, in other words towards solutions based on a mixture of management and technological systems which harmonise so as to achieve the greatest benefits for the community, both in terms of the economy and in terms of the protection of the environment and of public health. E.U. countries have promoted national legislation in compliance with this directive.

2.2 Trends in Incineration

Waste disposal planning in Italy and in the other E.U. countries is definitely going towards the revaluation of incineration with energy recovery as the central element of integrated strategies. This concept has been strongly affirmed by the intervention of the different delegations which took part in the World-Wide Symposium "Pollution in Large Cities: Science & Technology for Planning Environmental Quality" - Padova, Italy, February 1994, sponsored by the W.H.O. (World Health Organization).

The deep renewed interest in this technology, which encountered strong opposition in the '70s and '80s in many countries, is mainly linked to the following motives:

1. The formidable progress achieved in flue gas treatment systems, which now account for more than 50% of the overall investment costs;
2. The considerable advantage of energy recovery, the most interesting among all those resources (including materials) that can be recovered from refuse.

   This concept has a particular economic significance for the Italian situation. In fact, as Italy imports from abroad (France) up to 40% of the electric energy it needs, a norm has been enacted which rewards with particularly favourable tariffs the assignment of self-produced electric energy to ENEL (National Agency for Electric Energy).
3. The currently pursued possibility of disposing pretreated refuse by incineration, so as to improve their combustion characteristics and at the same time to reduce their content in inert and the connected risks of emission (heavy metals).
4. A solution which is effectively able to cope with the problems of urban territory in the medium-long run.

As far as the most important aspect is concerned, that is, the environmental impact of emissions, it can be noted that the progress achieved in recent years has lead to the construction of sophisticated emission control systems (based on: post-combustion chamber for flue gas, lime and activated carbon treatment; fabric filtering; final washing; possible insertion of NOx removal systems). Table 2 shows the results which can be obtained with the latest generation of plants:

Table 2: *Comparison Between the Achievable Limits with the Latest Generation of Incineration Plants and the Limits of Plants Built at the End of the 1980s.*

Pollution parameter		**Plant generation**	
		End of 1980s	*Current*
TCDD eq.	(ng/Nmc)	50-100	0.1
Particulate	(mg/Nmc)	40	10
HCl	(mg/Nmc)	50	10
Hg	(mg/Nmc)	0.1	0.01
Cd	(mg/Nmc)	0.1	0.01
Pb	(mg/Nmc)	3	0.2
PAH (Polycyclic Aromatic Hydrocarbons)	(mg/Nmc)	0.05	0.005
NO_x	(mg/Nmc)	400	100

Note: End of '80s plants provided with post-combustion chamber, electro-filtration and final washing of flue gas.

2.3 Trends in the Sanitary Landfill Sector

At present in Italy the allocation of controlled MSW landfills represents not only an environmental risk, but also a considerable social risk. Local populations, strongly aware of the problems connected to road traffic refuse and above all to malodorous gas emissions, decidedly refuse any proposal of allocation on their territory. This state of affairs causes, especially in the most densely populated areas, situations of actual "refuse emergencies" with desperate searches for possible outlets in areas further away or sometimes even abroad. In latter years Milan and its hinterland have suffered from this kind of emergency.

But the other E.U. countries have also suffered quite a lot from the same syndrome.

How to overcome the negative environmental impact of controlled landfills nowadays is the object of particular research and applied studies.

The opinion has become more and more widespread that it is necessary to act in order to reduce the putrescible material content of disposed waste. It is in fact the cause of certain operational problems of current refuse landfills, especially as far as their first years of life are concerned (bad smells, biogas migrations, leachate production). This objective is pursued by admitting to the landfill only the residues of recycling and incineration activities. In some cases, instead, biological degradation of the organic substance most likely to ferment is carried out by using brief (10-15 days) stages of accelerated fermentation. This is applied both to organic fraction mechanically pre-selected from raw refuse and to raw refuse which has simply been shredded.

Recent Italian legislation (D.L. n°22 of 5-2-1997) imposes the disposal in landfills solely of the residues from recycling and combustion operations (with energy recovery) starting from the year 2000. The legislation of France and other E.U. countries contains analogous provisions.

2.4 Trends in the Recovery-recycling Sector

Among the recovery plants, composting was very popular in the early 1980s when 930,000 ton/year were disposed of in this way. However, following the new laws concerning compost quality, in which severe restrictions on heavy metal content and use of compost were established, the number of composting plants effectively in operation has decreased and in 1989 no more than 80,000 ton/year of compost were produced (Ministry of Environment, 1989). This figure corresponds roughly to 400,000 ton/year of processed MSW.

Currently, 43 plants for raw MSW composting have been built in Italy. Some of these plants can treat refuses mixed with sludge originated at municipal wastewater treatment plants. The total processing capacity is about 2,400,000 metric tons of wastes per year, representing about 10% of the MSWs currently produced in Italy. On average, one of these plants can process 200 t/day of incoming wastes.

Urbini and Zorzi [2] have evaluated over a period of several years (1985-1993) the quality of the compost produced at some plants located in Italy. Specifically, this study identified the effects of sources of waste and processing technologies on the quality of the compost, and compared the quality of the compost to that of the most widely used commercial fertilizers.

Based on the information summarized in Tables 3 and 4 the following conclusions can be drawn:

1. Materials derived from a non-selected MSW source usually present low organic fraction (21 samples out of 41 did not meet the minimum requirement set by the regulation, i.e., 40%);
2. The humus level of half of the tested samples did not meet the minimum requirement set by the regulation, i.e., 20%;
3. Compliance with the standards for metal concentrations was not achieved in almost all cases. The limit for lead, however, was exceeded in 21 out of 37 samples;
4. The limits for glass and plastic residues were not complied with in nearly half of the samples;
5. Based on the biological indexes, most of the compost derived from MSWs is not well stabilized, as a result of not a long enough curing period, and shows a low germination index and high oxygen demand.

Table 3: *Comparison Between the Characteristics of Some Compost Produced in Italy, from Unselected Refuses, and those of Some Organic Natural Fertilizers*

MATERIAL	Zn mg/kg	Cu mg/kg	Ni mg/kg	Pb mg/kg	Cd mg/kg	Cr mg/kg	Hg mg/kg	As mg/kg	Glass %	Plastic %	IG %	IR mgO_2 /kg VDS
Compost from MSW (% of samples not in compliance with the Law)	869 (3)	409 (11)	89 (8)	779 (62)	5 (3)	245 (5)	1.45 (0)	- -	5.4 (56)	1.3 (53)	34 -	235 -
Limits of the DPR 915	<2500	< 600	< 200	< 500	< 10	< 510	< 10	< 10	< 3	< 1	-	-
Manure	245	54	10	32	> 5	30	-	-	-	-	82	-
Fowl-manure	550	280	9	23	> 5	16	-	-	-	-	-	-
Peat	78	27	37	15	> 5	89	-	-	-	-	87	-

The values are the averages between the analyzed samples and are referred to the dry substance.

LEGENDA: IG = germination index. The optimum values are > 70.
IR = respiration index. The optimum values are < 130 mgO_2/kg of Volatile Dry Substances

Table 4: *Comparison between the Characteristics of some Compost Produced in Italy, from Unselected Refuses, and those of some Organic Natural Fertilizers*

Material	Moisture %	pH	E.S.C. µS/cm	Ash %	Org. Subs. %	C/N	N %	P_2O_5 %	K_2O %	HR %	HA/FA
Compost from MSW (% of samples not in compliance with the Law)	30.4 (38)	8.15 (20)	4307 -	49.9 -	41.7 (51)	16.6 (0)	1.48 (12)	0.77 (8)	0.76 (15)	20.4 (49)	1.26 -
Limits of the DPR 915	< 33	6-8.5	-	-	> 40	< 30	> 1	> 0.5	> 0.4	> 20	-
Manure	72.3	8.38	2,424	28.2	63.2	18.8	1.93	1.73	1.78	21.3	1.45
Fowl-manure	42.3	8.47	6,851	34.4	56.8	11.9	3.13	4.53	3.11	19.5	0.61
Peat	61.7	6.40	691	27.6	64.9	37.4	1.13	0.22	0.15	18.7	2.21

The values are the averages between the analyzed samples and are referred to the dry substance, excepting the pH, the Electric Specific Conductivity (at 25°C) and the water content.

LEGENDA: HR = humus ratio (total humus C/organic C). HA/FA = humus acid C/fulvic acid C.

Except for some sporadic uses, the uncertainties associated with the quality of compost from unselected refuses caused some difficulties in the marketing of this product, ultimately resulting in the failure of several composting enterprises. As a result, composting of the source-selected organic fraction of refuses has emerged as an adequate and promising alternative. The possible reconversion of the existing plants has so far been a problem, having an estimated capital cost of about 640 million US dollars (USD).

The reasons for the failure of raw MSW composting in Italy [3], as well as in other industrialized E.U. countries, can partly be found in inadequate design and operation. But the main cause affecting compost production and quality is MSW organic fraction (food & yard wastes) content, which, according to De Fraja Frangipane [4], decreased from about 50% (average percent by weight) in 1976 to 27% in 1988. Several studies carried out over the last decade have shown that further reduction of the organic fraction in MSWs has occurred. So in many cases percentages of 10-20% were measured. As a result, it has been a continuous challenge to separate a "clean" organic fraction from the raw refuses which would guarantee compliance with the quality standards set by the applicable regulation for the final characteristics of the compost. Consequently, a strong evolution of the standard processing steps for compost production was noticed in the last 20 years. The technological process modifications also resulted in higher capital costs (a four-fold increase over the last 20 years), taking into account the updating of 1977 costs.

The poor quality of the compost obtained from unselected refuses has led to an increased awareness that only a source selection of high organic content refuses can provide an environmentally sound compost with acceptable agronomic characteristics. This can be achieved by implementing programs for the segregation of the organic fraction before collection. These programs would start involving the big waste producers, such as food processing industries, large grocery chains and catering centers.

A total of 32 plants are operating in Italy for the production of compost from source selected refuses. The total treatment capacity will be 550,000 t/yr, which represents about 2% of the MSWs generated at present in Italy.

Strong momentum is being witnessed in Italy for the proliferation of enterprises in the quality compost field. For instance, the practice of source selected biomass recovery is now well established in the Venetia region; 30 public and private enterprises have been authorized (or soon will be) to treat source selected refuses.

A quality control board has recently been established within the organization of the Italian compost producers (C.I.C., Consorzio Italiano Compostatori) to certify the quality of compost based on standards provided by a technical-scientific committee.

The most common uses of compost include:

1. the horticulture-floriculture-nursery
2. fungiculture
3. the seedling-nursery
4. the green maintenance sector (for public and private areas).

Compost is generally used to prepare the culture substrates for the above-mentioned activities and it can effectively replace 25-50% (volume/volume) of the peat traditionally used for this purpose.

Separate collection, which is strongly supported by environmentalist movements, has captured the attention of public opinion and of public administrators. Besides the fractions which can be recovered (moist organic substance, paper, glass, aluminium cans, plastic), interest has also turned to dangerous urban refuse so as to carry out the most controlled disposal possible (expired medicines, exhausted batteries, containers of toxic or inflammable products, etc.). In recent planning, recoveries of over 25% have been scheduled in the short term.

The same Italian Ministry of the Environment in the above-mentioned legal provision (D.L. n° 22 of 5/2/1997) has established a target recovery of at least 50% of packaging refuse (at least 25% as material; the remaining fraction to be destined for energy recovery) to be realized within 5 years.
The technical-scientific world is also looking at this trend with some interest, but more carefully. During the above-mentioned Symposium on pollution in large cities the importance of achieving gradual progress in the sector was underlined, however verifying each time the real economic and social advantages of the collection and above all the actual marketability of the products obtained. In other words the need to avoid a leap in the dark is affirmed and also to uphold the concept that separate collection is not "the solution" to the problem, but merely a useful small block of the quoted "integrated solution"; a usefulness which requires constant confirmation as to the market validity of recovered products, the acceptability of the economic burden on the citizen and the willingness to collaborate on the part of family groups sometimes required to accomplish excessively complex tasks of domestic selection.

3 Material Balance Of Planned "Integrated Solutions"

In Figure 1 there is a model draft of a material balance resulting from the recent MSW disposal planning (1996)in some Provinces of the Lombardy Region in Italy.

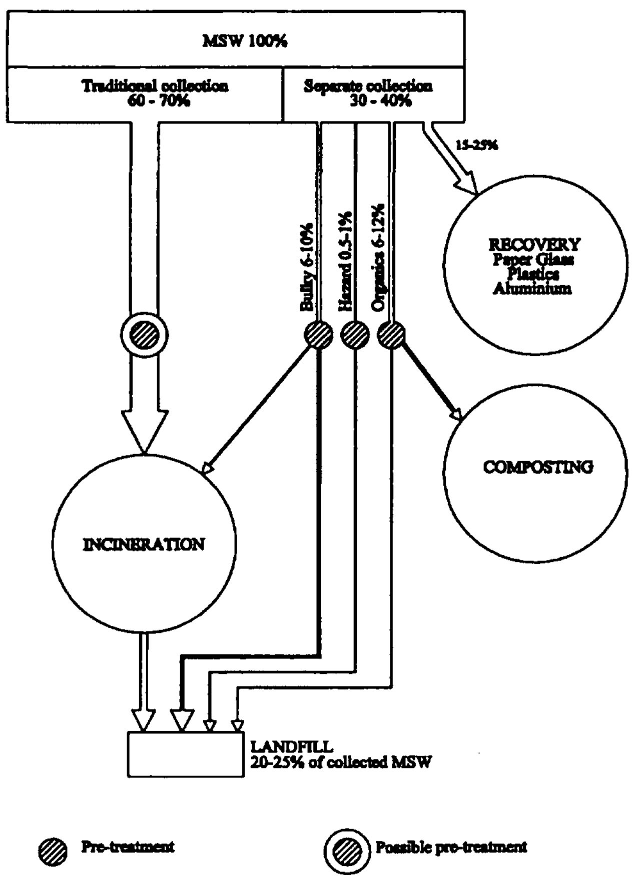

Figure 1: *Simplified Material Balance of an Integrated Solution for MSW Management.*

As can be seen, the main element of the integrated solution is incineration (60-70% of collected MSW), which in some cases is foreseen after preselection of the refuse has taken place (so as to aid the separation of inert and of moist organic substance). Separate collection (30-40%) brings about an overall material recovery of around 25-30%. The residues, amounting to 20-25% of all the refuse collected, are sent to controlled landfills.

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REUSE OF STABILIZED WASTE AS CONSTRUCTION MATERIALS

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Abstract

This study aimed to asses the feasibility of concrete production using stabilized waste as an addition to natural aggregates. Two inorganic waste streams were considered: foundry residues and fly ashes from municipal solid waste incineration. They were treated by means of a commercial cement-based stabilization/solidification process (using cement, lime and sodium silicate). After several days of curing, they were dried, milled, and sieved before being used as fine aggregate for concrete production. Produced concrete was then subjected to conventional physical-mechanical testing procedures (compression, traction, flexure, modulus of elasticity, shrinkage). In samples containing 200 kg waste/m^3 concrete, a very high compressive strength was achieved after 28 days curing time. Besides, leaching behavior of the concrete was evaluated, by means of different kinds of leaching tests. Experimental results showed a remarkable reduction of metal leaching of concrete with respect to stabilized waste. In some cases (foundry residues), the same behavior was observed in "natural" concrete (produced with natural aggregates) and "waste containing" concrete.

1 Introduction

Waste disposal is a well known problem, becoming more and more important, due to the difficulties in finding final disposal areas and to the necessity to avoid negative effects on the environment. Besides, the necessity to minimize the use of natural resources must be considered. For these reasons, wastes recovery must be improved.
Many kinds of industrial wastes may be recovered as construction materials. In Italy, according to the Ministerial Decree n. 22 of 5/2/97 [4], for example, the following materials can be used as construction materials:

- some kinds of slags deriving from non ferrous materials manufacturing, in the production of cement, bitumen conglomerate, concrete, road foundation, after passing a leaching test;

- foundry slags, in the production of cement, concrete, bricks, for earth embankment, road foundation and railway-road bed, for environment reclamation, after passing a leaching test;
- rolling and pressing flakes, in concrete production;
- wastes formed by bricks, plasters, reinforced and not concrete, that may be reused in construction after mechanical treatment and metal separation, after passing a leaching test. According to this regulation, it may be possible to reuse demolition materials as aggregate in concrete; this, till now, has been prohibited by UNI 8520 regulation [9] (Ministry of Public Works Decree, N. 19/96 [7]), that allows only the use of natural aggregate in concrete. There's also a CEN regulation project, by which aggregate suitability is to be evaluated based on its characteristics rather than on its origin;
- burnt tile scraps and foamed clay, in tiles production;
- refractory material wastes, in the production of construction materials, concrete and bitumen conglomerates;
- foundry sands from secondary fusion of non ferrous metals, in the production of cement, cement and bitumen conglomerates, embankment and road foundation, after passing a leaching test;
- some kinds of sludge from industrial wastewater treatment, in construction material production;
- fly ashes from biomass combustion and heavy ashes from municipal waste incineration, in cement production and, in some cases (biomass ashes), in concrete production.

Other wastes, such as sludge from wastewater treatment, may be employed as raw materials in cement production.

These possibilities deal with not hazardous waste recovery. Indeed, this experimental work considers hazardous wastes which may become environmentally safe after a stabilization/solidification process. A new Decree about hazardous waste recovery should be published in the next months.

2 Aggregates in Concrete Production

Today, in Italy only sands and fine gravel coming from open quarries and drifts are currently used in concrete production. They are generally recent or new drifts, which offer good quality materials (ancient drifts are often characterized by lower quality materials).

For these reasons, quarries have been almost always located near active river-beds and high-water beds, with negative effects on the environment (also from the hydraulic point of view).

Present Italian regulation, for these reasons, doesn't allow aggregate extraction from rivers and reduces the possibilities in all near areas. Nevertheless, in Italy, extractive practice in water courses is regulated by the state (main water-courses) and by regional hydraulic services (smaller water courses); this means that aggregate excavation can be authorized for hydraulic regime optimization. In all the other cases, quarries are authorized and controlled by local administrations, on the ground of general plans approved by the regions. Anyway, these quarries, too, cause often negative environmental impacts, especially if they are used for uncontrolled waste disposal or if they collect materials transported by surface water.

Another important problem is that these materials are not a renewable natural resource. A huge amount of this natural resource is normally used in concrete production. It's difficult to estimate the amount of material extracted from river-bed and state property areas (which are authorized by the state). On the contrary, it's possible to estimate the amount extracted from quarries which are under regional control, even if it is often underestimated for the presence of non authorized activities. Some official data report that 102.000.000 m^3 of construction materials were produced in 1981, 18.000.000 m^3 of which only in the region Lombardia. In this region, an annual extraction of sand and gravel of 22.000.000 m^3 was authorized during

1990-96 period, excluding aggregates excavated from river-beds. In comparison with official data of 1981, in the same region there was a 25% average annual increase from 1981 to 1996; if we extrapolate this value to the national production, we could find at least 127.000.000 m^3 for the annual production; this number is significant to represent the environmental effect of this activity.
For this reasons, it's necessary to use other materials for concrete production in place of natural aggregates: refuses deriving from large quarries of stone products, road and railway trenches, excavations, etc. or other "non conventional materials" like those considered in this work.

3 Experimental Work

Two wastes have been studied in order to asses the possibility to use them, after stabilization/solidification, for concrete production. Considered materials are: foundry residues and fly ashes from municipal solid waste incineration.

3.1 Waste characteristics

Chemical characteristics of the wastes, listed in Table 1, show that they must be classified as "toxic and noxious" wastes, according to the Italian D.P.R. 915/82 [5]. Some metals are in fact above the limit concentration (see column 4 in Table 1 [1]); they are chromium for the foundry residues, mercury and cadmium for municipal waste incineration fly ashes. Most metals have higher concentration in the latter waste, except chromium, that is higher in foundry waste, and lead, that shows similar values in both wastes.

Table 1: *Chemical Characteristics of Raw Wastes*

Parameter	**Foundry residues**	**M.S.W.I. fly ashes**	**Limits for toxicity (D.C.I. 27/7/84)** (mg/kg)
105°C residue (%)	99.4	98.9	
600°C residue (%)	95.7	94.4	
Lead (mg/kg)	2671	2601	5000
Cadmium (mg/kg)	39	134	100
Chromium (mg/kg)	336	76	100
Chromium VI (mg/kg)	Traces	23	100
Arsenic (mg/kg)	< 0.06	4.6	100
Selenium (mg/kg)	< 0.02	12	100
Mercury (mg/kg)	2.0	109	100
Soluble copper (mg/kg)	0.98	5.9	5000
Phenols (mg/kg)	< 0.1	< 0.1	500
Free cyanide (mg/kg)	< 0.1	< 0.1	500

Leaching tests have been carried out on both wastes with two procedures described in Italian regulations [1]: acetic acid (0,5 M) and carbon dioxide leaching tests. Metal concentration in the leaching solution has been analyzed using atomic absorption spectrophotometry technique.
It can be generally observed that the highest metal concentrations in the leachate have been measured for those metals which have higher concentration in the waste. For their leaching

behavior, waste disposal in IIB or IIB super landfills (according to Italian classification [1]) is not allowed.

3.2 Stabilization/Solidification Procedure

A cement based (cement, lime and sodium silicate) stabilization/solidification technique has been used for waste treatment. Portland cement causes the solidification of the stabilized waste; lime causes metal precipitation (as insoluble hydroxides) and maintains the waste pH around optimal values to avoid metal leaching; sodium silicate improves the solidification process and so the physical-mechanical properties of the final product.
Both the two wastes have been treated using two different reagent composition; the following amounts, referred to waste weight, were used: 12% cement, 8% calcium dioxide and 5% sodium silicate (used only in one of the two processes).
The stabilization/solidification treatment consisted of three main steps: homogenization of raw waste; waste mixing with reagents and water for 15 minutes and, finally, curing for several days.

3.3 Characteristics of Stabilized Wastes

Waste can be reused in the field of construction only if it complies with specific quality standards indicated by the UNI Norms for construction materials. Particularly, the stabilized wastes have been characterized and compared to natural aggregate, according to UNI 8520 Norm [9] (alkali reactivity and organic matter content).
Moreover, they have been tested with the same leaching procedures applied to the raw wastes. These tests have been performed at different curing times (from 1 to 84 days).
In the foundry residues there is a minimum of metal leachibility after 7 days of curing; in the following days metal concentration in the leachate increases, but it's always lower than the limitations to be respected for the disposal in IIB landfills [1] (Tab. A, L. 319/76 [2]).
The addition of sodium silicate decreases the solubility of lead with acetic acid leaching test, but it doesn't influence the mobility of the other metals. The stabilization/solidification process significantly reduces the leachibility for most metals. A similar behavior was confirmed by carbon dioxide leaching test.
Also for the municipal solid waste incineration fly ashes the minimum leachibility for metals is reached in 7 days of curing; in the following days, leachibility stabilizes to higher constant values.
For metals with the lowest concentration in the waste, only selenium exceeds Tab. A limitation; moreover, the addition of sodium silicate reduces the solubility of selenium and arsenic, while lead leaching seems to be increased. Among the other metals, only cadmium and chromium VI concentrations are above the Tab. A limitations, depending on the pH value. Also for this waste, metal mobility is significantly reduced after stabilization/solidification treatment and the same behavior is confirmed by carbon dioxide leaching test.
It's possible to conclude that metal concentrations in the leachate are reduced, in most cases, after stabilization; minimum solubility is reached in general after 7 days of curing, but it may increase for the pH variability (due to the matrix carbonation) or, in other cases (e. g. copper), for complexing effects. For chromium, at high pH values, oxidation processes may be promoted.

3.4 Concrete Specimens Preparation

The aim of this work was to study the feasibility of concrete production using stabilized waste as an addition to natural aggregates in concrete.

Five different concrete mixtures were prepared (Table 2): one only with natural aggregates and four with different amounts of wastes, stabilized with cement, lime and sodium silicate (after 60 days of curing). All the specimens were prepared with the same mix-design (Table 3), but with different amounts of wastes (from 11% to 22% of natural aggregate), that could be employed only after drying, grinding and sieving.

Table 2: *Composition of Concrete Mixtures*

MIXTURE	water/ cement	RECYCLED AGGREGATE				NATURAL AGGREGATE (kg/m^3)
		waste	dosage (kg/m^3)	% with respect to natural aggregate	Ømax. (mm)	
I	0.44	-	-	-	-	1819
II	0.54	FR	200	11	1.25	1619
III	0.58		400	22	1.25	1419
IV	0.44	FA	200	11	2.50	1619
V	0.49		400	22	2.50	1419

FR: stabilized foundry; FA: stabilized fly ashes

Table 3: *Concrete Mix-design*

PARAMETER	CHARACTERISTIC	DOSAGE/VALUE
Cement	Ptl, 32.5 R class	350 kg/m^3
Slump	-	20 cm
Natural aggregate	Ømax. = 15 cm	1800 kg/m^3
Superfluidificant additive	Rheobuild	3.5 l/m^3
Water/Cement	-	0.44÷0.58

3.5 Physical and Mechanical Characteristics of Concrete

Wastes can be reused in the field of construction only if the final product complies with specific standard quality, which is reported in the Technical Norms of Ministerial Decree 9/1/96 [7].

Concrete specimens were subjected to conventional physical-mechanical testing procedures, as defined in UNI Norms for construction materials: absolute gravity, water absorption, compression, traction, flexure, shrinkage and modulus of elasticity. The main parameter is the compressive strength: the minimum value to be reached is 15 MPa.

Figure 1 shows that all the concrete mixtures, except that containing the higher amount of incineration fly ashes (number V), reach the minimum compressive strength of 15 MPa, already after 7 days of curing. Anyway, the addition of waste to concrete decreases the compressive strength due to both the lower characteristics of recycled aggregate (with respect to natural materials) and the presence of metals that could inhibit cement hydration.

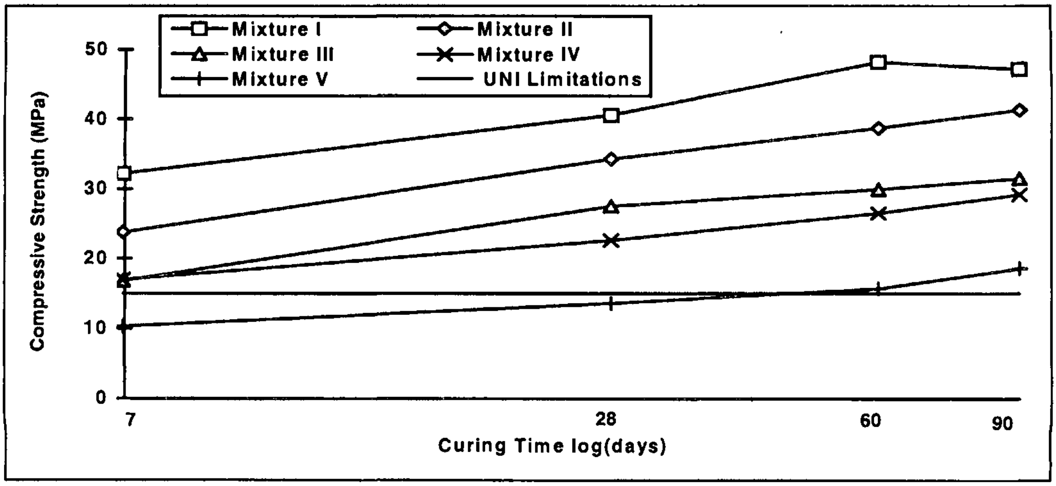

Figure 1: *Compressive Strength of Concrete Mixtures*

As far as the other mechanical parameters are concerned, all the concrete samples containing waste show worse quality with respect to natural concrete. It's nevertheless interesting to point out that some of these mechanical parameters (such as flexure and tension strength, modulus of elasticity) improve significantly after long curing times (90 and 120 days), probably due to the pozzolanic properties of the wastes, causing the progressive improving of concrete characteristics.

3.6 Conventional Leaching Tests

Concrete samples were tested with both acetic acid and carbon dioxide leaching procedures. In general, experimental results showed a remarkable reduction of metal leaching of concrete with respect to stabilized waste. After 28 days of curing, in samples with 200 kg waste/m^3 concrete, all metal concentrations (Cr, Cu, Cd, Se, Pb) in the leachate are not higher than Tab. A (L. 319/76 [2]) values (Tab. 4). Lead exceeds its limit at different curing times, but the same behavior has been observed in natural concrete. Copper and lead (the latter only in some samples) increase their leachibility between the 28th and 64th day of curing.

Table 4: *Results of the Leaching Test after 28 Days of Curing*

PARAMETER	TEST/MIXTURE						
	Test A I	Test A II	Test A IV	Test C I	Test C II	Test C IV	Table A Law 319/76
Copper	0.1	0.1	0.1	0.1	0.1	0.1	0.10
Lead	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2
Cadmium	0.02	<0.02	<0.02	0.02	<0.02	<0.02	0.02
Total chromium	0.3	<0.1	1.1	0.3	<0.1	1.1	2
Arsenic	<0.06	<0.06	<0.06	<0.06	<0.06	0.06	0.5
Selenium	0.05	<0.02	<0.02	0.05	<0.02	<0.02	0.03

Test A: acetic acid procedure; Test C: carbon dioxide procedure; concentration are expressed in mg/L. Mixture I: concrete with natural aggregate; mixture II: concrete containing stabilized foundry residues (200 kg/m^3); mixture IV: concrete with stabilized municipal solid waste incineration fly ashes (200 kg/m^3)

Concrete samples containing foundry residues show lower metal leachibility than those with incineration fly ashes and their behavior is comparable to that of natural concrete (which shows also higher metal concentration, in some cases). Not significant differences have been observed between the results of the two leaching procedures. It's interesting to notice that high chromium VI concentrations (higher than Tab. A, but not ten times greater) have been measured not only in "recycled" concrete, containing treated waste, but also in "natural" concrete, containing only natural aggregate. In fact, it's well known that cement may contain chromium VI which gives an allergic property.

3.7 Leaching Tests on Monolithic Samples

Above discussed leaching tests are those required by Italian regulation to evaluate waste leaching behavior. The authors have already published the results of a study showing that it's not possible, with these procedures, to obtain reliable and reproducible results [3]. In this work, considering that these materials are not real wastes but manufactured products containing waste, it would be more interesting to use a leaching test for monolithic sample.
A different leaching test had already been tested on other materials [6]; in this work all the concrete samples were tested with a standardized Dutch procedure for monolithic sample (NVN 5432). During this test, the sample (generally a cylinder of 5 cm in diameter and length) is placed for 64 days in a water and nitric acid solution (pH=4), with a liquid/solid ratio (in volume) of 5/1 without mixing. The leaching solution must be changed at regular time steps (1, 2, 4, 8, 16, 32 and 64 days) and analyzed (with ICP-plasma technique in this work). This test was applied to the same concrete mixtures shown in Table 2 (on cubic samples with 4 cm side).

Table 5: *Results of the NVN 5432 Leaching Test after 28 Days of Curing (sum of concentrations recorded in all 7 steps, values in mg/L)*

PARAMETER	MIXTURE				
	I	II	III	IV	V
Copper	0.144	0.089	0.108	0.147	0.223
Lead	0.366	0.410	0.750	0.397	0.299
Cadmium	ILS	ILS	ILS	ILS	ILS
Chromium	1.31	1.850	0.580	4.166	4.245
Arsenic	0.283	0.448	<0.200	0.417	0.283
Selenium	ILS	ILS	ILS	ILS	ILS

ILS = lower than sensitive limit

As shown in Table 5, copper, lead and arsenic have similar leaching behavior in all the specimens. As far as chromium is concerned, there are similar concentrations in concrete containing foundry residues and natural aggregate, while higher values characterize fly ash concrete samples.
The 5/2/97 Ministerial Decree [4] (subsequent to this work) prescribes a leaching procedure that is conceptually similar to the Dutch monolithic test, except that it uses deionized water rather than nitric acid solution. This isn't an important difference when leaching procedures are applied to concrete samples, because the nitric acid solution with pH=4 contains a negligible acid amount in comparison with the alkalinity immediately released by the samples. In other words, the acid solution reaches immediately pH values above 10. On the contrary, the two procedures differ in renewal times of the extraction solution: Italian test considers 8 steps (at 2, 8, 24, 48, 72, 102, 168 and 384 hours (16 days)), while Dutch procedure, as described before, prescribes 7 steps (at 1, 2, 4, 8, 16, 32 and 64 days).
The Italian regulation defines also the limit Concentration for metals, but these can't be compared with Dutch leaching test, due to the different renewal times . It's worth observing also that the new limits defined in Italian regulation are more restrictive than those prescribed for waste leaching tests: they are similar to those defined for drinking water (or more restrictive, such as for copper).

4 Conclusions

From the results of this work it's possible to draw some considerations about the reuse of stabilized waste in concrete production.

- All the four stabilized wastes (obtained applying to both the considered wastes two different stabilization/solidification treatments), show worse chemical and physical characteristics than natural aggregate; nevertheless they seem to be suitable for concrete production (concerning alkali reactivity and organic matter content).
- Moreover, the acetic acid and carbon dioxide leaching tests show a lower metal leachibility after waste stabilization.
- From the physical-mechanical characterization of concrete (compression, traction, flexure, modulus of elasticity, shrinkage) carried out after different curing times, it can be seen that the reuse of stabilized waste, as an addition to natural aggregate, decreases the mechanical quality of concrete. Nevertheless it must be observed that all the concrete samples (except those with high amount of stabilized fly ashes (400 kg/m^3)) reach the minimum compressive strength value (15 MPa) required for concrete standards, after 28 days of curing. Concrete containing 200 kg/m^3 of foundry residues reaches compressive strength greater than 30 MPa, after 28 days of curing.
- The environmental compatibility of "recycled" concrete is confirmed by leaching tests, which show a similar behavior in "natural" concrete (produced only with natural aggregate) and "waste containing" concrete.

In conclusion, recycled concrete could find different applications in the field of construction (depending on the waste dosage) such as the realization of foundations or cofferdams, the manufacturing of manholes, curbs and pipes and, in the best cases, the realization of casted or pre-mixed primary structures.

Authors contribution

Carlo Collivignarelli carried out the coordination and scientific supervision of the work.
Vincenzo Riganti was involved in the chemical aspects.
Sabrina Sorlini and Giorgio Bertanza carried out the experimental work and data analysis.
Giuseppe Marchetti was involved in the analysis of the general problem of natural aggregate consumption.

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THE INFLUENCE OF SOME OPERATING CONDITIONS ON CONTAMINANT RELEASE FROM WASTE MATERIALS

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Abstract

The aim of the present paper is to show the influence of some parameters on leaching behavior of wastes by means of both theoretical considerations and data from some laboratory tests.
Several leaching tests have been proposed either for regulatory or research purposes in order to evaluate the release of harmful constituents that may occur when a waste is contacted with a solvent. Leaching tests are dependent on a number of parameters, which are related both to the characteristics of the waste before and after contact with the leaching solution (pre-treatments and extraction procedures) and to the operating conditions maintained during the test. Investigating how such parameters can actually affect the rate and the extent of leaching is usually not feasible when performing a standard leaching test, which generally prescribes that a set of parameters be kept constant during the extraction procedure. Anyway, by varying one of the operating parameters at a time, the influence of each of them separately can be determined.

1 Introduction

In general, a leaching test involves contacting a waste material with a liquid phase (leachant) for a given time under specified conditions. After contact, the liquid phase (leachate) will contain a number of species extracted from the waste.
Several variations have been proposed in order to investigate leaching behavior, or, more correctly, specific aspects of leaching behavior, so as to predict the extent and rate of leaching.
The relative rate at which leaching occurs, as well as contaminant concentrations in the leachate, are of major relevance.
Leaching tests, irrespective of the selected operating conditions, are carried out in order to meet a number of goals. First of all, a leaching test should allow the leachable constituents of the waste to be identified and their concentration in the leachate to be evaluated under reference conditions. Evaluations of contaminant concentrations as detected in the leachate

my be useful for several issues: *1)* to compare wastes against performance criteria for evaluation of their final destination; *2)* to compare different treatment processes, so as to determine whether a given process results in superior containment of contaminants; *3)* to perform a quality control in waste treatment and verify the efficiency of a treatment process using a simple pass/fail criterion; *4)* to obtain a typical leachate composition to perform treatability experiments.
A leaching test may also be used to provide information concerning contaminant release under conditions that more closely approximate the actual disposal site. As a result, determining how to express leaching over time and quantifying the partition coefficients and kinetics parameters is of critical importance when mathematical models are to be used to predict long-term leaching. This also results in a risk assessment through the estimate of the potential impact a given waste may exert on the environment when it is disposed of.

2 The Leaching Process

Leaching is the result of chemical reactions at the scale of the interface separating individual particles, which act to mobilize contaminants, coupled with transport processes that may be governed by advection, diffusion or a combination of both, depending on the magnitude of leachant flow.
Contact between leachant and waste can occur according to different pathways: the leachant can percolate through the waste (in the case of porous materials), or can flow around the waste (in the case of monolithic products), or both. In the former case, contaminant release from the waste occurs primarily as a result of percolation through the materials pores and therefore is usually controlled by solubility constraints. Contaminant release is dictated by the partial dissolution and desorption of mineral phases at the particle interface, until chemical equilibrium is attained. The latter is conversely the case when liquid flow is predominantly around, rather than through, the material; hence, the primary liquid/solid contact occurs at the outer surface of the waste, where chemical equilibrium is generally not attained. Contaminant release may in this case occur as a result of either molecular diffusion from the bulk waste or wash-out of the surface of the waste form caused by leachant renewal.
The ultimate impact of leaching on the environment occurs when contaminants are transported away from the waste. If water flows through the solid material, advective transport causes contaminants that have been mobilized by reactions at the pore scale to be transported through the waste at various velocities, depending on the actual flow pattern of the water within the pores [2]. In this case, the factor controlling contaminant transport through to the liquid phase is mobilization from the solid material at the interface.
If the values of chemical equilibrium concentration (indicated as C_{eq}), interface concentration (indicated as C_i), and concentration at an infinite distance from the interface (C_∞) are considered, the driving force for contaminant mobilization is given by the difference C_{eq} - C_i,: when $C_i < C_{eq}$, the mass flux of the contaminants is from the solid to the liquid, while the converse happens when $C_i > C_{eq}$. Since no resistance exists for contaminant transport within the liquid, the concentration will be the same as at the interface at any point in the liquid (see Figure 1a) [8]. In this case, the rate of contaminant mobilization in the hypothesis of steady-state conditions at the surface is independent on concentration, therefore concentration varies linearly as a function of time.
Conversely, if there is no flowing water within the porous waste, soluble constituents may still be transported by molecular diffusion as a result of concentration gradients. In this case concentration as a function of distance from the interface follows a pattern like that presented in Figure 1b. The rate of diffusion in the liquid depends on the square root of time.

Together, mechanical dispersion and diffusion constitute the lumped parameters known as hydrodynamic dispersion. A situation intermediate between the two cases explained above is presented in Figure 1 c.

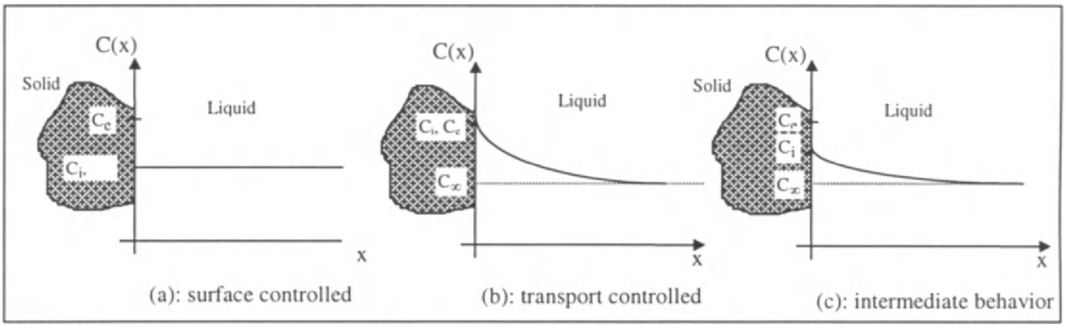

Figure 1: *Surface- and Transport-Controlled Leaching Mechanisms*

3 The Main Parameters Affecting Leaching

The results obtained by performing leaching tests are affected by a large number of parameters and need careful evaluation in order to consider the influence exerted by the operating variables on the system behavior.
The main parameters influencing leaching test results may be classified according to the following categories: *1)* waste properties and sample preparation procedures; *2)* operating conditions. Proper evaluation of these parameters is of critical importance in order to correctly interpret the results and to select the suitable procedure to simulate the leaching scenario of interest.

3.1 The Influence of Variables Related to Sample Preparation

Depending on the nature of the waste and the kind of the test to be performed, some pretreatment steps may be necessary, among which the most common ones are:

- liquid/solid separation;
- particle size reduction;
- curing;
- aging.

For waste materials with high water content, a preliminary liquid/solid separation may be performed when the solid portion of the waste only is to be subjected to the leaching test. This allows the influence of the leachant only on the extent and rate of leaching to be evaluated.
The liquid/solid separation may be accomplished by means of gravity thickening, centrifugation, filtration or drying.
The liquid phase resulting from liquid/solid separation may be analyzed separately to estimate the pore solution composition or added to the final leachate for subsequent analysis. The estimation of pore solution composition is of basic importance in order to predict the extent of release of specific elements. For example, the pore solution within solidified waste forms is generally highly alkaline, thereby under such conditions formation of soluble hydroxy-complexes is likely to occur; for this reason, a lower release than would be predictable simply based on contaminant concentration in the waste will be measured [3].
In some cases, however, care should be taken in order to prevent any modification in waste characteristics. For example, when liquid/solid separation is accomplished through drying, a loss of volatile compounds from the solid matrix should be prevented if they are of interest;

when it is performed on solidified materials, modifications may also occur as result of the loss of hydration water.
Liquid/solid separation is also usually performed after the test through filtration in order to separate the liquid solution from the leached waste for subsequent analysis. In doing so, it must be taken into account that all the precipitates are retained by the filter and thereby escape the following chemical analysis. As a result, the extent of contaminant leaching from the waste may be in some cases underestimated.
Particle size reduction is required for most extraction tests. The objective is to increase the surface area where contact between leachant and waste occurs, and therefore to reduce the time required for chemical equilibrium to be attained.
Curing may be performed on solidified waste forms to provide enough time for hydration reactions of the binder components to take place. This allows the waste sample to be subjected to the leaching test to gain physical and engineering properties, such as high mechanical strength, low permeability and low specific surface, that are all aspects controlling the extent of leachability. As hydration reactions proceeds, contaminants are more strongly immobilized within the solidified matrix as a result of either physical (precipitation in the form of insoluble compounds) or chemical mechanisms (fixation through formation of compounds with cement hydrates, chemical adsorption or solid solution in hydrate structure). Thus, contaminant release from solidified waste materials is expected to decrease with increasing curing time, as shown in Figure 2, which refers to a cementitious mixture of fly ash (FA) and Portland cement (C) at a FA/C ratio equal to 1.50 by weight [4].

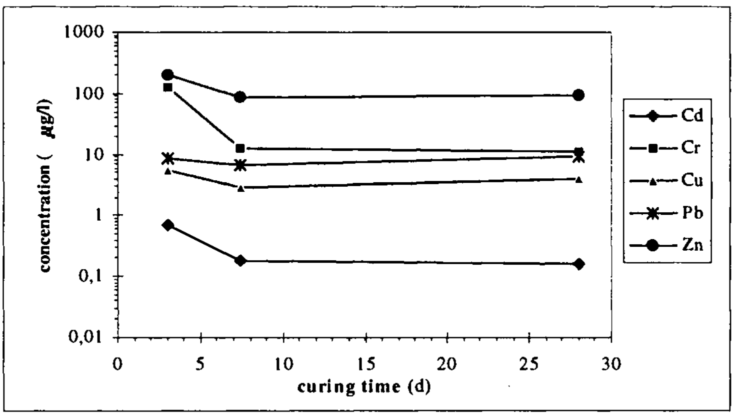

Figure 2: *Heavy Metals Release as a Function of Curing Time*

Aging accounts for a series of physical, chemical and biological alterations a waste may undergo over time. The aging reactions are diagenic in nature and are promoted by thermodynamic instability of, or incongruence between, mineral phases. The slow, irreversible conversion which leads to the formation of more stable species is the process that corrects instability. Due to aging reactions, a waste material becomes more "rock-like" in its mineralogy and phase compatibility [6].

3.2 The influence of the Operating Parameters

Liquid phase composition
The extent of contaminant release from the solid phase is strongly affected by the initial leachant composition, especially at high liquid-to-solid (L/S) ratios or for aggressive solutions.
The release mechanisms as influenced by leachant composition are summarized in Table 1.

The pH of the leaching solution is the most important parameter affecting the interactions between ions in solutions. Since generally a complex system like the leachant/waste system involves competing chemical equilibria, the presence of one or more common ions will shift those equilibria towards left or right, to an extent depending on the solubility product value. Thus, this will cause precipitation or dissolution of the compounds of interest to occur.
Depending on leachate pH, many ionic species will form solid compounds due to co-precipitation phenomena. It has been observed [8] that the solubility of metallic co-precipitates (such as $Cr(OH)_3$-$Fe(OH)_3$) is considerably lower than the one of the oxides of the single metals.

Table 1: *Release Mechanisms as Affected by the Chemical Properties of the Leachant*

Chemical property	**Release mechanisms**
pH	dissolution/precipitation of metals speciation of organic compounds adsorption/desorption of organic compounds
Redox potential	oxidation/reduction of inorganic compounds
Ionic strength	ion exchange speciation solubility product
Complexing or chelating agents	metals solubility
Buffer capacity	all the above mechanisms

Heavy metals solubility generally attains a minimum at pH values within the range 7.5 ÷ 11; under either strongly acidic or alkaline conditions the solubility will noticeably increase (amphoteric behavior). Examples of pH-dependent leaching for MSW bottom ash are provided in Figure 3 [6].

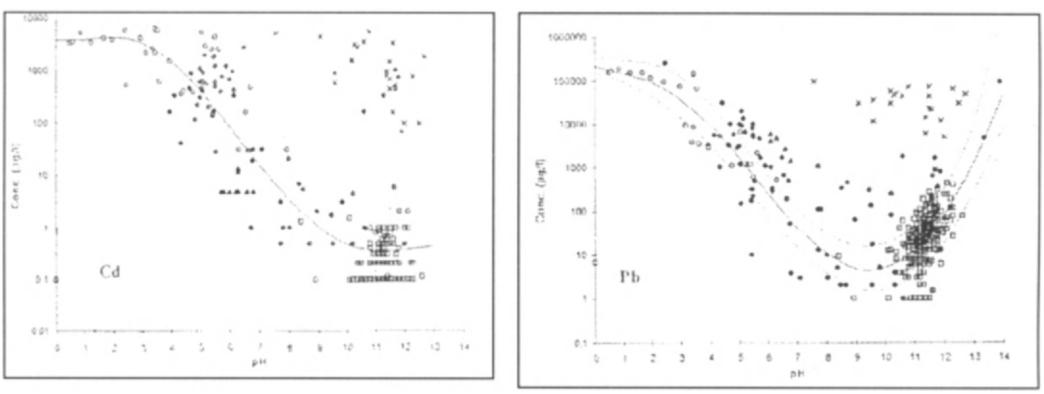

Figure 3: *pH - dependent Leaching for Cd and Pb in MSW Bottom Ash*

The value of redox potential determines the chemical form of the species of interest in solution and therefore affects their solubility. For example, it is known that trivalent chromium forms a sparingly soluble hydroxide, whereas hexavalent chromium forms soluble chromates (CrO_4^{2-}) and dichromates ($Cr_2O_7^{2-}$).
Ionic strength is a measure of the electric field due to the presence of ions in solution. The extent of electrostatic interactions between ions rapidly increases with their charge and concentrations. Ionic strength affects contaminant leachability from a waste material basically according to the following mechanisms [1]: *1)* may increase the solubility of solutes by reducing their activity coefficient (which varies with the square root of ionic strength); *2)* may cause ion exchange phenomena to occur between ions in solution and toxic metal ions in the waste, thus determining their extraction from the waste; *3)* may promote precipitation due to

the reduction of the electrical double layer around colloidal particles and their consequent coagulation.
The presence of ligands, i.e. coordinating groups which a cation is covalently bonded to, strongly affects metals solubility in the leachate. The resulting species, referred to as complex ions, are indeed generally highly soluble and can therefore be extracted from the waste. As a result, metals solubility in the leaching solution cannot be predicted on the basis of the solubility products of the various precipitates, but may be significantly changed by the presence of ligands (such as chlorides, carbonates, etc.). As an example, Table 2 shows cadmium release from different MSW fly ashes resulting from a leaching test using 10^{-3}M nitric acid for a contact period of 3 days. Based on the solubility product of cadmium hydroxide, a concentration of soluble cadmium lower than $1.13 \cdot 10^{-6}$ mg/l would be expected at the values of final pH indicated in Table 2. The increase in solubility may thereby be ascribed to the high chlorides concentrations in the examined fly ash, responsible for the formation of highly soluble cadmium complexes.

Table 2: *Cd Release from Different MSW Fly Ashes*

pH	Concentration (mg/l)
10.92	0.02
10.89	0.03
10.60	0.05
10.64	0.10

Liquid-to-solid ratio
The L/S ratio directly affects the concentration of a given compound that can be obtained in the leachate, which is controlled by a number of concomitant factors, such as the quantity and solubility of the species and the nature of the physical and chemical reactions determining the bulk and surface diffusion phenomena.
The L/S ratio can be expressed in several different ways:
- volume of leachant/mass of solid [l/kg];
- mass of leachant/mass of solid [kg/kg];
- volume of leachant/surface area of solid (for monolithic materials) [l/m^2/g].

Besides, in the first two expressions, the mass of solid material can be evaluated either on a wet weight or dry weight basis. Some confusion may also arise when calculating the total leachant volume, depending on whether or not the liquid portion of the waste is included in the total volume. The choice of an appropriate value of the L/S ratio depends also on the objectives of the leaching test, on the solubility of the examined species and on analytical constraints.
The L/S ratio should be low enough to avoid concentrations to be lower than analytical detection limits, and, on the other hand, should be high enough to prevent the extent of contaminant release to be limited by saturation of the liquid phase. The adopted L/S values are usually between 0,1 and 100.
Generally, four different pathways can be observed for contaminant release from granular materials as a function of the L/S ratio (see Figure 4, [6]):
1) For highly soluble constituents (such as alkaline metals and halogens), a rapid release is observed as a function of the L/S ratio due to undersaturation of such elements in the leaching solution. In this case the element concentration in the leachate is inversely proportional to the L/S ratio. If the curve of cumulative release is drawn, its profile indicates a rapid wash-out at low L/S ratios (less than 1 ÷ 2), followed by a zero-slope pattern at higher L/S ratios. The available quantity (which is represented by the final value which the curve tends to) is therefore almost totally released at low L/S ratios, until depletion occurs.

2) When the release of a species is limited by solubility, the concentration in the leachate is independent on the L/S ratio. In this case, cumulative release is approximately linear with the L/S ratio, its slope being related to the solubility of the examined species.
3) When some species exist controlling solubility of the components of interest (for example sulfates release being limited by the presence of barium), release takes place only after a certain time interval, corresponding to the time required for depletion of such a species to occur (delayed release). The rate of cumulative release increases roughly linearly as a function of the L/S ratio.
4) When the solubility of the element of interest is enhanced by the presence of a complexing agent (as chlorides do with respect to cadmium), cumulative release as a function of the L/S ratio proceeds initially at a greater slope than for higher L/S ratios. Unlike for case 1, depletion does not occur, therefore the curve has no asymptote and the available quantity is not attained.

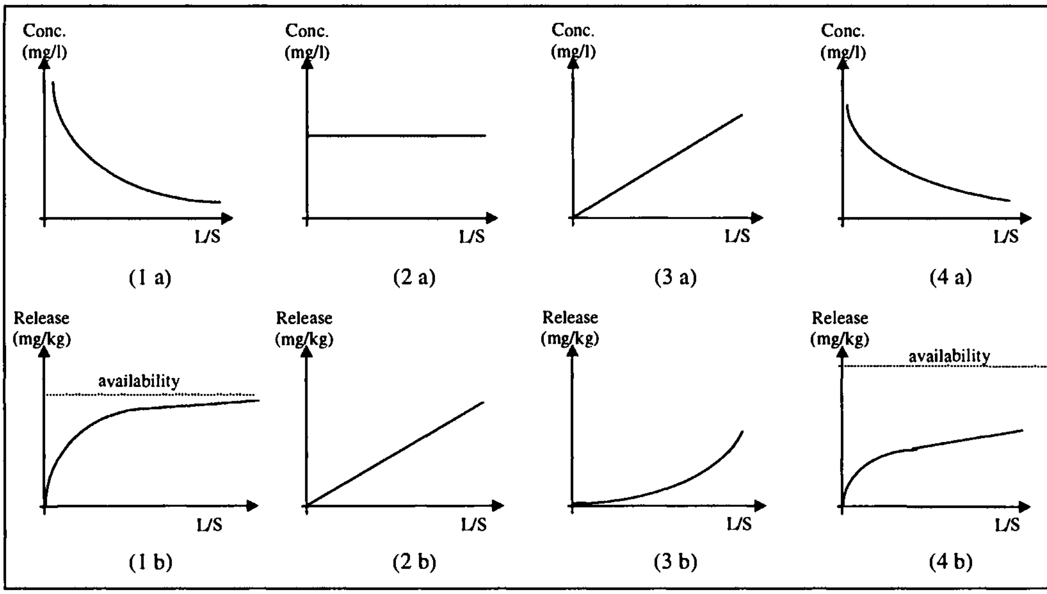

Figure 4: *Release as a Function of the L/S Ratio*

The L/S ratio scale can be changed into a time scale when data concerning the rate of contact between the leaching solution and the waste at the final disposal site are available, the conversion factor being the annual water infiltration rate. As an example, considering a sanitary landfill having a height of 10 m, if the wastes have a specific weight of 1000 dN/m^3 and the annual infiltration rate is 30 cm/y, the annual increment in L/S ratio will be 0.03. Thereby, a cumulative L/S ratio of 0.9 will be reached after 30 years [10].

It must be emphasized that care should be taken when evaluating the L/S ratio for solidified materials. As a matter of fact, depending on the waste/binder ratio, the effective L/S ratio (as calculated with respect to the amount of waste only in the sample) is higher than the overall L/S ratio. This is of basic importance when the leaching test is applied as a pass/fail criterion in order to evaluate the effectiveness of a solidification treatment.

Besides, the results of a leaching test may be hidden if the actual L/S ratio is not considered. As an example, in Figure 5 the results of a dynamic leaching test in terms of cumulative release of copper are reported both as a function of the overall or the effective L/S ratio. It can be seen that, if the curves are drawn as a function of elution time (Fig. 5a), copper release from the sample with FA/C = 0.25 is always higher than the one from the sample with FA/C = 1.50. This incongruence can be removed when the curves are represented versus the effective L/S ratio (Fig. 5b) [5].

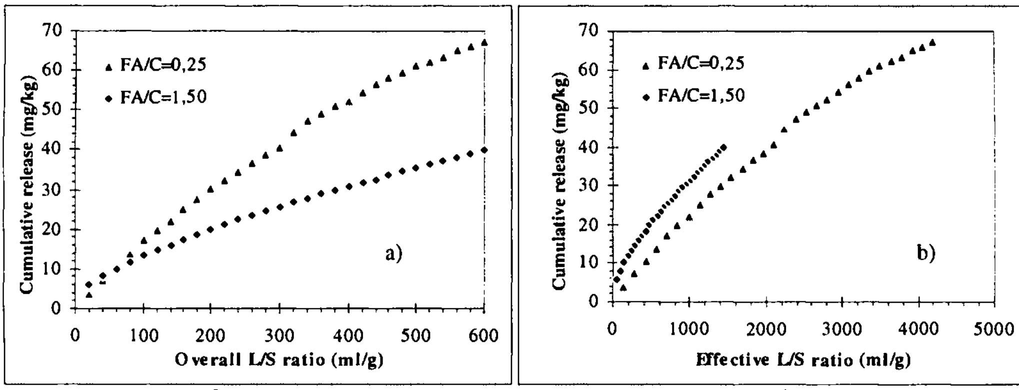

Figure 5: *Cumulative Release of Cu as a Function of the Actual and Effective L/S ratio*

Specific surface

Particle size, porosity and morphology influence the relative surface area available for chemical reactions to take place. They also influence the magnitude of the diffusion pathlength and the type of internal and external mass transfer resistance that occurs as solutes or solvents diffuse into or out of particles.

The contact surface between the liquid solution and the waste material is a factor of critical importance, particularly for monolithic specimens. Contaminants may be extracted from the external boundaries of the solid materials (where it is contacted by the leaching solution), whereas release from the inner parts of the solid material occurs only as a result of molecular diffusion due to concentration gradients, the rate of which is considerably lower.

The extent of leaching generally increases with decreasing particle size (and therefore increasing specific surface). As an example, in Table 3 the results of a modified version of the acetic acid leaching test performed on ground solidified sludge specimens are reported [4].

Table 3: *Heavy Metals Release from Ground Solidified Specimens*

	Sample	Cd (mg/l)	Crtot (μg/l)	Cu (mg/l)	Ni (μg/l)	Pb (μg/l)	Zn (mg/l)
curing time: 3 d	$M_{0,F}$	2.3	367.1	60.0	285.9	153.2	39.8
	$M_{0,M}$	0.9	117.4	20.0	106.7	44.1	16.2
	$M_{0,C}$	1.1	112.6	22.0	110.8	36.1	19.8
	$M_{1,F}$	2.8	417.2	88.0	257.9	129.3	48.4
	$M_{1,M}$	0.8	148.6	18.0	161.7	61.7	14.0
	$M_{1,C}$	1.2	106.1	24.0	144.2	18.6	21.2
curing time: 7 d	$M_{0,F}$	2.6	410.5	64.0	273.5	96.5	44.0
	$M_{0,M}$	0.8	152.6	18.0	111.1	43.4	14.6
	$M_{0,C}$	1.0	168.5	20.0	114.5	40.5	17.0
	$M_{1,F}$	2.2	370.0	60.0	260.5	93.5	41.2
	$M_{1,M}$	1.1	254.6	26.0	146.6	75.3	19.2
	$M_{1,C}$	2.0	185.0	26.0	117.6	40.0	24.6
curing time: 28 d	$M_{0,F}$	3.5	355.8	100.0	237.5	90.0	51.8
	$M_{0,M}$	1.2	186.8	28.0	109.9	31.1	20.2
	$M_{0,C}$	0.9	123.6	20.8	102.3	32.6	15.4
	$M_{1,F}$	2.6	372.2	62.0	172.5	72.9	43.4
	$M_{1,M}$	1.2	218.3	22.0	109.0	35.5	18.8
	$M_{1,C}$	1.3	156.2	26.0	99.5	28.6	11.0

C: Coarse, M: Medium, F: Fine; 0: W/C=0, 1: W/C=0.1

However, a number of investigators found that in some cases for granular materials the reverse takes place. Such an apparent contradiction may be explained on the basis of the higher acid neutralization capacity smaller particles may have (at least at the initial stages of leaching). In these instances, during the initial phases of leaching smaller particles may release alkaline elements to a greater extent than larger particles, thus causing pH to increase. Under these conditions, with major reference to heavy metals, contaminant release from solid matrix is pH-controlled. The pH raise results therefore in hindering the extraction of those elements which are less soluble at high pH values and conversely in promoting the extraction of those elements (Zn, Pb) which are highly soluble under alkaline conditions. This happens until the acid neutralization capacity reaches a certain threshold value.

Contact time

The total amount of time that the leachant is in contact with the waste before the steady-state conditions are attained (chemical equilibrium) will influence the amount of contaminants released. In extraction tests, the contact time equals the duration of the test; conversely, in dynamic tests it is a function of flow rate or number of elutions, as well as test duration. In Figure 6 cumulative release of cadmium and zinc as a function of the square root of elution time for a dynamic leaching test is illustrated. The linear trend of the curves indicates that contaminant leaching is controlled by the molecular diffusion from within the waste [5].

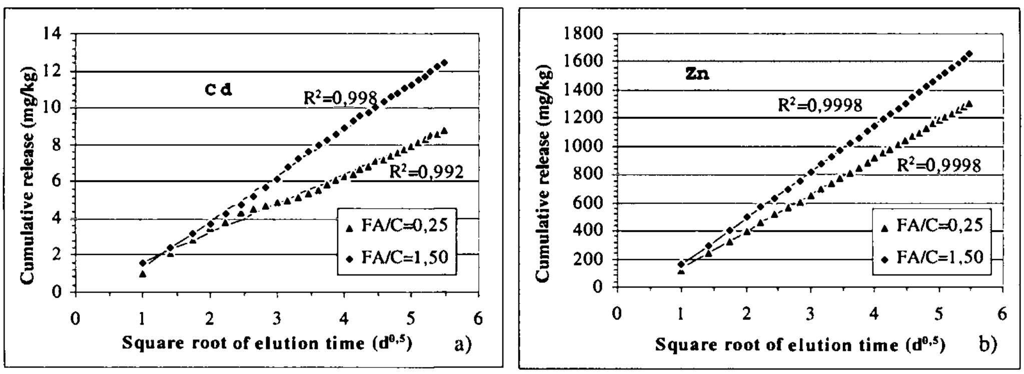

Figure 6: *Cumulative Release as a Function of the Square Root of Elution Time*

Ideally, a leaching test should allow equilibrium conditions to be attained for the contaminants of interest, and the release kinetics as a function of time to be evaluated. On the other hand, the contact time should be such as to prevent the occurence of biological and secondary processes which may interfere with the leaching process. Obviously, contact time is a function of the waste form: for granular materials the time required for reaching chemical equilibrium is on the order of hours to days, whereas for monolithic samples it may range from weeks to months.

The value of the required contact time is also a function of the method of contact between the liquid and the solid phase.

Method of contact

When studying the transfer of contaminants from a waste to a liquid, all the aspects related to the operating conditions that may promote mass transfer (such as agitation) to the liquid or to other components of the system (primarily the leaching vessel and the atmosphere) must be carefully evaluated. Any buildup of the leached species at the liquid/solid interface reduces the driving force for extraction, thus agitation is provided in order to maintain the maximum concentration gradient at the liquid/solid interface, so that steady-state conditions are approached at a faster rate.

In a static or non-agitated test, contaminant diffusion at the L/S interface proceeds at a decreasing rate with decreasing concentration gradient. No mixing is provided because the

kinetics of contaminant diffusion within the leachate is assumed to be faster than the rate at which other mechanisms (such as surface dissolution or diffusion from within the waste) evolve.
Different methods may be used to provide agitation, including shaking (wrist action or reciprocation), stirring (magnetic or mechanic), tumbling, gas bubbling.

4 Conclusions

This paper presented an overview of the main phenomena occurring during the leaching process and of the parameters affecting the extent and the degree of solubilization.
A correct understanding of process complexity and of the influence exerted by a large number of parameters (such as physical and chemical waste properties, operating conditions, etc.) is required to achieve the following objectives:

- select the proper procedure to predict the extent of leaching under the actual conditions occurring when a waste is contacted by a liquid phase;
- interpret the apparent discrepancies that may exist between the expected and actual behavior of the material subjected to the test;
- develop more accurate tests for regulatory or lab purposes, according to the proposed target.

A future work will be focused on understanding the interactions existing between the different parameters during the leaching process. Proper modified versions of the available standard leaching tests are going to be carried out in order to widely define the influence of all the parameters described above in the cases where information is still missing.

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THE MUNICIPAL WASTE MANAGEMENT AND THE SUSTAINABLE DEVELOPMENT IN A BIG CITY: ROME

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Abstract

The city of Rome represents a particular and very interesting case of study. In fact it is one of the most densely populated city in Italy and, at the same time, it presents different patterns of urbanisation. In fact the central-historical areas are full of ancient and artistic evidences, while the remaining part of the city is interested by an heterogeneous urbanisation regarding high density zones, residential zones, office zones, agricultural suburban zones and industrial and handicraft suburban zones. For these reasons, different strategies are adopted to obtain an effective, efficient and economic solid waste management in the city.
The aim of this paper is to present the solid waste management systems and the technologies adopted in the city of Rome.

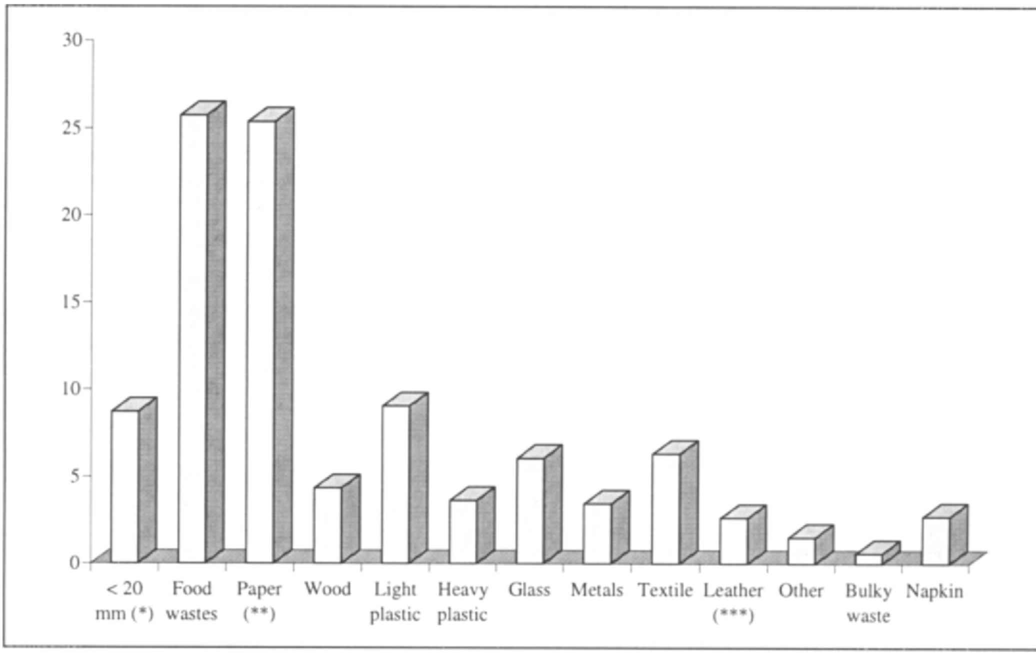
1 Introduction

The description of the solid waste management in Rome, is a particular and very interesting case of study. The object of this paper is to present the real management experience of a big city, like Rome.
Rome city's resident population is about 3 million inhabitants, moreover there are about 2 million of commuters, tourists, non-regular residents and so on.
The territory of Rome's municipality, is about 1300 km^2, and it's very heterogeneous and hard to administer just because it is the most extensive agricultural territory and, at the same time, the most densely populated one of Italy.
The diversity of Rome urban area is a distinctive feature of the city: different patterns of urbanisation have occurred across the city. This particular urbanisation is the result of differences in economics, religious and historical developments. Now there are new planning regulations to preserve artistic evidences and for environmental revaluation and revitalisation. The common purpose of these programmes is to save and improve the ecosystem of this wonderful city (and so to create job, too). Now 64% of the territory is not allowed for any building; due to this fact, Rome has one of the highest protected areas rate in Europe.

The renewal and re-use of old sites represents a great opportunity for an ecological restructure of both urban and suburban zones, according to a sustainable development; moreover the creation of new and adequate green areas, can improves the standard of living.
Urban cleaning and waste management belong to the project of Rome retraining.

2 Waste Management: the Present Situation

Rome produces about 1.5 million metric tons of refuse per year, and 90% are domestic waste (4000 t/d). There is only one site for disposal of solid waste: the big "Malagrotta" landfill (over 280 Ha of surface). Besides, the A.M.A. has a thermodestruction plant (120 t/d), for sanitary waste.
Figure 1 shows the typical physical composition of municipal solid waste (MSW) in the city of Rome.



(*) Waste with dimension less then 20 mm; (**) Paper and cardboard; (***) Leather and rubber

Figure 1: *Typical Physical Composition of Municipal Solid Waste in the City of Rome*

Actually the separated collection of materials (glass, metals, paper, plastic) represents the 7% in weight of the whole solid waste, but the goal is to reach the 15% by 1999 spring. In order to obtain this percentage of separated materials collection, more than 20.000 new containers will be positioned in the city.
The municipal environmental company of Rome (A.M.A.: Azienda Municipale Ambiente) attends the waste management in the city. Primary emphasis is laid on:

- the reduction of the waste generation;
- the re-use of materials;
- the source-separation of different materials and the recycling of the useful ones;
- the optimisation of final disposal and the reduction of landfilling;
- the minimization of environmental pollution through new thermodestruction plants and treatment processes.

The distribution of containers for the collection of source-separated materials in the city of Rome, referred to the month of December 1997, is described in the Table below.

Table 1: *Distribution of the Containers for Source-Separated Materials in the City of Rome (December 1997)*

Circoscrizione	Residential Population	Residential Population (%)	Surface (Km^2)	Surface (%)	Container for paper	Container for glass	Container for glass, plastic and metals
I	122.228	4,36	14,30	1,11	129	12	157
II	125.422	4,48	13,67	1,06	3	227	2
III	58.881	2,10	5,91	0,46	4	116	1
IV	210.513	7,51	97,82	7,61	7	332	6
V	188.808	6,74	49,15	3,82	417	220	422
VI	136.494	4,87	7,92	0,62	2	198	1
VII	128.101	4,57	19,60	1,52	3	181	2
VIII	191.940	6,85	113,35	8,82	61	214	61
IX	137.687	4,91	8,07	0,63	429	103	428
X	182.679	6,52	38,68	3,01	632	130	631
XI	141.546	5,05	47,29	3,68	600	40	615
XII	152.158	5,43	183,17	14,25	689	82	687
XIII	184.225	6,58	150,64	11,72	827	87	830
XV	157.818	5,63	70,88	5,51	307	143	306
XVI	150.814	5,38	73,13	5,69	401	34	446
XVII	76.415	2,73	5,61	0,44	65	7	96
XVIII	133.723	4,77	68,67	5,34	132	149	131
XIX	178.718	6,38	131,28	10,21	163	167	162
XX	143.219	5,11	186,70	14,52	5	165	2
	2.801.389		**1.285,84**		**4.876**	**2.607**	**4.986**

The Table 2 shows some information about the separated collection of materials in the city of Rome in the month of December 1997.

Table 2: *Separated Collection of Materials in the City of Rome (December 1997)*

Circoscrizione	Commingled MSW (t/m)	Source-separed paper waste (t/m)	Source-separed glass and mix glass,plastic and metals waste (t/m)	Total Source-separed waste (t/m)	Total MSW (t/m)	Specific production of MSW (kg/capita d)	Specific production of Total Source-separed waste (kg/capita y)
I	9.296	68	70	138	9.434	2,49	13,29
II	6.074	2	95	97	6.171	1,59	9,11
III	2.659	1	56	57	2.716	1,49	11,40
IV	6.709	7	92	99	6.808	1,04	5,54
V	5.895	165	142	307	6.202	1,06	19,14
VI	4.695	0	35	35	4.730	1,12	3,02
VII	4.422	2	36	38	4.460	1,12	3,49
VIII	6.012	19	43	62	6.074	1,02	3,80
IX	4.475	250	155	405	4.880	1,14	34,63
X	5.759	323	209	532	6.291	1,11	34,29
XI	5.012	248	135	383	5.395	1,23	31,86
XII	5.369	331	187	518	5.887	1,25	40,08
XIII	5.940	285	211	496	6.436	1,13	31,70
XV	4.493	150	107	257	4.750	0,97	19,17
XVI	5.492	232	159	391	5.883	1,26	30,53
XVII	3.607	50	54	104	3.711	1,57	16,02
XVIII	4.785	75	63	138	4.923	1,19	12,15
XIX	5.455	83	89	172	5.627	1,02	11,33
XX	5.097	5	46	51	5.148	1,16	4,19
	101.246	**2.296**	**1.984**	**4.280**	**105.526**	**1,26**	**17,62**

3 The Analysis of the Waste Management Problems, in the City of Rome

The analysis of the waste management in the city of Rome can leads to interesting results, peculiar for most of the metropolis belonging to the developed Countries. We are of opinion that this description underlines the problems and the resolution methods projected for the city of Rome and allow to compare them with the other international experiences.

First of all, the most important subjects at the European attention, and in particular at the Italian one, are the sustainable development and a concrete employment polity (in Italy, the average rate of unemployment is higher than 10%, with highest value in the Southern part of the country)

The waste management of the city of Rome is carried out by means of two different methodologies. The first one is the methodology adopted in the central-historical zone of the city ("I circoscrizione"). A high level of mechanisation of the waste management is not allowed in this zone, due to the town planning typology and to the existing bonds.

Therefore, in the central zone of Rome, the solid waste collection methodology adopted is the outdoor one, even if this handling method has a high specific cost.

The collection of source-separated materials and other innovating collecting systems find different problems for the limitations we have discussed previously. Moreover, it has to be considered that the central-historical zone of Rome guests a huge amount of workers and tourists and that it is plenty of restaurants, bars, pubs and so on. Therefore the solid waste specific production in this part of the city is higher then in the others. Moreover, waste collection has to be carried out during night-time and it creates a lot of problems regarding noises, safe in working conditions, etc..

The remaining part of the city (higher than the 99% of the total surface) is interested by a heterogeneous. urbanisation regarding high-density zones, residential zones, office zones, agricultural suburban zones and industrial and handicraft suburban zones. Table 3 shows the differences between the composition of municipal solid waste generated in the several zones of the city.

Table 3: *Physical Composition of Municipal Solid Waste in the City of Rome*

Component	Percent by weight							
	Central zone	**Popular zone**	**Residential zone**	**Residential and commercial zone**	**Industrial and handycraft suburban zone**	**Office zone**	**Miscellaneous zone**	**Typical composition in the city**
Waste with dimension less then 20 mm	8,16	9,14	7,54	9,84	6,94	11,85	8,16	**8,71**
Food wastes	22,60	28,21	26,88	25,67	3,87	20,01	22,62	**25,72**
Paper and cardboard	32,40	20,83	22,91	32,47	50,91	34,16	32,26	**25,36**
Wood	1,80	5,53	4,67	2,45	2,16	3,34	1,98	**4,33**
Light plastic	9,18	7,70	9,40	9,80	11,66	9,78	9,18	**9,03**
Heavy plastic	3,88	3,18	3,32	4,44	3,73	5,64	3,88	**3,63**
Glass	8,84	6,06	5,58	4,90	4,48	6,33	8,84	**6,04**
Metals	3,20	4,03	3,06	2,40	5,47	3,05	3,20	**3,45**
Textiles	4,82	6,86	8,11	2,99	6,74	1,73	4,82	**6,31**
Leather and rubber	1,47	2,86	3,47	1,00	2,82	1,27	1,47	**2,64**
Other	1,67	1,65	1,89	0,50	1,22	0,81	1,59	**1,50**
Bulky waste	0,00	1,22	0,26	0,00	0,00	0,46	0,00	**0,58**
Napkins	1,98	2,71	2,90	3,54	0,00	1,61	1,98	**2,70**

In all this remaining part of the city, a high-mechanised waste collecting method is adopted, using tree different kinds of containers. The first container is used for the "heavy" recyclable materials, such as glass, metals and plastic, the second one is used for paper and the last one is used for the commingled waste. The waste collection is carried out, wherever it is possible, using big size vehicles in witch containers are mechanically emptied (side-loader with the only driver). The road sweeping is organised with long journeys and using middle or big size vehicles.

Table 4 shows the characteristic data of the city of Rome; these data are distinguished for the 19 Rome's districts ("Circoscrizioni").

Table 4: *Characteristic Data - City of Rome*

Circoscrizione	Residential population	Surface (km^2)	Solid waste production (t/y)
I	122.228	14,3	101.332
II	125.422	13,67	62.303
III	58.881	5,91	30.418
IV	210.513	97,82	75.319
V	188.808	49,15	67.269
VI	136.494	7,92	47.133
VII	128.101	19,6	48.212
VIII	191.940	113,35	70.837
IX	137.687	8,07	52.996
X	182.679	38,68	69.821
XI	141.546	47,29	55.594
XII	152.158	183,17	59.995
XIII	184.225	150,64	76.834
XV	157.818	70,88	56.390
XVI	150.814	73,13	62.285
XVII	76.415	5,61	39.455
XVIII	133.723	68,67	56.391
XIX	178.718	131,28	61.465
XX	143.219	186,7	58.220
	2.801.389	**1.285,84**	**1.314.845**

It has to be underlined that the actual waste management standards adopted by the AMA, regard a daily collection; moreover on Sunday and during holiday times, a partial collection is carried out.

The main problems of the collection system are related to the road networks and to the inadequacy of the existing infrastructures. The congested traffic is a crisis factor for the whole system., especially during day-time. The road networks are always inadequate and do not respond to the needs of the city; first because the huge growth of the city and second because of the archaeological bonds that not allow the realisation or the enlargement of street, underground, etc..

The AMA with the University of Rome, has studied a new way of collecting solid waste using transfer stations to transport waste from road vehicles to the city's railway. The advantage is that the railway can be used during the night-time, with a consequently reduction of pollution (both gaseous and noisy emissions). At least two transfer stations (tyre rail) are going to be activated within next years.

In the last years a lot of new projects has been achieved, with regard to the infrastructures and plants for the solid waste management of the city of Rome,. We can summon: outskirts headquarters, establishments and workshops for more than 1.200 heavy vehicles, new waste treatment plants, such as the 20.000 t/y composting plant and the two plants in witch the waste is separated into different material flows. The Table 5 shows the present situation of municipal solid waste plants in the city of Rome.

Table 5: *The Present Situation of the Municipal Solid Waste Plants in the City of Rome*

Plant	**Type of Solid Waste**	**Plant Capacity**	**Present Situation**	**Property**
One Landfill	MSW		in operation	private
Three Landfills	Bulky waste and C/D waste		in operation	private
One Plant for the Waste Separation	Commingled MSW	1,200 t/d	in operation	private
One Plant for the Waste Separation	Source-separed (mixed glass, metals and plastic)	90 t/d	in operation	private
One Plant for the Waste Separation	Source-separed (mixed glass, metals and plastic)	40 t/d	on the stocks	private
One Composting Plant	Food waste from markets	100 t/d	on the stocks	AMA
Two Composting Plants	Yard wastes	10,000 t/d	on the stocks	private
One Incineration Plant	Hospital waste	120 t/d	in operation	AMA
One Volume Reduction Plant	Bulky waste		in operation	AMA

The promise is to guarantee, within the 2000 year, a new network of infrastructures and new waste management system methodologies to reduce the quantities of solid waste generated, by the use of solid waste treatment systems, witch allow to obtain materials and energy recovery.

4 Conclusion

This paper shows the waste management system and the technologies adopted in Rome, a big occidental city. This represent a complex and expensive activity(the Azienda Municipale Ambiente annual budget is about 330 million US$), mainly due to variety and dimension of municipal areas.

Waste management in Rome is very difficult, in central-historical areas that are full of ancient and artistic evidence. At the same time, the new congested outskirts are complex and heavy in terms of urban hygiene services.

Different strategies are adopted to face these difficulties. Anyway the goal is to obtain effective, efficient and economic services with customer (citizen) satisfaction.

New regulations and European legislation, in agreement with environmental and social development, will allow a real waste minimization and restricting consumerism.
Mayor costs of new collection and treatment organization, together with plans of high investment, will create job and will guarantee environment preservation.
The future growth of the city will be founded on eco-sustainable development.

WASTE MANAGEMENT SYSTEMS IN INDUSTRIALIZED AND DEVELOPING COUNTRIES - GENERATION, QUALITY, DISPOSAL -

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Abstract

Waste generation rates and waste quality are strongly influenced by the economic conditions. Integrated solid waste management systems should be established in all countries. An inertization of waste prior to disposal should be mandatory. Combustion with energy recovery can also be an option for middle-income and developing countries. Recommendations are made to adjust the management system and waste combustion technology to the needs of such countries.

1 Historical Development

All human activity leaves some kind of waste behind. As long as only few groups of early men were roaming the countryside the garbage they left over were food scraps like bones from their prey, ashes from their fires and some broken pottery. Life was hard in those times and people had to save their resources. Hence it can be emphasized that the per capita production of waste was rather low. From a today's viewpoint of waste management such materials from daily living can be characterized as a mixture of readily degradable organic food residuals and inert mineral matter. This material was dumped in pits close to the settlements. The putrescible fraction disintegrated soon. The inert matter stayed and today archaeologists are eager to detect such places and learn from the remnants about former life. In this respect waste can be looked upon as a testimony of history and may even be assigned a cultural value.
Things changed with time. A growing population produced increasing amounts of garbage. Furthermore, altered living conditions and consumer habits as well as the ongoing industrialization during the last two centuries changed the properties of waste substantially. Drastic effects were caused by the upcoming utilization of fossil energy sources, especially of oil and gas, which reduced the fraction of ashes. The same raw materials pushed the

development of chemical industry which started to develop a totally new category of materials entering rapidly all areas of life and showing up as rapidly in the waste stream, too.
The disposal of waste became more and more difficult the higher the population density grew. Offensive smell pushed the development of some kind of organized waste management system in very early times already. The Holy Bible, the fundamental book of Christianity, gives evidence that about 3 000 years ago already the garbage of old Jerusalem was brought to the Kidron river where it was burnt in a permanently supported fire [1]. Central European cities established waste collection systems in the Middle Age operated by prisoners or whores and started to take the waste to near-by farms were it was used as fertilizer.
During the last century another and more endangering aspect of waste handling was detected: household waste carries all kinds of infectious ingredients. This gave reason especially for medical doctors to call for an effective inertization of the waste prior to disposal and paved the way for the development of waste incineration in England around 1875 [2].
The fundamental problems associated with waste management and disposal which became manifest in early times already are more or less a target still today. Local conditions like the status of industrialization, the socio-economic situation, or even climate, preferred settling structure and preferences in diet influence waste volume and quality. Since there is no uniform waste stream, there is no uniform solution for waste management. Optimal strategies can only be expected if all local conditions are carefully considered.
In the following the attempt will be made to characterize the waste in different parts of the world in terms of volume and quality and to relate it to economic conditions. On this basis disposal and inertization strategies suitable in middle-income and developing countries will be discussed.

2 Waste Volume and Quality

2.1 The Economic Disparity

In historical times waste was that material which was of no longer use and was discarded. Today even the definition of waste is controversially discussed [3]. In our context we will stay with the simple old-fashioned definition given above. There is evidence that waste, its volume as well as its composition, depend strongly on the living conditions, on the cultural, social, economic, and industrial status in a region. It seems rather difficult to define a single parameter which accounts for all influences. In order to simplify the problem it is assumed that the major influences are associated with the state of industrialization and that the gross domestic product (GDP) can be used as a first approach to this parameter. The world map shown in Fig. 1 reveals the great disparity of economic conditions in different regions of the world.

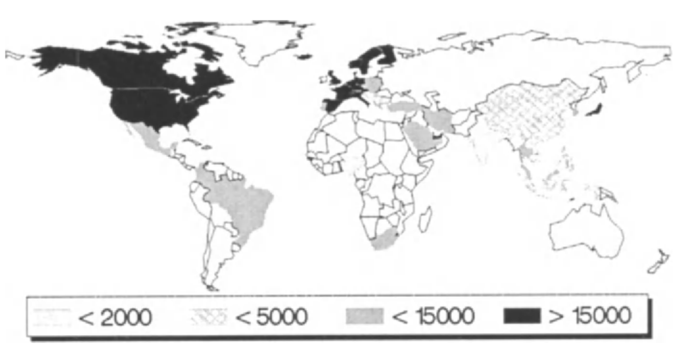

Figure 1: *GDP Expressed in US-$ per capita for Selected Countries [4]*

Poor countries with GDP's of approx. 2 000 US-$ predominate in Asia and Africa. Countries of high prosperity with GDP's up to > 20 000 US-$ accumulate in Europe, North America and in East Asia. Whereas the poor countries are mainly characterized by traditional agriculture or nomadism, the prospering states are centres of trade and industry. In some cases, however, the profit from natural resources like oil overrules the importance of industry. This ranking, of course, may change with time but the changes we saw during the last decades seemed more to increase the gap between the extremes than to fill it. Nevertheless, in future industrialization will get more and more influence on the living condition everywhere.
In view of waste management the population density plays a major role. Waste disposal will be more difficult in densely populated regions. In many developing states, e.g. in Africa, the average population density is rather low. Looking at it more closely, however, we see a dramatic drift to the cities with all accompanying problems such as rapidly growing slums with poor or no infrastructure, unemployment, social and/or demographic conflicts. It is obvious that in such areas waste disposal seems to be a problem of rather low priority, but in reality it has a great impact on human health, not to speak about long-term ecological effects.

2.2 Waste Generation

Whereas economic data are easily available, valid data on waste generation and even more on waste composition are rarely found in literature. Furthermore, the reliability of such data is rather poor. Sometimes the published numbers base only on more or less sound estimates, they may include commercial and industrial waste or not, etc.. Political or other biases may complicate the interpretation and interfere seriously with any comparison between countries. In principal, such data are rather old: e.g. the latest official numbers for German waste generation date back to 1993.
The data discussed in this paper have been gathered from official statistics (e.g. Eurostat, German Statistisches Bundesamt, OECD, US-EPA), from specific journals (e.g. Warmer Bulletin, Umwelt), from publications in scientific journals and from discussions with single experts. Due to the limited space the numerous sources cannot be referenced here.

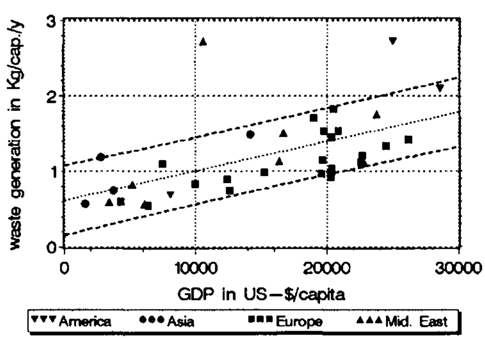

Figure 2: *Waste Generation as a Function of the GDP for Countries in Various Continents (linear fit, 70% confidence limit)*

Nevertheless, the attempt will be made to compile waste generation numbers from selected countries including almost all highly industrialized states in Europe, North America and Asia, some middle-income states with GDP's between 5 000 and 15 000 US-$/capita and also some developing countries with GDP's of less than 5 000 US-$/capita.
A visualization of these data shown in Fig. 2 reveals a distinct correlation of waste production rates and GDP. The outliers can be identified as Saudi Arabia and Canada. The graph gives evidence that people in poorer countries are forced to make better use of their resources and cannot afford to buy a lot of short-lived consumables. Hence the waste from such regions

should mainly consist of food residues and ashes - as was always typical for countries the economy of which bases mainly on agriculture and nomadism.

2.3 Waste Characterization

The data available for the composition of waste are much less precise than those of waste generation. Waste analysis is a complicated and time consuming procedure. Average data for a single state are difficult to be obtained since local conditions and seasonal changes may vary a lo and the respective graphs are characterized by a wide range of scattering. However, if the validity of the data is carefully considered some generic conclusions can be drawn from such informations.

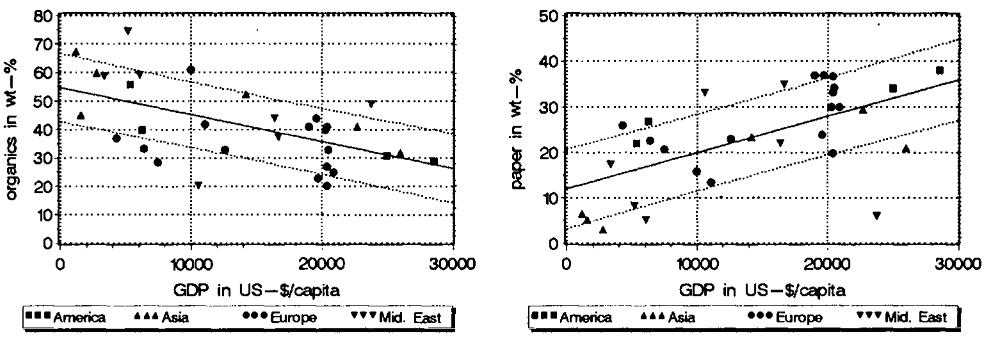

Figure 3: *Organic Fraction (left) and Paper (right) in the Waste as a Function of the GDP for Countries in Various Continents (linear fit, 70% confidence limit)*

The above made speculation concerning the waste quality in developing countries is supported by a closer look into the composition of their waste stream. The left graph in Fig. 3 shows the organic fraction of the waste as a function of the GDP. The graph indicates that the fraction of food waste is much higher in developing countries than it is in industrialized ones. Consequently the fraction of paper (right graph in Fig. 3) and of plastics (left graph in Fig. 4) is more dominant in the industrialized regions.

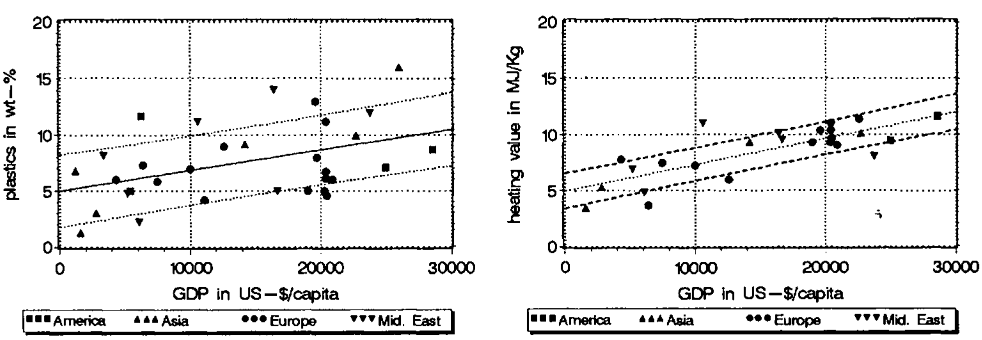

Figure 4: *Plastics in the Waste (left graph) and Lower Heating Value (right graph) as a Function of the GDP for Countries in Various Continents (linear fit, 70% confidence limit)*

Regarding waste management strategies, some additional parameters are of major interest: the humidity and the calorific value of the waste. Only few data sets contain information about the humidity. As a general rule it can be stated that the humidity is mainly associated with the organic waste fraction. In Europe and North America the waste humidity varies typically

between 30 and 40 wt.-%. From East Asian regions, e.g. Korea, humidity values up to 70 % (especially during the Monsoon season) have been reported.
The humidity influences the calorific value of the waste. From the above made considerations it is evident that waste in developing countries is characterized by low heating values (down to < 5 MJ/Kg) whereas in industrialized countries this parameter can exceed 12 MJ/Kg. In some cases directly measured lower heating values were available, if not, these were calculated using the waste composition data. Regarding the influence of the GDP on the waste composition it is not surprising that there is a strong correlation between the GDP in a single country and the heating value of its waste (compare right graph in Fig. 4).

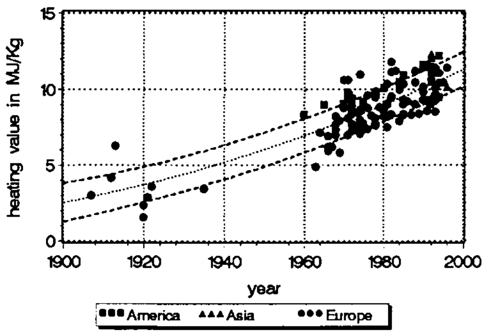

Figure 5: *Development of the Heating Value of Municipal Solid Waste in Industrialized Countries (cubic fit, 70% confidence limit)*

The economic conditions and along with these the waste composition in developing countries will presumably change in future into the direction of the situation we find in industrialized countries today. This suggests an increase in heating value similar to the development we have seen in the industrialized regions during this century. In the beginning of this century the waste in Central Europe had similar composition as we find today in the developing regions. As Fig. 5 documents, the lower heating value of European and North American municipal solid waste increased significantly since 1900 and is eventually still increasing.

3 Waste Management Strategies

3.1 The Waste Management Hierarchy

During the last decade many countries have tried to solve their waste problem in a sustainable way - that is without creating any impact on human health or the environment today as well as in future - and started to develop waste management policies [5]. Considering the variability of waste streams it seems evident that there is no standard answer to the problem. Practicable waste management systems have to take into account all local peculiarities and conditions.
In this context usually a hierarchy of waste management based on prevention, reuse, recycling, composting/anaerobic digestion, energy recovery and disposal is discussed. The hierarchy is no protocol to be strictly followed in practice but it should be used as a guide-line in establishing integrated waste management systems [6]. This is often ignored in political discussions and some proposals in that area seem rather born by faith than by rational consideration. A good example is the former German debate about the ecological profits of material recycling of plastics against energy recovery. Meanwhile it is accepted that all waste management systems. These have especially to balance the ecological benefits and the economical expenses of the system.
Regarding the waste hierarchy in terms of its applicability for middle-income and developing countries there is no doubt that this guide-line will prove to be very useful. Although for the

time being there is a low waste production rate, it has to be assumed that this rate will increase with increasing economical prosperity if no action is taken against such development.

3.2 Reuse and Recycling

Many countries have started extensive programs to divert and recycle all kinds of waste fractions starting with glass and metals and ending with plastics. Although in parts very successful, some politically promoted programs pointed out to be very expensive. Middle-income and developing countries should learn from such experiences. In many regions reuse and recycling are today established in an unorganized way on local or private level, sometimes by people scavenging on landfills. In terms of waste management this activity is welcome, the health risk associated with treating raw waste, however, calls for other - unfortunately more expensive - solutions.

3.3 Composting

Since long times composting is practiced in rural areas to convert the organic waste fraction into a soil-like material which is used as fertilizer. There are many attempts found in industrialized states to promote composting or alternatively anaerobic digestion. The major obstacle for the success of this treatment strategy is the compost quality. To prevent contamination of soil by heavy metals, the organic waste fraction has to be separated with care. From experience this is more easily achieved in rural areas. Other but minor handicaps of composting are offensive smell and the needed space. Biological treatment produces no inert material and should not be seen as competition to thermal treatment processes.
In regions with less population density composting could be very useful since it reduces the amount of material to be disposed of and it supplies fertilizer. Another advantage is the reduction of the typically high humidity in the residual waste stream which increases its calorific value. To guarantee the required high quality of the separately collected material educational measures have to be implemented.

3.4 Landfilling

Regardless of philosophical or political perceptions and technical efforts: all waste management systems need a landfill for final disposal. For centuries landfilling was pure dumping of trash on sites close to the settlements. There are two major obstacles associated with landfilling of untreated waste: its decomposition generates landfill gases, especially methane, which contribute to the greenhouse effect and leachates containing heavy metals and salts which may pollute the groundwater. Such impacts have to be minimized and hence siting and operating a sanitary landfill has meanwhile become an expensive task. In calculating the cost the high expenses for aftercare measures on the closed landfill must be considered. That is why there is a tendency to be seen in many regions (e.g. in Europe [7]) to ban the disposal of reactive material on a landfill.

3.5 Municipal Solid Waste Combustion

Waste combustion has been used since more than 100 years to disinfect the waste stream, to reduce its volume and hence to save space on the landfill. A number of densely populated industrialized states practice combustion for 50 - 80 % of their waste stream (e.g. Japan, Switzerland, Denmark). Other states in Europe and America have a lower combustion rate but this is assumed to increase due to the principal of inertization prior to disposal.
The major aims of municipal solid waste combustion can be summarised as follows:

- destruction of organic pollutants and inertization of inorganic waste ingredients,
- utilization of the energy inventory of the waste,
- compliance with the respective air emission regulations, and
- minimization of technical effort and process costs.

Today more than 2 500 waste combustion plants are in operation world-wide.. The predominant technology is the combustion on a grate with more than 1 000 units [8]. A grate system requires almost no waste pretreatment and enables self-sustained combustion of waste with lower heating values between approx. 6 and 15 MJ/Kg. In some countries, especially in Japan, the combustion in fluidized bed systems is practiced, too. This technology requires in most cases a size reduction and some metal removal. Less than 100 units are in operation world-wide.

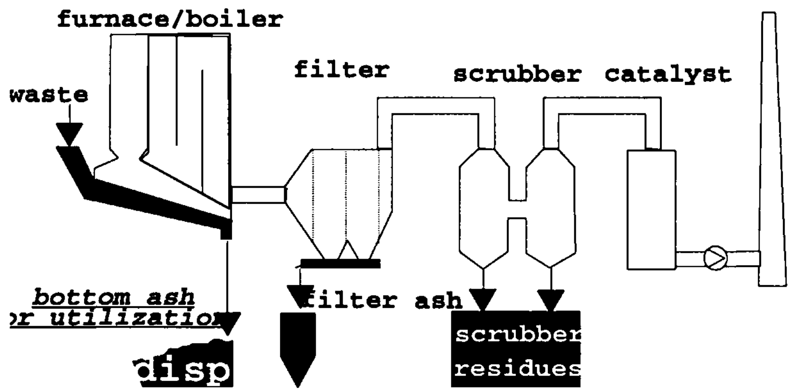

Figure 6: *Scheme of a Typical Municipal Solid Waste Combustion Plant (grate system)*

A scheme of a waste combustion plant equipped with a grate is shown in Fig. 6. The facility comprises typically a furnace, a boiler and an air pollution control system with a filter, a scrubber and in many cases a catalyst for NO_x abatement. Often a polishing stage (e.g. charcoal filter or jet stream injection) is installed at the back end to guarantee the compliance with any emission limits.

Bottom ashes are sintered and rather inert materials. The residual carbon level can be kept well below 1 wt.-% and the PCDD/F concentrations are in the order of 1 - 5 ng(I-TE)/Kg which resembles values analysed in Central European natural surface soils.

Bottom ashes have an elution stability which enables - after metal removal and aging - their utilization as secondary building material [9]. Fig. 7 displays the results of leaching tests on German ashes, standardized to the limits for utilization in road construction [10]. To give an idea about the environmental quality of such materials the respective test results for concrete samples are included in the bar graph. A comparison makes evident that bottom ashes have the potential to replace conventional building materials with only marginal influence on the environment.

The recovery of energy is an important aspect of waste combustion. The total efficiency of a waste combustion plant is of course lower than that of a power plant due to the energy consumption of all subsidiary units. If only electrical power is produced, the efficiency is 20 - 22 %. If power production and heat utilization are combined, the total efficiency can reach 60 - 70 % of the energy in the waste. The contribution of energy from waste to the power production in industrialized countries is rather low. The respective number for Germany which burns approx. 25 % of its municipal solid waste is about 1 %. If all waste would be burnt approx. 5 % of the electricity could be substituted.

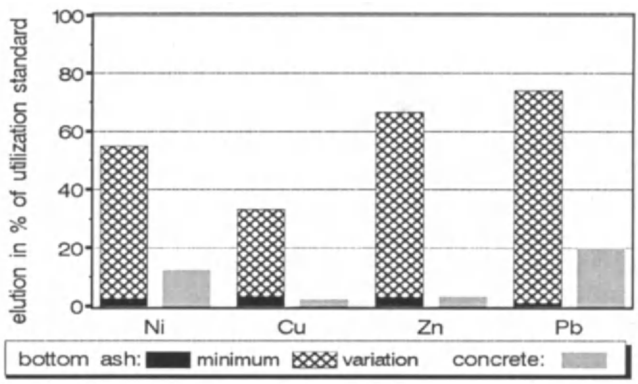

Figure 7: *Leaching Stability of Bottom Ashes and Concrete in Percent of the German Limit for Utilization in Road Construction (German DEV S4 test)*

In middle-income and in developing countries the situation is better in view of the potential as can be seen by the data compiled in Table 1. The theoretical contributions look promising but in reality those portions will not be reached. It has to be considered that for the near future waste combustion should only be implemented in densely populated areas. Furthermore, the low heating value of the waste in such areas makes the combustion difficult and calls for extra strategies, e.g. the co-combustion of other waste streams like wood, shredder residues or even of coal.

Table 1: *Theoretical Contribution of Waste Combustion to Electricity Supply*

country	GDP [US-$/cap.]	waste gener. [Kg/cap./d]	heating value [MJ/Kg]	electr. cons. [KWh/y]	contr. waste [%]
P.R. of China	2 800	0.8	5.3	684	12
Germany	20 400	1.45	9.4	5 730	5 (1)
India	1 600	0.6	4.7	419	14
Mongolia	2 060	0.8	5	1 215	6

The combustion of one tonne of waste requires approx. 4 500 m^3 of air. Hence air pollution control is an important aspect in waste combustion. Pollutants of special concern are polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/F) and mercury (Hg) with the PCDD/F of highest public interest. The potential of waste combustion plant for the destruction of even thermally stable organic compounds is extremely high. The PCDD/F and other chlorinated organic species found in the flue gas are formed from products of incomplete combustion mainly in the boiler of the plant. This reaction can to a great extent be suppressed by an improved burnout which is achieved by good combustion control. High calorific values of the waste are promoting this effect. In this respect the situation in countries with low-calorific waste is not favourable.

Table 2: *Environmental Relevance of the Stack Emissions from Waste Combustion (Germany)*

component	stack emission	background concentration	additional immission
HCl	5 mg/m^3	30 $\mu g/m^3$	0.15 $\mu g/m^3$
SO_2	20 mg/m^3	20 $\mu g/m^3$	0.6 $\mu g/m^3$
Cd	5 $\mu g/m^3$	3 ng/m^3	0.15 ng/m^3
Hg	10 $\mu g/m^3$	5 ng/m^3	0.3 ng/m^3
PCDD/F (I-TE)	0.05 ng/m^3	100 fg/m^3	1.5 fg/m^3

The air emission standards are of similar stringency all over the world and the emission out of modern waste combustion plants, regardless of the type of applied gas cleaning strategy, is extremely low. A compilation of typical stack emissions, ambient air concentrations (for Germany) and calculated immission concentrations in Table 2 indicates that waste combustion has only a marginal influence on the air quality.

In this context it seems necessary to discuss the fundamentals of setting and of complying with air emission standards. E.g. in many regulations the air emission limit for NO_x is 200 mg/m^3 measured as NO_2. The respective raw gas concentration in a modern waste combustion plant is in the order of 500 mg/m^3. Such emission levels would in most countries care for a contribution of approx. 1 % to the total NO_x emission. It seems questionable whether the expenses for investment (approx. 50 US-$ per ton capacity) and operation (approx. 10 US-$/ton) can be justified by an achieved reduction in NO_x emission contribution to the total from 1 down to 0.2 %.

Most installations of air pollution control systems are rather complex and make waste combustion expensive. At the moment even in industrialized regions there is a trend to simplify the technology of such plants without changing their environmental compatibility significantly [11]. New designs rely more on a perfect combustion control in order to minimize the formation of pollutants in the flue gas. The principle of best available technology (BAT) is slowly replaced by that of best available technology not entailing excessive cost (BATNEEC).

For the needs of middle-income and developing countries simple and robust strategies are required At locations close to the ocean or along big rivers wet scrubbing is recommended since it is characterized by minimum solid residues. If dry scrubbing is applied the addition of charcoal is needed to remove Hg and PCDD/F. NO_x abatement should not be implemented.

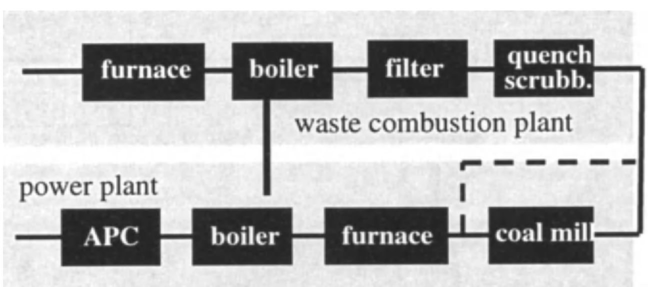

Figure 8: *Combination of Municipal Solid Waste Combustion and Coal Fired Power Plant*

A strategy to reduce the technological efforts as well as the costs has recently been proposed: the combination of a waste combustion and a coal fired power plant [12]. The flue gas of the waste combustor is dedusted in a fabric filter and cleaned in a simple wet acid scrubber which removes 90 % of the HCl and almost the entire Hg are removed. It is than used as carrier gas for the ground coal and fed directly into the burner of the power plant. PCDD/F are destroyed in the furnace, NO_x is reduced in the reburning zone and SO_2 is taken care of in the gas cleaning system of the power plant. The steam of the waste boiler is fed into the steam circuit of the power plant. This combination allows low-calorific waste to be adjusted in its heating value by addition of coal.

4 Conclusions and Recommendations

Waste generation and waste quality are strongly influenced by the economic situation in a certain region. In industrialized and densely populated areas waste disposal is a topic of concern and political regulation. The major aims are to reduce the waste stream and to reuse and recycle as many fractions as possible. Such strategies have to be considered with care due to their economy before they are adopted in other regions of the world.

Waste combustion is widely used in industrialized regions rather to inertize the waste stream prior to its disposal than to utilize the energy. In middle-income and in developing countries both aspects can be useful if a simple, robust and low-cost combustion technology is implemented.

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