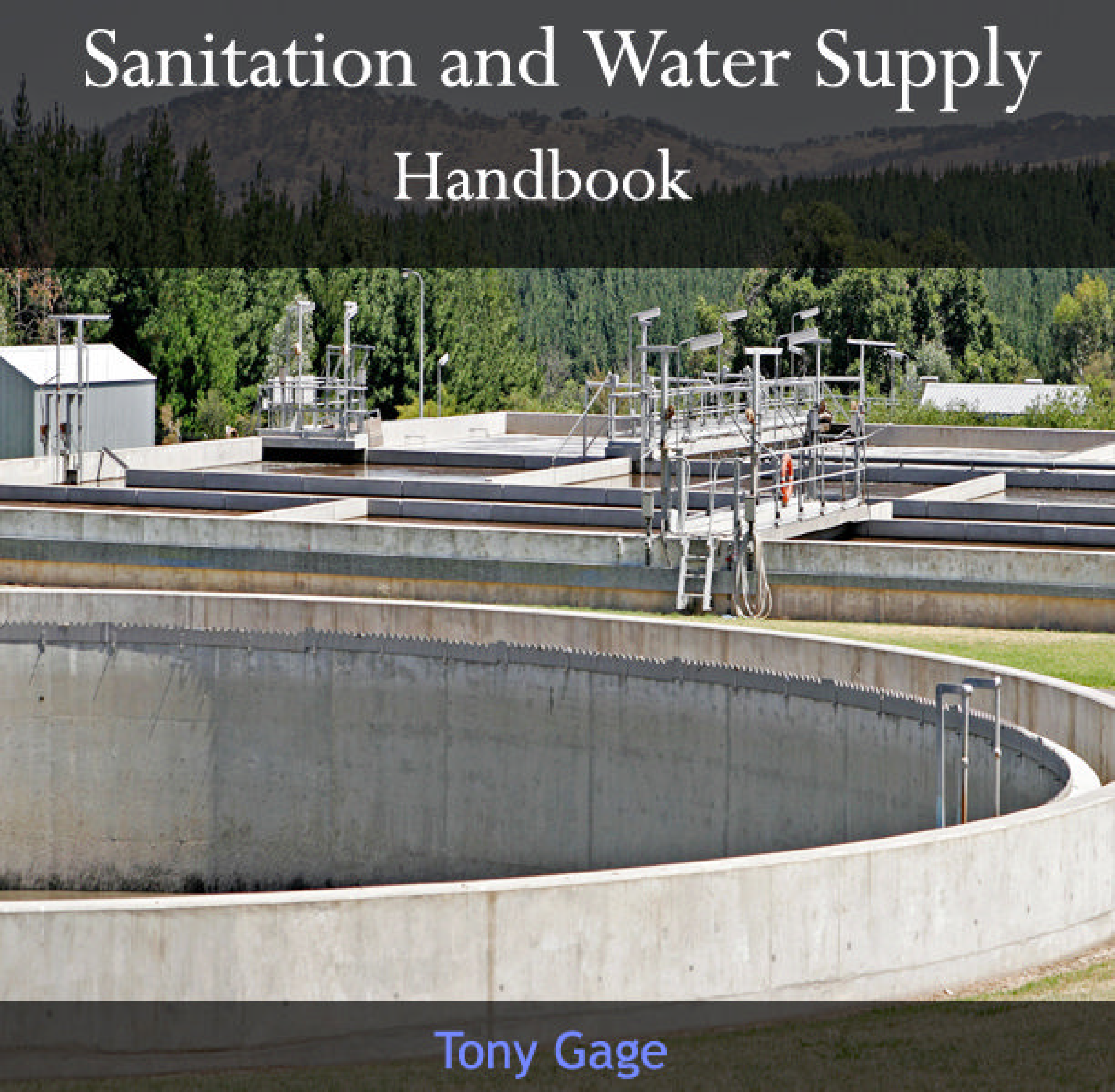
Sanitation and Water Supply Handbook



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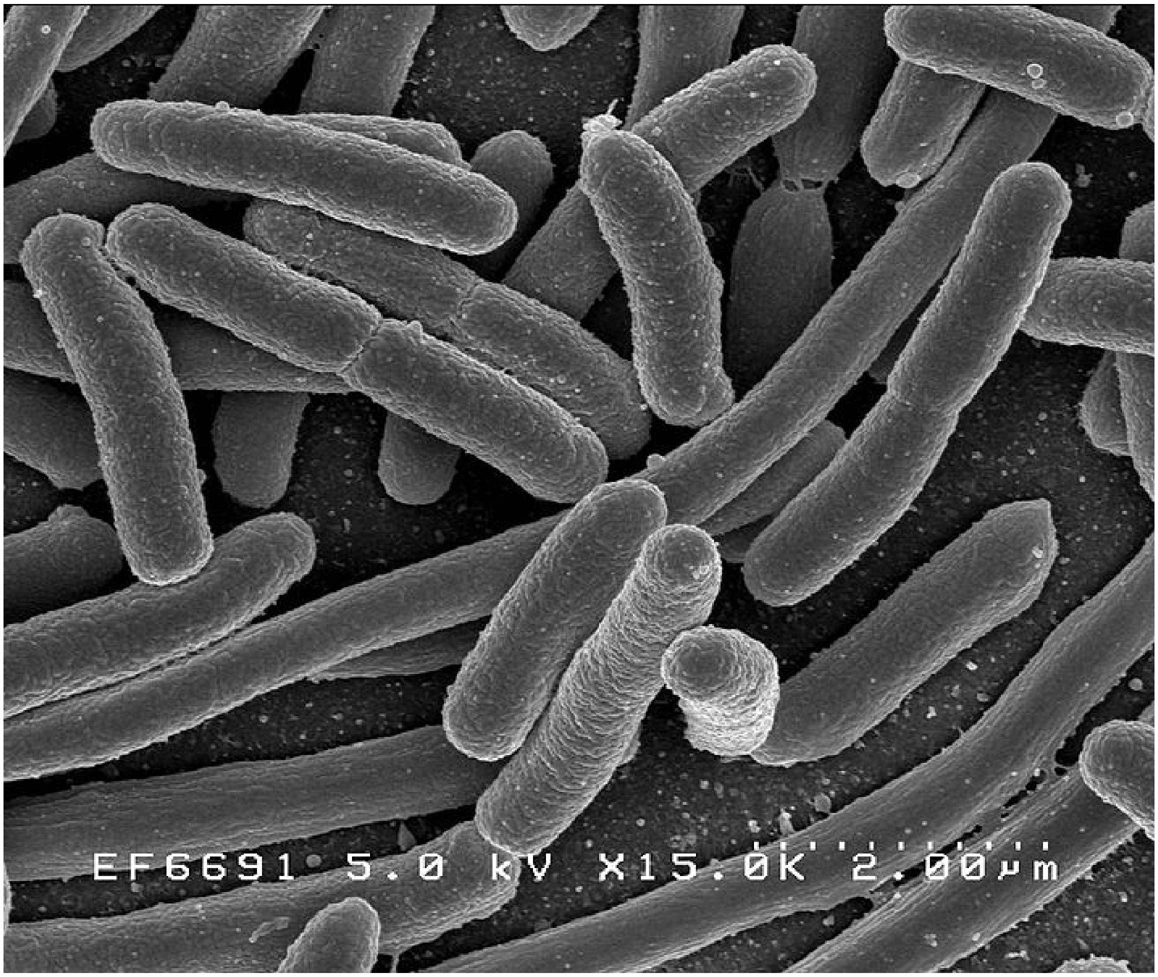
Chapter- 1

Sanitation

Sanitation is the hygienic means of promoting health through prevention of human contact with the hazards of wastes. Hazards can be either physical, microbiological, biological or chemical agents of disease. Wastes that can cause health problems are human and animal feces, solid wastes, domestic wastewater (sewage, sullage, greywater), industrial wastes, and agricultural wastes. Hygienic means of prevention can be by using engineering solutions (e.g. sewerage and wastewater treatment), simple technologies (e.g. latrines, septic tanks), or even by personal hygiene practices (e.g. simple handwashing with soap). Sanitation as defined by the WHO (World Health Organisation); Sanitation generally refers to the provision of facilities and services for the safe disposal of human urine and faeces. Inadequate sanitation is a major cause of disease world-wide and improving sanitation is known to have a significant beneficial impact on health both in households and across communities. The word 'sanitation' also refers to the maintenance of hygienic conditions, through services such as garbage collection and wastewater disposal.



E. Coli bacteria under magnification

The term "**sanitation**" can be applied to a specific aspect, concept, location, or strategy, such as:

- **Basic sanitation** - refers to the management of human feces at the household level. This terminology is the indicator used to describe the target of the Millennium Development Goal on sanitation.
- **On-site sanitation** - the collection and treatment of waste is done where it is deposited. Examples are the use of pit latrines, septic tanks, and imhoff tanks.
- **Food sanitation** - refers to the hygienic measures for ensuring food safety.
- **Environmental sanitation** - the control of environmental factors that form links in disease transmission. Subsets of this category are solid waste management, water and wastewater treatment, industrial waste treatment and noise and pollution control.
- **Ecological sanitation** - a concept and an approach of recycling to nature the nutrients from human and animal wastes.

History

The earliest evidence of urban sanitation was seen in Harappa, Mohenjo-daro and the recently discovered Rakhigarhi of Indus Valley civilization. This urban plan included the world's first urban sanitation systems. Within the city, individual homes or groups of homes obtained water from wells. From a room that appears to have been set aside for bathing, waste water was directed to covered drains, which lined the major streets. Houses opened only to inner courtyards and smaller pole.

Roman cities and Roman villas had elements of sanitation systems, delivering water in the streets of towns such as Pompeii, and building stone and wooden drains to collect and remove wastewater from populated areas - for instance the Cloaca Maxima into the River Tiber in Rome. But there is little record of other sanitation in most of Europe until the High Middle Ages. Unsanitary conditions and overcrowding were widespread throughout Europe and Asia during the Middle Ages, resulting periodically in cataclysmic pandemics such as the Plague of Justinian (541-42) and the Black Death (1347–1351), which killed tens of millions of people and radically altered societies.

Very high infant and child mortality prevailed in Europe throughout medieval times, due not only to deficiencies in sanitation but to insufficient food for a population which had expanded faster than agriculture. This was further complicated by frequent warfare and exploitation of civilians by brutal rulers. Life for the average person at this time was indeed 'nasty, brutish and short.

Wastewater sanitation

Wastewater collection

The standard sanitation technology in urban areas is the collection of wastewater in sewers, its treatment in wastewater treatment plants for reuse or disposal in rivers, lakes or the sea. Sewers are either combined with storm drains or separated from them as sanitary sewers. Combined sewers are usually found in the central, older parts or urban areas. Heavy rainfall and inadequate maintenance can lead to combined sewer overflows or sanitary sewer overflows, i.e. more or less diluted raw sewage being discharged into the environment. Industries often discharge wastewater into municipal sewers, which can complicate wastewater treatment unless industries pre-treat their discharges.

The high investment cost of conventional wastewater collection systems are difficult to afford for many developing countries. Some countries have therefore promoted alternative wastewater collection systems such as condominial sewerage, which uses smaller diameter pipes at lower depth with different network layouts from conventional sewerage.

Wastewater treatment

Sewage treatment plant, Australia.

In developed countries treatment of municipal wastewater is now widespread, but not yet universal. In developing countries most wastewater is still discharged untreated into the environment. For example, in Latin America only about 15% of collected sewerage is being treated.

Reuse of wastewater

The reuse of untreated wastewater in irrigated agriculture is common in developing countries. The reuse of treated wastewater in landscaping (esp. on golf courses), irrigated agriculture and for industrial use is becoming increasingly widespread.

In many peri-urban and rural areas households are not connected to sewers. They discharge their wastewater into septic tanks or other types of on-site sanitation.

Ecological sanitation

Ecological sanitation is sometimes presented as a radical alternative to conventional sanitation systems. Ecological sanitation is based on composting or vermicomposting toilets where an extra separation of urine and feces at the source for sanitization and recycling has been done. It thus eliminates the creation of blackwater and eliminates fecal pathogens from any still present wastewater (urine). If ecological sanitation is practiced municipal wastewater consists only of greywater, which can be recycled for gardening. However, in most cases greywater continues to be discharged to sewers.

Sanitation and public health

The importance of waste isolation lies in an effort to prevent water and sanitation related diseases, which afflicts both developed countries as well as developing countries to differing degrees. It is estimated that up to 5 million people die each year from preventable water-borne disease, as a result of inadequate sanitation and hygiene practices. The affects of sanitation have also had a large impact on society. Published in *Griffins Public Sanitation* proven studies show that higher sanitation produces more attractiveness.

Global access to improved sanitation

The Joint Monitoring Program for water and sanitation of WHO and UNICEF has defined improved sanitation as

- connection to a public sewer
- connection to a septic system
- pour-flush latrine
- simple pit latrine
- ventilated improved pit latrine

According to that definition, 62% of the world's population has access to improved sanitation in 2008, up 8% since 1990. Only slightly more than half of them or 31% of the world population lived in houses connected to a sewer. Overall, 2.5 billion people lack access to improved sanitation and thus must resort to open defecation or other unsanitary forms of defecation, such as public latrines or open pit latrines. This includes 1.2 billion people who have access to no facilities at all. This outcome presents substantial public health risks as the waste could contaminate drinking water and cause life threatening forms of diarrhea to infants. Improved sanitation, including hand washing and water purification, could save the lives of 1.5 million children who suffer from diarrheal diseases each year.

In developed countries, where less than 20% of the world population lives, 99% of the population has access to improved sanitation and 81% were connected to sewers.

Solid waste disposal

Hiriya Landfill, Israel.

Disposal of solid waste is most commonly conducted in landfills, but incineration, recycling, composting and conversion to biofuels are also avenues. In the case of landfills, advanced countries typically have rigid protocols for daily cover with topsoil, where underdeveloped countries customarily rely upon less stringent protocols. The importance of daily cover lies in the reduction of vector contact and spreading of pathogens. Daily cover also minimises odor emissions and reduces windblown litter. Likewise, developed countries typically have requirements for perimeter sealing of the landfill with clay-type soils to minimize migration of leachate that could contaminate groundwater (and hence jeopardize some drinking water supplies).

For incineration options, the release of air pollutants, including certain toxic components is an attendant adverse outcome. Recycling and biofuel conversion are the sustainable options that generally have superior life cycle costs, particularly when total ecological consequences are considered. Composting value will ultimately be limited by the market demand for compost product.

Sanitation in the developing world

The United Nations Millennium Development Goals (MDGs) include a target to reduce by half the proportion of people without access to basic sanitation by 2015. In December 2006, the United Nations General Assembly declared 2008 'The International Year of Sanitation', in recognition of the slow progress being made towards the MDGs sanitation target. The year aims to develop awareness and action to meet the target. Particular concerns are:

- Removing the stigma around sanitation, so that the importance of sanitation can be more easily and publicly discussed.
- Highlighting the poverty reduction, health and other benefits that flow from better hygiene, household sanitation arrangements and wastewater treatment.

Research from the Overseas Development Institute suggests that sanitation and hygiene promotion needs to be better 'mainstreamed' in development, if the MDG on sanitation is to be met. At present, promotion of sanitation and hygiene is mainly carried out through water institutions. The research argues that there are, in fact, many institutions that should carry out activities to develop better sanitation and hygiene in developing countries. For example, educational institutions can teach on hygiene, and health institutions can dedicate resources to preventative works (to avoid, for example, outbreaks of cholera).

The Institute of Development Studies (IDS) coordinated research programme on Community-led Total Sanitation (CLTS) is a radically different approach to rural sanitation in developing countries and has shown promising successes where traditional rural sanitation programmes have failed. CLTS is an unsubsidized approach to rural sanitation that facilitates communities to recognize the problem of open defecation and take collective action to clean up and become ‘open defecation free’. It uses community-led methods such as participatory mapping and analysing pathways between feces and mouth as a means of galvanizing communities into action. An IDS 'In Focus' Policy Brief suggests that in many countries the Millennium development goal for sanitation is off track and asks how CLTS can be adopted and spread on a large scale in the many countries and regions where open defecation still prevails.

Sanitation in the food industry

Modern restaurant food preparation area.

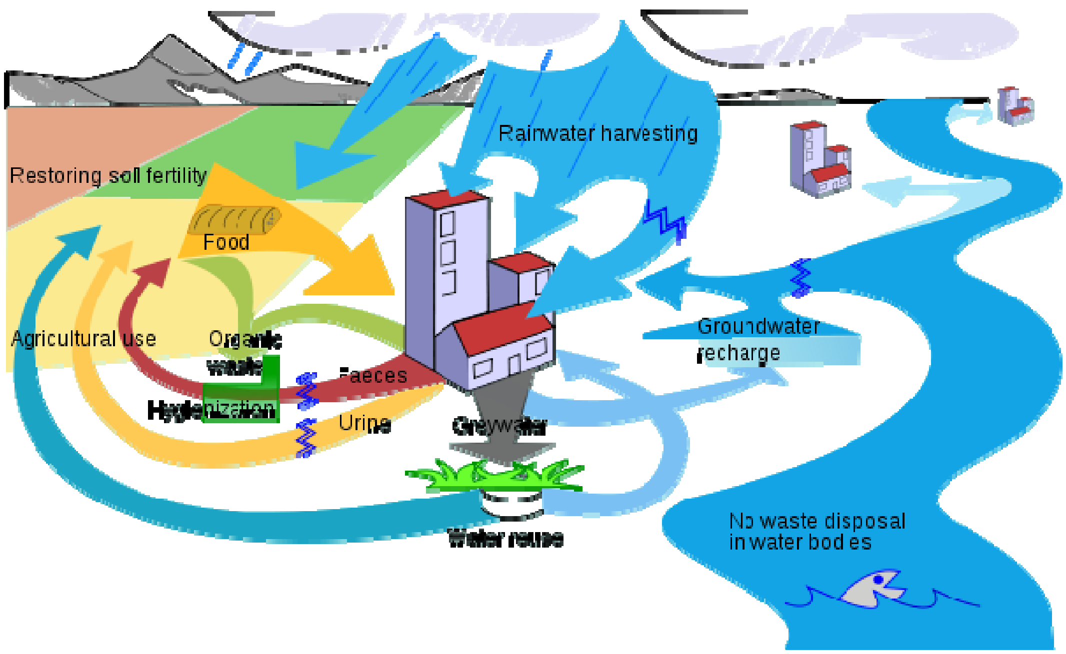
Sanitation within the food industry means to the adequate treatment of food-contact surfaces by a process that is effective in destroying vegetative cells of microorganisms of public health significance, and in substantially reducing numbers of other undesirable microorganisms, but without adversely affecting the product or its safety for the consumer (U.S. Food and Drug Administration, Code of Federal Regulations, 21CFR110, USA). Sanitation Standard Operating Procedures are indispensable for food industries in US, which are regulated by 9 CFR part 416 in conjunction with 21 CFR part 178.1010. Similaly in Japan, food hygiene has to be reached through the compliance of Food Sanitation Law.

Additionally, in the food and Biopharmaceutical industries, the term sanitary equipment means equipment that is fully cleanable using Clean-in-place (CIP), and Sterilization in place (SIP) procedures: that is fully drainable from cleaning solutions and other liquids. The design should have a minimum amount of deadleg or areas where the turbulence during cleaning is not enough to remove product deposits. In general, to improve cleanability, this equipment is made from Stainless Steel 316L, (an alloy containing small amounts of molybdenum). The surface is usually electropolished to an effective surface roughness of less than 0.5 micrometre, to reduce the possibility of bacterial adhesion to the surface.

Chapter- 2

Ecological Sanitation

Ecological sanitation, also known as **ecosan** or **eco-san**, is a sanitation process that uses human blackwater and sometimes immediately eliminates fecal pathogens from any still present wastewater (urine) at the source. The objectives are to offer economically and ecologically sustainable and culturally acceptable systems that aim to close the natural nutrient and water cycle.



Introduction to ecological sanitation

Ecological sanitation (ecosan) offers a new philosophy of dealing with what is presently regarded as waste and wastewater. Ecosan is based on the systematic implementation of reuse and recycling of nutrients and water as a hygienically safe, closed-loop and holistic alternative to conventional sanitation solutions. Ecosan systems enable the recovery of nutrients from human faeces and urine for the benefit of agriculture, thus helping to preserve soil fertility, assure food security for future generations, minimize water pollution and recover bioenergy. They ensure that water is used economically and is recycled in a safe way to the greatest possible extent for purposes such as irrigation or groundwater recharge.

The main objectives of ecological sanitation are:

- To reduce the health risks related to sanitation, contaminated water and waste
- To prevent the pollution of surface and ground water
- To prevent the degradation of soil fertility
- To optimise the management of nutrients and water resources.

History of reuse-oriented sanitation approaches

In a very broad sense the recovery and use of urine and feces has been practiced over millennia by almost all cultures. The uses were not limited to agricultural production (although for modern application this may be of most relevance), like the Romans who were well aware of the disinfecting attributes of urine and also used it for washing clothing.

The most widely known example of the diligent collection and use of human excreta in agriculture is China. Reportedly, the Chinese were aware of the benefits of using excreta in crop production before 500 B.C., enabling them to sustain more people at a higher density than any other system of agriculture. The value of "night soil" as a fertilizer was clearly recognized with well developed systems in place to enable the collection of excreta from cities and its transportation to fields.

Elaborate systems were developed in urban centers of Yemen enabling the separation of urine and excreta even in multi-story buildings. Feces were collected from toilets via vertical drop shafts, while urine did not enter the shaft but passed instead along a channel leading through the wall to the outside where it evaporated. Here, feces were not used in agriculture but were dried and burnt as fuel.

In Mexico and Peru, both the Aztec and Inca cultures collected human excreta for agricultural use. In Peru, the Incas had a high regard for excreta as a fertilizer, which was stored, dried and pulverized to be utilized when planting maize.

In the Middle Ages, the use of excreta and greywater was the norm. European cities were rapidly urbanizing and sanitation was becoming an increasingly serious problem, whilst at the same time the cities themselves were becoming an increasingly important source of agricultural nutrients. The practice of using the nutrients in excreta and wastewater for agriculture therefore continued in Europe into the middle of the 19th Century. Farmers, recognizing the value of excreta, were eager to get these fertilizers to increase production and urban sanitation benefited.

The increasing number of research and demonstration projects for excreta reuse carried out in Sweden from the 1980s to the early 21st century aimed at developing hygienically safe closed loop sanitation systems. Similar lines of research began elsewhere, for example in Zimbabwe, in the Netherlands, Norway and Germany. These closed-loop sanitation systems became popular under the name "ecosan", "dewats", "desar", and other abbreviations. They placed their emphasis on the hygenisation of the contaminated flow streams, and shifted the concept from waste disposal to resource conservation and safe reuse.

Concepts of ecological sanitation

Ecological sanitation (Ecosan) is a new holistic paradigm in sanitation, which is based on an overall view of material flows as part of an ecologically and economically sustainable wastewater management system tailored to the needs of the users and to the respective local conditions. It does not favour a specific sanitation technology, but is rather a new philosophy in handling substances that have so far been seen simply as wastewater and water-carried waste for disposal.

According to Esrey et al. (2003) ecological sanitation can be defined as a system that:

- Prevents disease and promotes health
- Protects the environment and conserves water
- Recovers and recycles nutrients and organic matter

Ecosan offers a flexible framework, where centralised elements can be combined with decentralised ones, waterborne with dry sanitation, high-tech with low-tech, etc. By considering a much larger range of options, optimal and economic solutions can be developed for each particular situation.

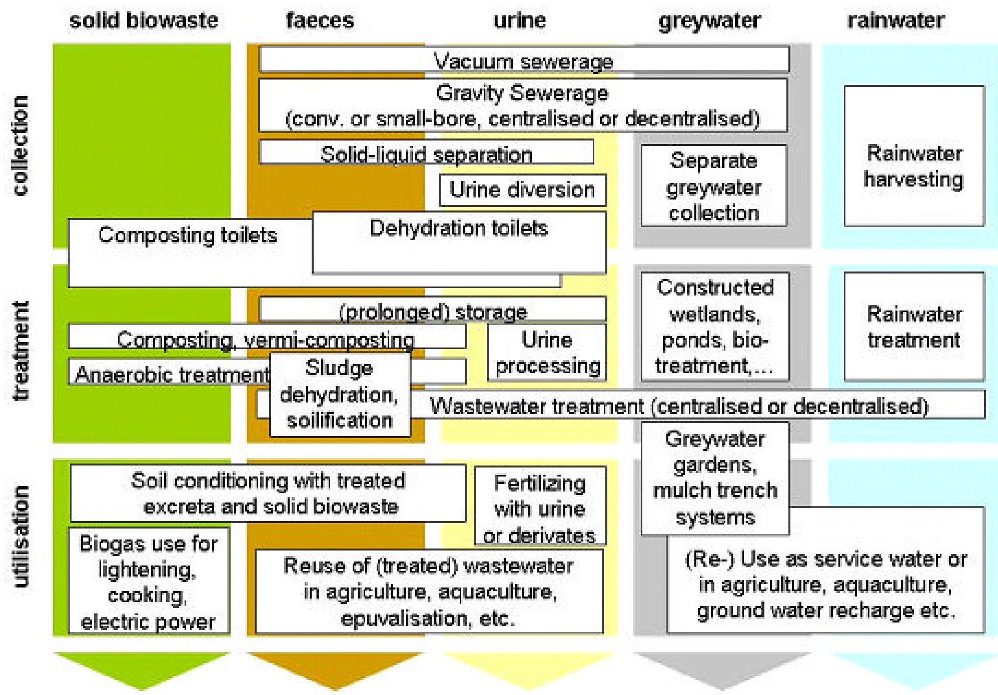
Thus, the most important advantages of ecological sanitation systems are:

- Improvement of health by minimising the introduction of pathogens from human excreta into the water cycle
- Promotion of safe, hygienic recovery and use of nutrients, organics, trace elements, water and energy
- Preservation of soil fertility
- Contribution to the conservation of resources through lower water consumption, substitution of mineral fertiliser and minimisation of water pollution
- Improvement of agricultural productivity and food security
- Preference for modular, decentralised partial-flow systems for more appropriate cost-efficient solutions adapted to the local situation
- Promotion of a holistic, interdisciplinary approach
- Material flow cycle instead of disposal of valuable resources

Technologies of ecosan systems

Determining ecosan systems as ecological sanitation is not easy, for it is not just one specific technology, but a new approach based on an ecosystem-oriented view of material flows.

The following diagram gives an overview of the different collection, treatment and reuse possibilities of the five flow streams considered in ecological sanitation systems:



Project examples

Examples of ecosan projects can be found among others in the collection of project data sheets of gtz ecosan or on the Enhanced Global Map of ecosan activities by EcoSanRes . In the following some examples are given that underline the diversity of ecosan projects:

Guangxi province, China - large-scale project of urine diverting dehydration toilets
The dissemination programme of ecological dry toilets for Hsinchu County, Guangxi province, one of the poorest provinces in China, started in 1997 with support of UNICEF, SIDA and the Red Cross and has been expanded to 17 provinces until the year 2003. By this year, the scale of the project had increased to approximately 685,000 toilet units – today more than one million double vault urine diversion dehydration toilets (UDDTs) are installed in rural areas of China.

In UDDTs, urine and faeces are collected separately: The urine is collected in the front and lead by a plastic pipe to a storage canister from where it can be used as a fertilizer in agriculture, the faeces fall at the back in one of two ventilated storage chambers and are covered with ash for better dehydration. After about one year of storage the dried material can be removed and used as a soil conditioner in agriculture.

KfW, Frankfurt, Germany - vacuum toilets + greywater treatment The sanitation concept of the modern office building “Ostarkarde” of the KfW Bankengruppe in Frankfurt is based on a separate excreta and greywater collection. While urine and faeces are collected via vacuum toilets and a vacuum sewerage using much less water for flushing, the greywater from hand washing and kitchen is collected and treated separately in a compact activated sludge reactor combined with membrane filtration. The treated greywater is then reused for toilet flushing and cleaning water. The amount of greywater can be reduced by 76% by this cost-efficient system which could be one of the prior choices for sanitation systems of newly constructed office buildings.

Tanum Municipality in Sweden has introduced urine separation toilets to recover phosphorus.

Arguments for the use of ecological sanitation

Often, water used in flush toilets is of drinking quality. Only 1% of global water is drinkable, therefore, it is a precious resource. Water fit to be drunk is being used for other purposes that can use lesser quality water, such as toilets.

Mixing feces and urine makes treatment difficult. All waste water treatment plants use some natural/biological processes, but nature does not normally have this waste water, so there are no microbes that can deal with this mix. In order to treat waste, treatment plants have to do this in stages. Each stage treats a different component of the mix by creating the right environment for microbes to do their work (aerobic, anaerobic, anoxic and the right pH). This is costly and requires energy.

A mix of domestic and industrial effluent in water cannot be treated properly, for heavy metals and other pollutants make this water unsuitable for reuse. This is normally discharged into the ground or water bodies.

Because of the complexity of the treatment process, treatment plants tend to be large. This requires costly infrastructure to build and maintain it, often out of the reach of poorer communities.

John Jeavons argues that "Each person's urine and manure contain approximately enough nutrients to produce enough food to feed that person." Urea is the major component of urine, yet we produce vast quantities of urea by using fossil fuels. By properly managing urine, treatment costs as well as fertilizer costs can be reduced. Feces also contains recognized nutrients, and could be used for modern agriculture, as micronutrient deficiency is a significant problem.

Chapter- 3

Sewage Treatment

The objective of sewage treatment is to produce a disposable effluent without causing harm to the surrounding environment and prevent pollution.

Sewage treatment, or **domestic wastewater treatment**, is the process of removing contaminants from wastewater and household sewage, both runoff (effluents) and domestic. It includes physical, chemical, and biological processes to remove physical, chemical and biological contaminants. Its objective is to produce an environmentally-safe fluid waste stream (or treated effluent) and a solid waste (or treated sludge) suitable for disposal or reuse (usually as farm fertilizer). Using advanced technology it is now possible to re-use sewage effluent for drinking water, although Singapore is the only country to implement such technology on a production scale in its production of NEWater.

Origins of sewage

Sewage is created by residential, institutional, and commercial and industrial establishments and includes household waste liquid from toilets, baths, showers, kitchens, sinks and so forth that is disposed of via sewers. In many areas, sewage also includes liquid waste from industry and commerce.

The separation and draining of household waste into greywater and blackwater is becoming more common in the developed world, with greywater being permitted to be used for watering plants or recycled for flushing toilets. Most sewage also includes some surface water from roofs or hard-standing areas and may include stormwater runoff.

Sewerage systems capable of handling stormwater are known as combined systems or combined sewers. Such systems are usually avoided now since they complicate and thereby reduce the efficiency of sewage treatment plants owing to their seasonality. The wide variability in flow, affected by precipitation, also leads to a need to construct much larger, more expensive, treatment facilities than would otherwise be required. In addition, heavy storms that contribute greater excess flow than the treatment plant can handle may overwhelm the sewage treatment system, causing a spill or overflow. Modern sewered developments tend to be provided with separate storm drain systems for rainwater.

As rainfall travels over roofs and the ground, it may pick up various contaminants including soil particles and other sediment, heavy metals, organic compounds, animal waste, and oil and grease. Some jurisdictions require stormwater to receive some level of treatment before being discharged directly into waterways. Examples of treatment processes used for stormwater include retention basins, wetlands, buried vaults with various kinds of media filters, and vortex separators (to remove coarse solids). Sanitary sewers are typically much smaller than storm sewers, and they are not designed to transport stormwater. In areas with basements, backups of raw sewage can occur if excessive stormwater is allowed into a sanitary sewer system.

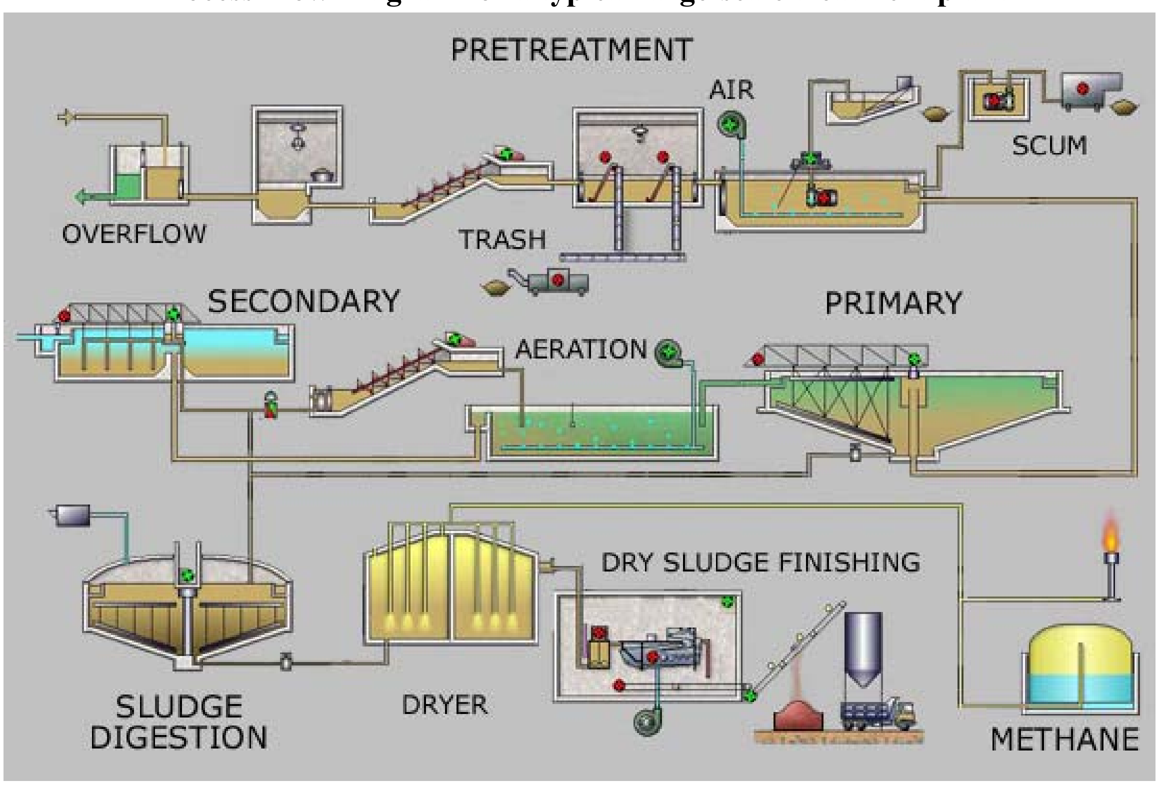
Process overview

Sewage can be treated close to where it is created, a decentralised system, (in septic tanks, biofilters or aerobic treatment systems), or be collected and transported via a network of pipes and pump stations to a municipal treatment plant, a centralised system. Sewage collection and treatment is typically subject to local, state and federal regulations and standards. Industrial sources of wastewater often require specialized treatment processes.

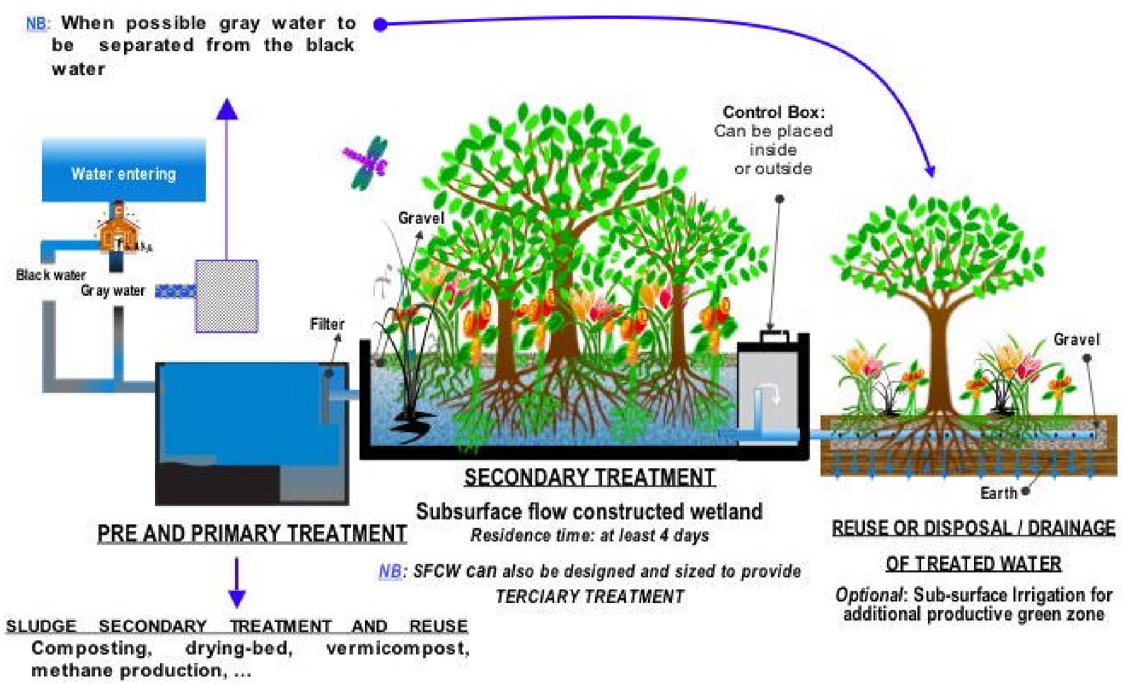
Sewage treatment generally involves three stages, called primary, secondary and tertiary treatment.

- *Primary treatment* consists of temporarily holding the sewage in a quiescent basin where heavy solids can settle to the bottom while oil, grease and lighter solids float to the surface. The settled and floating materials are removed and the remaining liquid may be discharged or subjected to secondary treatment.
- *Secondary treatment* removes dissolved and suspended biological matter. Secondary treatment is typically performed by indigenous, water-borne micro-organisms in a managed habitat. Secondary treatment may require a separation process to remove the micro-organisms from the treated water prior to discharge or tertiary treatment.
- *Tertiary treatment* is sometimes defined as anything more than primary and secondary treatment in order to allow rejection into a highly sensitive or fragile ecosystem (estuaries, low-flow rivers, coral reefs,...). Treated water is sometimes disinfected chemically or physically (for example, by lagoons and microfiltration) prior to discharge into a stream, river, bay, lagoon or wetland, or it can be used for the irrigation of a golf course, green way or park. If it is sufficiently clean, it can also be used for groundwater recharge or agricultural purposes.

Process Flow Diagram for a typical large-scale treatment plant



Process Flow Diagram for a typical treatment plant via Subsurface Flow Constructed Wetlands (SFCW)



Pre-treatment

Pre-treatment removes materials that can be easily collected from the raw waste water before they damage or clog the pumps and skimmers of primary treatment clarifiers (trash, tree limbs, leaves, etc.).

Screening

The influent sewage water is screened to remove all large objects carried in the sewage stream. This is most commonly done with an automated mechanically raked bar screen in modern plants serving large populations, whilst in smaller or less modern plants a manually cleaned screen may be used. The raking action of a mechanical bar screen is typically paced according to the accumulation on the bar screens and/or flow rate. The solids are collected and later disposed in a landfill or incinerated. Bar screens or mesh screens of varying sizes may be used to optimize solids removal. If gross solids are not removed they become entrained in pipes and moving parts of the treatment plant and can cause substantial damage and inefficiency in the process.[:9]

Grit removal

Pre-treatment may include a sand or grit channel or chamber where the velocity of the incoming wastewater is adjusted to allow the settlement of sand, grit, stones, and broken glass. These particles are removed because they may damage pumps and other equipment. For small sanitary sewer systems, the grit chambers may not be necessary, but grit removal is desirable at larger plants.[:10]

An empty sedimentation tank at the treatment plant in Merchtem, Belgium.

Fat and grease removal

In some larger plants, fat and grease is removed by passing the sewage through a small tank where skimmers collect the fat floating on the surface. Air blowers in the base of the tank may also be used to help recover the fat as a froth. In most plants however, fat and grease removal takes place in the primary settlement tank using mechanical surface skimmers.

Primary treatment

In the primary sedimentation stage, sewage flows through large tanks, commonly called "primary clarifiers" or "primary sedimentation tanks." The tanks are used to settle sludge while grease and oils rise to the surface and are skimmed off. Primary settling tanks are usually equipped with mechanically driven scrapers that continually drive the collected sludge towards a hopper in the base of the tank where it is pumped to sludge treatment facilities.[:9-11] Grease and oil from the floating material can sometimes be recovered for saponification.

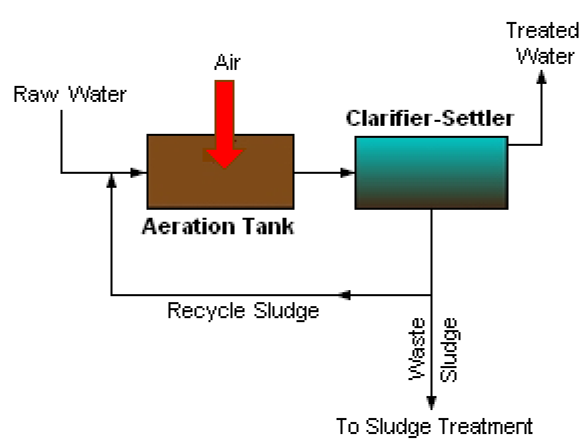
The dimensions of the tank should be designed to effect removal of a high percentage of the floatables and sludge. A typical sedimentation tank may remove from 60 to 65 percent of suspended solids, and from 30 to 35 percent of biochemical oxygen demand (BOD) from the sewage.

Secondary treatment

Secondary treatment is designed to substantially degrade the biological content of the sewage which are derived from human waste, food waste, soaps and detergent. The majority of municipal plants treat the settled sewage liquor using aerobic biological processes. To be effective, the biota require both oxygen and food to live. The bacteria and protozoa consume biodegradable soluble organic contaminants (e.g. sugars, fats, organic short-chain carbon molecules, etc.) and bind much of the less soluble fractions into floc. Secondary treatment systems are classified as *fixed-film* or *suspended-growth* systems.

- **Fixed-film** or **attached growth** systems include trickling filters and rotating biological contactors, where the biomass grows on media and the sewage passes over its surface.
- **Suspended-growth** systems include activated sludge, where the biomass is mixed with the sewage and can be operated in a smaller space than fixed-film systems that treat the same amount of water. However, fixed-film systems are more able to cope with drastic changes in the amount of biological material and can provide higher removal rates for organic material and suspended solids than suspended growth systems.[:11-13]

Roughing filters are intended to treat particularly strong or variable organic loads, typically industrial, to allow them to then be treated by conventional secondary treatment processes. Characteristics include filters filled with media to which wastewater is applied. They are designed to allow high hydraulic loading and a high level of aeration. On larger installations, air is forced through the media using blowers. The resultant wastewater is usually within the normal range for conventional treatment processes.



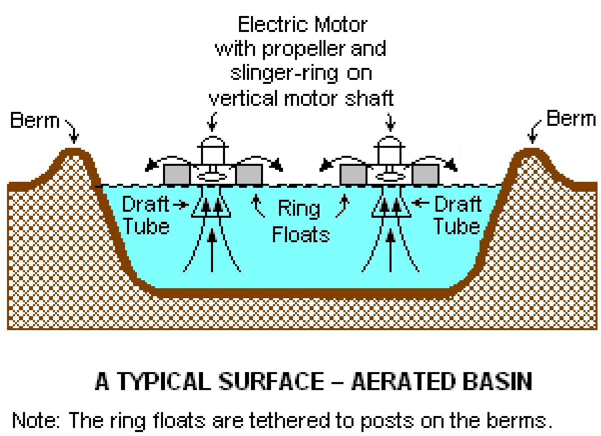
A generalized, schematic diagram of an activated sludge process.

A filter removes a small percentage of the suspended organic matter, while the majority of the organic matter undergoes a change of character, only due to the biological oxidation and nitrification taking place in the filter. With this aerobic oxidation and nitrification, the organic solids are converted into coagulated suspended mass, which is heavier and bulkier, and can settle to the bottom of a tank. The effluent of the filter is therefore passed through a sedimentation tank, called a secondary clarifier, secondary settling tank or humus tank.

Activated sludge

In general, activated sludge plants encompass a variety of mechanisms and processes that use dissolved oxygen to promote the growth of biological floc that substantially removes organic material.[:12-13]

The process traps particulate material and can, under ideal conditions, convert ammonia to nitrite and nitrate and ultimately to nitrogen gas.



A Typical Surface-Aerated Basin (using motor-driven floating aerators)

Surface-aerated basins (Lagoons)

Many small municipal sewage systems in the United States (1 million gal./day or less) use aerated lagoons.

Most biological oxidation processes for treating industrial wastewaters have in common the use of oxygen (or air) and microbial action. Surface-aerated basins achieve 80 to 90 percent removal of BOD with retention times of 1 to 10 days. The basins may range in depth from 1.5 to 5.0 metres and use motor-driven aerators floating on the surface of the wastewater.

In an aerated basin system, the aerators provide two functions: they transfer air into the basins required by the biological oxidation reactions, and they provide the mixing required for dispersing the air and for contacting the reactants (that is, oxygen, wastewater and microbes). Typically, the floating surface aerators are rated to deliver the amount of air equivalent to 1.8 to 2.7 kg O_2/kW·h. However, they do not provide as good mixing as is normally achieved in activated sludge systems and therefore aerated basins do not achieve the same performance level as activated sludge units.

Biological oxidation processes are sensitive to temperature and, between 0 °C and 40 °C, the rate of biological reactions increase with temperature. Most surface aerated vessels operate at between 4 °C and 32 °C.

Constructed wetlands

Constructed wetlands (can either be surface flow or subsurface flow, horizontal or vertical flow), include engineered reedbeds and belong to the family of phytorestoration and ecotechnologies; they provide a high degree of biological improvement and depending on design, act as a primary, secondary and sometimes tertiary treatment, also see phytoremediation. One example is a small reedbed used to clean the drainage from the elephants' enclosure at Chester Zoo in England; numerous CWs are used to recycle the water of the city of Honfleur in France and numerous other towns in Europe, the US, Asia and Australia. They are known to be highly productive systems as they copy natural wetlands, called the "Kidneys of the earth" for their fundamental recycling capacity of the hydrological cycle in the biosphere. Robust and reliable, their treatment capacities improve as time go by, at the opposite of conventional treatment plants whose machinery age with time. They are being increasingly used, although adequate and experienced design are more fundamental than for other systems and space limitation may impede their use.

Filter beds (oxidizing beds)

In older plants and those receiving variable loadings, trickling filter beds are used where the settled sewage liquor is spread onto the surface of a bed made up of coke (carbonized coal), limestone chips or specially fabricated plastic media. Such media must have large surface areas to support the biofilms that form. The liquor is typically distributed through perforated spray arms. The distributed liquor trickles through the bed and is collected in drains at the base. These drains also provide a source of air which percolates up through the bed, keeping it aerobic. Biological films of bacteria, protozoa and fungi form on the media's surfaces and eat or otherwise reduce the organic content.[:12] This biofilm is often grazed by insect larvae, snails, and worms which help maintain an optimal thickness. Overloading of beds increases the thickness of the film leading to clogging of the filter media and ponding on the surface. Recent advances in media and process micro-biology design overcome many issues with Trickling filter designs.

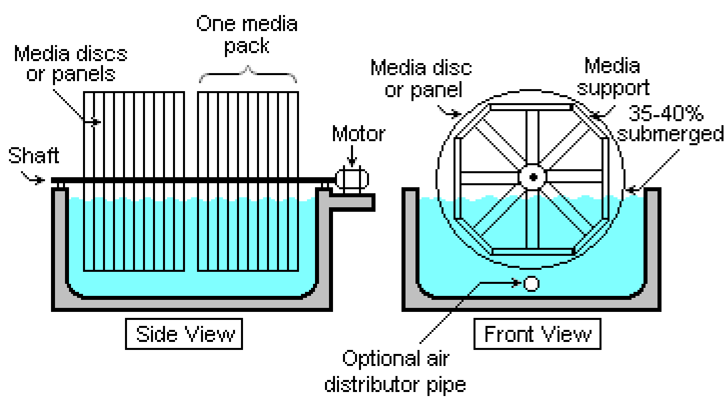
Soil Bio-Technology

A new process called Soil Bio-Technology (SBT) developed at IIT Bombay has shown tremendous improvements in process efficiency enabling total water reuse, due to extremely low operating power requirements of less than 50 joules per kg of treated water. Typically SBT systems can achieve chemical oxygen demand (COD) levels less than 10 mg/L from sewage input of COD 400 mg/L. SBT plants exhibit high reductions in COD values and bacterial counts as a result of the very high microbial densities available in the media. Unlike conventional treatment plants, SBT plants produce insignificant amounts of sludge, precluding the need for sludge disposal areas that are required by other technologies.

In the Indian context, conventional sewage treatment plants fall into systemic disrepair due to 1) high operating costs, 2) equipment corrosion due to methanogenesis and hydrogen sulphide, 3) non-reusability of treated water due to high COD (>30 mg/L) and high fecal coliform (>3000 NFU) counts, 4) lack of skilled operating personnel and 5) equipment replacement issues. Examples of such systemic failures has been documented by Sankat Mochan Foundation at the Ganges basin after a massive cleanup effort by the Indian government in 1986 by setting up sewage treatment plants under the Ganga Action Plan failed to improve river water quality.

Biological aerated filters

Biological Aerated (or Anoxic) Filter (BAF) or Biofilters combine filtration with biological carbon reduction, nitrification or denitrification. BAF usually includes a reactor filled with a filter media. The media is either in suspension or supported by a gravel layer at the foot of the filter. The dual purpose of this media is to support highly active biomass that is attached to it and to filter suspended solids. Carbon reduction and ammonia conversion occurs in aerobic mode and sometime achieved in a single reactor while nitrate conversion occurs in anoxic mode. BAF is operated either in upflow or downflow configuration depending on design specified by manufacturer.



Schematic diagram of a typical rotating biological contactor (RBC). The treated effluent clarifier/settler is not included in the diagram.

Rotating biological contactors

Rotating biological contactors (RBCs) are mechanical secondary treatment systems, which are robust and capable of withstanding surges in organic load. RBCs were first installed in Germany in 1960 and have since been developed and refined into a reliable operating unit. The rotating disks support the growth of bacteria and micro-organisms present in the sewage, which break down and stabilise organic pollutants. To be successful, micro-organisms need both oxygen to live and food to grow. Oxygen is obtained from the atmosphere as the disks rotate. As the micro-organisms grow, they build up on the media until they are sloughed off due to shear forces provided by the rotating discs in the sewage. Effluent from the RBC is then passed through final clarifiers where the micro-organisms in suspension settle as a sludge. The sludge is withdrawn from the clarifier for further treatment.

A functionally similar biological filtering system has become popular as part of home aquarium filtration and purification. The aquarium water is drawn up out of the tank and then cascaded over a freely spinning corrugated fiber-mesh wheel before passing through a media filter and back into the aquarium. The spinning mesh wheel develops a biofilm coating of microorganisms that feed on the suspended wastes in the aquarium water and are also exposed to the atmosphere as the wheel rotates. This is especially good at removing waste urea and ammonia urinated into the aquarium water by the fish and other animals.

Membrane bioreactors

Membrane bioreactors (MBR) combine activated sludge treatment with a membrane liquid-solid separation process. The membrane component uses low pressure microfiltration or ultra filtration membranes and eliminates the need for clarification and tertiary filtration. The membranes are typically immersed in the aeration tank; however, some applications utilize a separate membrane tank. One of the key benefits of an MBR system is that it effectively overcomes the limitations associated with poor settling of sludge in conventional activated sludge (CAS) processes. The technology permits bioreactor operation with considerably higher mixed liquor suspended solids (MLSS) concentration than CAS systems, which are limited by sludge settling. The process is typically operated at MLSS in the range of 8,000–12,000 mg/L, while CAS are operated in the range of 2,000–3,000 mg/L. The elevated biomass concentration in the MBR process allows for very effective removal of both soluble and particulate biodegradable materials at higher loading rates. Thus increased sludge retention times, usually exceeding 15 days, ensure complete nitrification even in extremely cold weather.

The cost of building and operating an MBR is usually higher than conventional wastewater treatment. Membrane filters can be blinded with grease or abraded by suspended grit and lack a clarifier's flexibility to pass peak flows. The technology has become increasingly popular for reliably pretreated waste streams and has gained wider acceptance where infiltration and inflow have been controlled, however, and the life-cycle costs have been steadily decreasing. The small footprint of MBR systems, and the high quality effluent produced, make them particularly useful for water reuse applications.

Secondary sedimentation

Secondary Sedimentation tank at a rural treatment plant.

The final step in the secondary treatment stage is to settle out the biological floc or filter material through a secondary clarifier and to produce sewage water containing low levels of organic material and suspended matter.

Tertiary treatment

The purpose of tertiary treatment is to provide a final treatment stage to raise the effluent quality before it is discharged to the receiving environment (sea, river, lake, ground, etc.). More than one tertiary treatment process may be used at any treatment plant. If disinfection is practiced, it is always the final process. It is also called "effluent polishing."

Filtration

Sand filtration removes much of the residual suspended matter.[:22-23] Filtration over activated carbon, also called *carbon adsorption,* removes residual toxins.[:19]

Lagooning

A sewage treatment plant and lagoon in Everett, Washington, United States.

Lagooning provides settlement and further biological improvement through storage in large man-made ponds or lagoons. These lagoons are highly aerobic and colonization by native macrophytes, especially reeds, is often encouraged. Small filter feeding invertebrates such as *Daphnia* and species of *Rotifera* greatly assist in treatment by removing fine particulates.

Nutrient removal

Wastewater may contain high levels of the nutrients nitrogen and phosphorus. Excessive release to the environment can lead to a build up of nutrients, called eutrophication, which can in turn encourage the overgrowth of weeds, algae, and cyanobacteria (blue-green algae). This may cause an algal bloom, a rapid growth in the population of algae. The algae numbers are unsustainable and eventually most of them die. The decomposition of the algae by bacteria uses up so much of oxygen in the water that most or all of the animals die, which creates more organic matter for the bacteria to decompose. In addition to causing deoxygenation, some algal species produce toxins that contaminate drinking water supplies. Different treatment processes are required to remove nitrogen and phosphorus.

Nitrogen removal

The removal of nitrogen is effected through the biological oxidation of nitrogen from ammonia to nitrate (nitrification), followed by denitrification, the reduction of nitrate to nitrogen gas. Nitrogen gas is released to the atmosphere and thus removed from the water.

Nitrification itself is a two-step aerobic process, each step facilitated by a different type of bacteria. The oxidation of ammonia (NH_3) to nitrite (NO_2^-) is most often facilitated by *Nitrosomonas* spp. (nitroso referring to the formation of a nitroso functional group). Nitrite oxidation to nitrate (NO_3^-), though traditionally believed to be facilitated by *Nitrobacter* spp. (nitro referring the formation of a nitro functional group), is now known to be facilitated in the environment almost exclusively by *Nitrospira* spp.

Denitrification requires anoxic conditions to encourage the appropriate biological communities to form. It is facilitated by a wide diversity of bacteria. Sand filters, lagooning and reed beds can all be used to reduce nitrogen, but the activated sludge process (if designed well) can do the job the most easily.[:17-18] Since denitrification is the reduction of nitrate to dinitrogen gas, an electron donor is needed. This can be, depending on the wastewater, organic matter (from faeces), sulfide, or an added donor like methanol.

Sometimes the conversion of toxic ammonia to nitrate alone is referred to as tertiary treatment.

Many sewage treatment plants use axial flow pumps to transfer the nitrified mixed liquor from the aeration zone to the anoxic zone for denitrification. These pumps are often referred to as *Internal Mixed Liquor Recycle* (IMLR) pumps. The sludge in the anoxic tanks must be mixed well (mixture of recirculated mixed liquor, return activated sludge [RAS], and raw influent) by using submersible mixers in order to achieve the desired denitrification.

Phosphorus removal

Phosphorus removal is important as it is a limiting nutrient for algae growth in many fresh water systems. It is also particularly important for water reuse systems where high phosphorus concentrations may lead to fouling of downstream equipment such as reverse osmosis.

Phosphorus can be removed biologically in a process called enhanced biological phosphorus removal. In this process, specific bacteria, called polyphosphate accumulating organisms (PAOs), are selectively enriched and accumulate large quantities of phosphorus within their cells (up to 20 percent of their mass). When the biomass enriched in these bacteria is separated from the treated water, these biosolids have a high fertilizer value.

Phosphorus removal can also be achieved by chemical precipitation, usually with salts of iron (e.g. ferric chloride), aluminum (e.g. alum), or lime.[:18] This may lead to excessive sludge production as hydroxides precipitates and the added chemicals can be expensive.

Chemical phosphorus removal requires significantly smaller equipment footprint than biological removal, is easier to operate and is often more reliable than biological phosphorus removal. Another method for phosphorus removal is to use granular laterite.

Once removed, phosphorus, in the form of a phosphate-rich sludge, may be stored in a land fill or resold for use in fertilizer.

Disinfection

The purpose of disinfection in the treatment of waste water is to substantially reduce the number of microorganisms in the water to be discharged back into the environment. The effectiveness of disinfection depends on the quality of the water being treated (e.g., cloudiness, pH, etc.), the type of disinfection being used, the disinfectant dosage (concentration and time), and other environmental variables. Cloudy water will be treated less successfully, since solid matter can shield organisms, especially from ultraviolet light or if contact times are low. Generally, short contact times, low doses and high flows all militate against effective disinfection. Common methods of disinfection include ozone, chlorine, ultraviolet light, or sodium hypochlorite.[:16] Chloramine, which is used for drinking water, is not used in waste water treatment because of its persistence.

Chlorination remains the most common form of waste water disinfection in North America due to its low cost and long-term history of effectiveness. One disadvantage is that chlorination of residual organic material can generate chlorinated-organic compounds that may be carcinogenic or harmful to the environment. Residual chlorine or chloramines may also be capable of chlorinating organic material in the natural aquatic environment. Further, because residual chlorine is toxic to aquatic species, the treated effluent must also be chemically dechlorinated, adding to the complexity and cost of treatment.

Ultraviolet (UV) light can be used instead of chlorine, iodine, or other chemicals. Because no chemicals are used, the treated water has no adverse effect on organisms that later consume it, as may be the case with other methods. UV radiation causes damage to the genetic structure of bacteria, viruses, and other pathogens, making them incapable of reproduction. The key disadvantages of UV disinfection are the need for frequent lamp maintenance and replacement and the need for a highly treated effluent to ensure that the target microorganisms are not shielded from the UV radiation (i.e., any solids present in the treated effluent may protect microorganisms from the UV light). In the United Kingdom, UV light is becoming the most common means of disinfection because of the concerns about the impacts of chlorine in chlorinating residual organics in the wastewater and in chlorinating organics in the receiving water. Some sewage treatment systems in Canada and the US also use UV light for their effluent water disinfection.

Ozone (O_3) is generated by passing oxygen (O_2) through a high voltage potential resulting in a third oxygen atom becoming attached and forming O_3. Ozone is very unstable and reactive and oxidizes most organic material it comes in contact with, thereby destroying many pathogenic microorganisms. Ozone is considered to be safer than chlorine because, unlike chlorine which has to be stored on site (highly poisonous in the event of an accidental release), ozone is generated onsite as needed. Ozonation also produces fewer disinfection by-products than chlorination. A disadvantage of ozone disinfection is the high cost of the ozone generation equipment and the requirements for special operators.

Odour Control

Odours emitted by sewage treatment are typically an indication of an anaerobic or "septic" condition. Early stages of processing will tend to produce smelly gases, with hydrogen sulfide being most common in generating complaints. Large process plants in urban areas will often treat the odours with carbon reactors, a contact media with bio-slimes, small doses of chlorine, or circulating fluids to biologically capture and metabolize the obnoxious gases. Other methods of odour control exist, including addition of iron salts, hydrogen peroxide, calcium nitrate, etc. to manage hydrogen sulfide levels.

Package plants and batch reactors

To use less space, treat difficult waste and intermittent flows, a number of designs of hybrid treatment plants have been produced. Such plants often combine at least two stages of the three main treatment stages into one combined stage. In the UK, where a large number of wastewater treatment plants serve small populations, package plants are a viable alternative to building a large structure for each process stage. In the US, package plants are typically used in rural areas, highway rest stops and trailer parks.

One type of system that combines secondary treatment and settlement is the sequencing batch reactor (SBR). Typically, activated sludge is mixed with raw incoming sewage, and then mixed and aerated. The settled sludge is run off and re-aerated before a proportion is returned to the headworks. SBR plants are now being deployed in many parts of the world.

The disadvantage of the SBR process is that it requires a precise control of timing, mixing and aeration. This precision is typically achieved with computer controls linked to sensors. Such a complex, fragile system is unsuited to places where controls may be unreliable, poorly maintained, or where the power supply may be intermittent.

Package plants may be referred to as *high charged* or *low charged*. This refers to the way the biological load is processed. In high charged systems, the biological stage is presented with a high organic load and the combined floc and organic material is then oxygenated for a few hours before being charged again with a new load. In the low charged system the biological stage contains a low organic load and is combined with flocculate for longer times.

Sludge treatment and disposal

The sludges accumulated in a wastewater treatment process must be treated and disposed of in a safe and effective manner. The purpose of digestion is to reduce the amount of organic matter and the number of disease-causing microorganisms present in the solids. The most common treatment options include anaerobic digestion, aerobic digestion, and composting. Incineration is also used albeit to a much lesser degree.[:19-21]

Sludge treatment depends on the amount of solids generated and other site-specific conditions. Composting is most often applied to small-scale plants with aerobic digestion for mid sized operations, and anaerobic digestion for the larger-scale operations.

Anaerobic digestion

Anaerobic digestion is a bacterial process that is carried out in the absence of oxygen. The process can either be *thermophilic* digestion, in which sludge is fermented in tanks at a temperature of 55°C, or *mesophilic*, at a temperature of around 36°C. Though allowing shorter retention time (and thus smaller tanks), thermophilic digestion is more expensive in terms of energy consumption for heating the sludge.

Anaerobic digestion is the most common (mesophilic) treatment of domestic sewage in septic tanks, which normally retain the sewage from one day to two days, reducing the BOD by about 35 to 40 percent. This reduction can be increased with a combination of anaerobic and aerobic treatment by installing *Aerobic Treatment Units* (ATUs) in the septic tank.

One major feature of anaerobic digestion is the production of biogas (with the most useful component being methane), which can be used in generators for electricity production and/or in boilers for heating purposes.

Aerobic digestion

Aerobic digestion is a bacterial process occurring in the presence of oxygen. Under aerobic conditions, bacteria rapidly consume organic matter and convert it into carbon dioxide. The operating costs used to be characteristically much greater for aerobic digestion because of the energy used by the blowers, pumps and motors needed to add oxygen to the process.

Aerobic digestion can also be achieved by using diffuser systems or jet aerators to oxidize the sludge.

Composting

Composting is also an aerobic process that involves mixing the sludge with sources of carbon such as sawdust, straw or wood chips. In the presence of oxygen, bacteria digest both the wastewater solids and the added carbon source and, in doing so, produce a large amount of heat.[:20]

Incineration

Incineration of sludge is less common because of air emissions concerns and the supplemental fuel (typically natural gases or fuel oil) required to burn the low calorific value sludge and vaporize residual water. Stepped multiple hearth incinerators with high residence time and fluidized bed incinerators are the most common systems used to combust wastewater sludge. Co-firing in municipal waste-to-energy plants is occasionally done, this option being less expensive assuming the facilities already exist for solid waste and there is no need for auxiliary fuel.[:20-21]

Sludge disposal

When a liquid sludge is produced, further treatment may be required to make it suitable for final disposal. Typically, sludges are thickened (dewatered) to reduce the volumes transported off-site for disposal. There is no process which completely eliminates the need to dispose of biosolids. There is, however, an additional step some cities are taking to superheat sludge and convert it into small pelletized granules that are high in nitrogen and other organic materials. In New York City, for example, several sewage treatment plants have dewatering facilities that use large centrifuges along with the addition of chemicals such as polymer to further remove liquid from the sludge. The removed fluid, called centrate, is typically reintroduced into the wastewater process. The product which is left is called "cake" and that is picked up by companies which turn it into fertilizer pellets. This product is then sold to local farmers and turf farms as a soil amendment or fertilizer, reducing the amount of space required to dispose of sludge in landfills. Much sludge originating from commercial or industrial areas is contaminated with toxic materials that are released into the sewers from the industrial processes. Elevated concentrations of such materials may make the sludge unsuitable for agricultural use and it may then have to be incinerated or disposed of to landfill.

Treatment in the receiving environment

The outlet of a wastewater treating plant flows into a small river

Many processes in a wastewater treatment plant are designed to mimic the natural treatment processes that occur in the environment, whether that environment is a natural water body or the ground. If not overloaded, bacteria in the environment will consume organic contaminants, although this will reduce the levels of oxygen in the water and may significantly change the overall ecology of the receiving water. Native bacterial populations feed on the organic contaminants, and the numbers of disease-causing microorganisms are reduced by natural environmental conditions such as predation or exposure to ultraviolet radiation. Consequently, in cases where the receiving environment provides a high level of dilution, a high degree of wastewater treatment may not be required. However, recent evidence has demonstrated that very low levels of specific contaminants in wastewater, including hormones (from animal husbandry and residue from human hormonal contraception methods) and synthetic materials such as phthalates that mimic hormones in their action, can have an unpredictable adverse impact on the natural biota and potentially on humans if the water is re-used for drinking water. In the US and EU, uncontrolled discharges of wastewater to the environment are not permitted under law, and strict water quality requirements are to be met. A significant threat in the coming decades will be the increasing uncontrolled discharges of wastewater within rapidly developing countries.

Effects on Biology

Sewage treatment plants can have multiple effects on nutrient levels in the water that the treated sewage flows into. These effects on nutrients can have large effects on the biological life in the water in contact with the effluent. Treatment ponds can include any of the following:

- Oxidation ponds, which are aerobic bodies of water usually 1-2 meters in depth that receive effluent from sedimentation tanks or other forms of primary treatment.

  * Dominated by algae

- Polishing ponds are similar to oxidation ponds but receive effluent from an oxidation pond or from a plant with an extended mechanical treatment.

  * Dominated by zooplankton

- Raw sewage lagoons or sewage lagoons are aerobic ponds where sewage is added with no primary treatment other than coarse screening.
- Anaerobic lagoons are heavily loaded ponds.

  * Dominated by bacteria

- Sludge lagoons are aerobic ponds, usually 2-5 meters in depth, that receive anaerobically digested primary sludge, or activated secondary sludge under water.

  * Upper layers are dominated by algae

Phosphorous limitation is a possible result from sewage treatment and results in flagellate-dominated plankton, particularly in summer and fall.

At the same time a different study found high nutrient concentrations linked to sewage effluents. High nutrient concentration leads to high chlorophyll a concentrations, which is a proxy for primary production in marine environments. High primary production means high phytoplankton populations and most likely high zooplankton populations because zooplankton feed on phytoplankton. However, effluent released into marine systems also leads to greater population instability.

A study done in Britain found that the quality of effluent effected the planktonic life in the water in direct contact with the wastewater effluent. Turbid, low-quality effluents either did not contain ciliated protozoa or contained only a few species in small numbers. On the other hand, high-quality effluents contained a wide variety of ciliated protozoa in large numbers. Due to these findings, it seems unlikely that any particular component of the industrial effluent has, by itself, any harmful effects on the protozoan populations of activated sludge plants.

The planktonic trends of high populations close to input of treated sewage is contrasted by the bacterial trend. In a study of *Aeromonas* spp. in increasing distance from a wastewater source, greater change in seasonal cycles was found the furthest from the effluent. This trend is so strong that the furthest location studied actually had an inversion of the *Aeromonas* spp. cycle in comparison to that of fecal coliforms. Since there is a main pattern in the cycles that occurred simultaneously at all stations it indicates seasonal factors (temperature, solar radiation, phytoplankton) control of the bacterial population. The effluent dominant species changes from *Aeromonas caviae* in winter to *Aeromonas sobria* in the spring and fall while the inflow dominant species is *Aeromonas caviae*, which is constant throughout the seasons.

Sewage treatment in developing countries

Few reliable figures on the share of the wastewater collected in sewers that is being treated in the world exist. In many developing countries the bulk of domestic and industrial wastewater is discharged without any treatment or after primary treatment only. In Latin America about 15% of collected wastewater passes through treatment plants (with varying levels of actual treatment). In Venezuela, a below average country in South America with respect to wastewater treatment, 97 percent of the country’s sewage is discharged raw into the environment. In a relatively developed Middle Eastern country such as Iran, Tehran's majority of population has totally untreated sewage injected to the city’s groundwater.

In Israel, about 50 percent of agricultural water usage (total use was 1 billion cubic metres in 2008) is provided through reclaimed sewer water. Future plans call for increased use of treated sewer water as well as more desalination plants.

Most of sub-Saharan Africa is without wastewater treatment.

Chapter- 4

Sewage Collection and Disposal

Deer Island Waste Water Treatment Plant serving Boston, Massachusetts, and vicinity.

Sewage collection and disposal systems transport sewage through cities and other inhabited areas to sewage treatment plants to protect public health and prevent disease. Sewage is treated to control water pollution before discharge to surface waters.

Collection

A sewage system may convey the wastewater by gravity to a sewage treatment plant. Where pipeline excavation is difficult because of rock or there is limited topographic relief (i.e., due to flat terrain), gravity collection systems may not be practical and the sewage must be pumped through a pipeline to the treatment plant. In low-lying communities, wastewater may be conveyed by vacuum. Pipelines range in size from pipes of six inches (150 mm) in diameter to concrete-lined tunnels of up to thirty feet (10 m) in diameter.

Community sewage can also be collected by an effluent sewer system, also known as a STEP system (Septic Tank Effluent Pumping). At each home, a buried collection tank is used to separate solids from the liquid effluent portion. Only the liquid portion is then pumped through small diameter pipe (typically 1.5" to 4") to downstream treatment. Because the wastestream is pressurized, the pipes can be laid just below the ground surface along the land's contour.

Sewage can also be collected by low pressure pumps and vacuum systems. A low pressure system uses a small grinder pump located at each point of connection, typically a house or business. Vacuum sewer systems use differential atmospheric pressure to move the liquid to a central vacuum station. Typically a vacuum sewer station can service approximately 1,200 homes before it becomes more cost-effective to build another station.

Design and analysis of collection systems

Design and sizing of sewage collection systems considers population served, commercial and industrial flows, flow peaking characteristics and wet weather flows. Combined sewer systems are designed to transport both stormwater runoff and sewage in the same pipe. Besides the projected sewage flow, the size and characteristics of the watershed are the overriding design considerations for combined sewers. Often, combined sewers can not handle the volume of runoff, resulting in combined sewer overflows and causing water pollution problems in nearby water bodies.

Separate sanitary sewer systems are designed to transport sewage alone. In communities served by separate sanitary sewers, another pipe system is constructed to convey stormwater runoff directly to surface waters. Most municipal sewer systems constructed today are separate sewer systems.

Although separate sewer systems are intended to transport only sewage, all sewer systems have some degree of inflow and infiltration of surface water and groundwater, which can lead to sanitary sewer overflows. Inflow and infiltration is highly affected by antecedent moisture conditions, which also represents an important design consideration in these systems.

A **sewer bed** is a piece of land typically used by a municipality for the dumping of raw sewage. Usually raw sewage was brought by truck or drawn by horses to be dumped, but the practice stopped back in the 1940s.

Historical sewage conveyance and disposal

The historical focus of sewage treatment was on conveyance of raw sewage to a natural body of water, e.g. a river or ocean, where it would be satisfactorily diluted and dissipated. Early human habitations were often built next to water sources. Rivers could double as a crude form of natural sewage disposal.

According to Teresi (2002):

The Indus architects designed sewage disposal systems on a large scale, building networks of brick effluent drains following the lines of the streets. The drains were seven to ten feet wide, cut at two feet below ground level with U-shaped bottoms lined with loose brick easily taken up for cleaning. At the intersection of two drains, the sewage planners installed cesspools with steps leading down into them, for periodic cleaning. By 2700 B.C., these cities had standardized earthenware plumbing pipes with broad flanges for easy joining with asphalt to stop leaks.

Ancient systems

The first sanitation system has been found at the prehistoric Middle East, in south-east of Iran near Zabol In Burnt City (Shahre soukhteh) areas. The first time an inverted siphon system was used, along with glass covered clay pipes, was in the palaces of Crete, Greece. It is still in working condition, after about 3000 years.

Higher population densities required more complex sewer collection and conveyance systems to maintain (somewhat) sanitary conditions in crowded cities. The ancient cities of Harappa and Mohenjo-daro of the Indus Valley civilization constructed complex networks of brick-lined sewage drains from around 2600 BC and also had outdoor flush toilets connected to this network.

The urban areas of the Indus Valley civilization provided public and private baths, sewage was disposed through underground drains built with precisely laid bricks, and a sophisticated water management system with numerous reservoirs was established. In the drainage systems, drains from houses were connected to wider public drains.

Ancient Minoan civilization had stone sewers that were periodically flushed with clean water.

Roman towns and garrisons in the United Kingdom between 46 BC and 400 AD had complex sewer networks sometimes constructed out of hollowed out Elm logs which were shaped so that they butted together with the down-stream pipe providing a socket for the upstream pipe.

A significant development was the construction of a network of sewers to collect waste water, which began from the Indus Valley civilization. In some cities, including Rome, Istanbul (Constantinople) and Fustat, networked ancient sewer systems continue to function today as collection systems for those cities' modernized sewer systems. Instead of flowing to a river or the sea, the pipes have been re-routed to modern sewer treatment facilities.

16th century

The system then remained with not much progress until the 16th century, where, in England, Sir John Harington invented a device for Queen Elizabeth (his godmother) that released wastes into cesspools.

However, many cities had no sewers and relied on nearby rivers or occasional rain to wash away sewage. In some cities, waste water simply ran down the streets, which had stepping stones to keep pedestrians out of the muck, and eventually drained as runoff into the local watershed. This was enough in early cities with few occupants but the growth of cities quickly overpolluted streets and became a constant source of disease. Even as recently as the late 19th century sewerage systems in parts of the highly industrialised United Kingdom were so inadequate that water-borne diseases such as cholera and typhoid were still common. In Merthyr Tydfil, a large town in South Wales, most houses discharged their sewage to individual cess-pits which persistently overflowed causing the pavements to be awash with foul sewage.

Industrial Revolution era

As an outgrowth of the Industrial Revolution, many cities in Europe and North America grew in the 19th century, frequently leading to crowding and increasing concerns about public health. As part of a trend of municipal sanitation programs in the late 19th and 20th centuries, many cities constructed extensive sewer systems to help control outbreaks of disease.[:29-34] Initially these systems discharged sewage directly to surface waters without treatment. The first comprehensive sewer system was built in Hamburg, Germany in the mid-19th century.[:43] [:2] The first such systems in the United States were built in the late 1850s in Chicago and Brooklyn.[:43]

As pollution of water bodies became a concern, cities attempted to treat the sewage before discharge. Early techniques involved land application of sewage on agricultural land. In the late 19th century some cities began to add chemical treatment and sedimentation systems to their sewers.[:28] In the United States, the first sewage treatment plant using chemical precipitation was built in Worcester, Massachusetts in 1890.[:29]

Chapter- 5

Micro Credit for Water Supply and Sanitation

Micro credit for water supply and sanitation is an innovative application of micro credit to provide loans to small enterprises and households in order to increase access to an improved water source and sanitation in developing countries. While most investments in water supply and sanitation infrastructure are financed by the public sector, current investment levels are insufficient to achieve universal access or, at the minimum, to reach the Millennium Development Goals related to water supply and sanitation. Commercial credit to public utilities is limited by low tariffs and insufficient cost recovery. Micro credits are a complementary or alternative approach to allow the poor to gain access to water supply and sanitation Funding is either provided to small-scale independent water providers who generate an income stream from selling water or to households in order to finance house connections, plumbing installations in their houses, or various forms of on-site sanitation such as septic tanks or latrines. While they have become increasingly common, many microfinance institutions still have only limited experience with financing investments in water supply and sanitation. While there have been many pilot projects in both urban and rural areas, just a small number have actually been scaled up.

Classification

According to an extensive study of microfinance in water supply and sanitation, there are three types of microcredit products in the water sector across urban and rural areas: 1. Retail loans aiming to improve access to water supply and sanitation at household level, 2. Loans for small and medium enterprises receiving micro credits for small water supply investments and
3. Loans for urban services upgrading and shared facilities in low income areas.

Retail loans for household water and sanitation

Retail loans for water and sanitation facilities are being offered to individuals by some large and commonly known microfinance institutions such as the Grameen Bank and the Vietnam Bank for Social Policies in South East Asia. In general, these credits are used to finance such things as bathrooms, toilets or water purifiers and range from 30 to 250 USD with a tenure generally less than three years. Although the potential market size is considered as huge in both rural and urban areas and some of these water and sanitation schemes have achieved a significant scale, compared to the microfinance institution's overall size and scope, they still play a minor role.

In 1999, all microfinance institutions in Bangladesh and more recent in Vietnam had reached only about 9 percent and 2.4 percent of rural households respectively. In both countries, the water and sanitation portfolio amounts to less than two percent of the microfinance institution's portfolio in total. However, borrowers for water supply and sanitation comprised 30 percent of total borrowers for Grameen Bank and 10 percent of total borrowers from Vietnam Bank for Social Policies.

Complementary to targeted micro credits, general purpose loans are increasingly gaining weight, as they are used for water and sanitation activities in India and a number of African countries (e.g. Benin, Zambia, and Uganda). For instance, the water and sanitation portfolio of the Indian microfinance institution SEWA Bank comprised 15 percent of all loans provided in the city of Admedabad over a period of five years.

Development aid institutions particularly focused on establishing linkage with local microfinance institutions. USAID for instance, has been actively involved by assisting microfinance institutions in designing micro credit products for the water supply sector in Indonesia.

Indonesia: Expanding customer base through cooperation
In 2006, the Bank Rakyat Indonesia signed a Memorandum of Understanding with the water utility PDAM Tanah to initiate water connections schemes on the basis of micro credits creating a win-win situation. The joint venture with technical support of the USAID Environmental Services Program is planned to be extended to other regions. By 2009, the involved institutions intend to have provided 10.000 households with water connections. According to Metha, the effort has resulted in benefits for the utility, the microfinance institution and for the customers who gained access to water supply. The utility benefited from the expanded customer base and additional water sales as it has helped to reduce its average costs by 42 percent over a period of three years and to reduce its non-revenue water ratio from a percentage of 56,5 in 2002 to 36 percent at the end of 2004. Furthermore, the impact assessment report c both institutions conclude, that the financial cooperation could be extended to finance PDAMS's need for additional banking services.

Vietnam: Sanitation Revolving Fund managed by the Women's Union
In 1999, the World Bank in cooperation with the governments of Australia, Finland and Denmark supported the creation of a Sanitation Revolving Fund with an initial working capital of USD 3 million. The project was carried out in the cities of Danang, Haiphong and Quang Ninh. The overall aim was to provide small loans (USD 145) to low-income and poor households for targeted sanitation investments such as septic tanks, urine diverting/composting latrines or sewer connections. Households willing to participate needed to join a savings and credit group of 12 to 20 people. Members of those groups were required to live near to each other to ensure community control. The loans had a catalyst effect for household investment. With loans covering approximately two thirds of

investment costs, households had to find complementary sources of finance (from family and friends). In contrast to a centralized, supply-driven approach, where government institutions design a project with little community consultation and no capacity building for the community, this approach was strictly demand driven and thus required the Sanitation Revolving Fund to develop awareness raising campaigns for sanitation. Managed by the microfinance-experienced Women's Union of Vietnam, the Sanitation Revolving Fund gave 200.000 households the opportunity to finance and build sanitation facilities over a period of seven years. With a leverage effect of up to 25 times the amount of public spending on household investment and repayment rates of almost 100 percent, the fund is seen as a best practice example by its financiers and thus considered to be scaled up with further support of the World Bank and the Vietnam Bank for Social Policies.

Small and medium enterprise (SME) loans for water and sanitation

SME-type loans are used for investments by community groups, for private providers in greenfield contexts or for rehabilitation measures of water supply and sanitation. Supplied by mature microfinance institutions, these loans are seen as suitable for other suppliers in the value chain such as pit latrine emptiers and tanker suppliers. With the right frame conditions such as solid a policy environment and clear institutional relationships, there is a market potential for small-scale water supply projects.

In comparison to retail loans on the household level, the experience with loan products for SME is fairly limited. These loan programs remain mostly at pilot level. However, the design of some recent projects using micro credits for community-based service providers in some African countries (such as those of the K-Rep Bank in Kenya and Togo) shows a sustainable expansion potential. In the case of Kenya's K-Rep Bank, the Water and Sanitation Program, which facilitated the project, is already exploring a countrywide scaling up.

Kenya: K-Rep Bank finances community water projects
Kenya has numerous community-managed small water enterprises. The financial and institutional frame conditions are enhancing the provision of commercial finance. The water and sanitation program in Africa has launched an initiative to use micro credits for the local water and sanitation sector. As part of this initiative, the commercial microfinance bank K-Rep provides loans to 21 community-managed water projects. The Global Partnership on Output-based Aid supports the programme by providing partial subsidies. Every project is pre-financed with a loan up to 80 percent of the project costs (in average USD 80.000). After an independent verification process, certifying a successful completion, a part of the loan is refinanced by a 40 percent Global Partnership on Output-based Aid subsidy. The remaining loan repayments have to be generated from water revenues. In Addition, technical management assistance grants are provided to assist with the project development and to enable the development of market based Business Development Services sector for small water projects. The assistance for further 21 projects have been approved by the Global Partnership on Output-based Aid and the European Union Water Facilities.

Togo: Micro credits for the productive use of rainwater-harvesting tanks and shallow boreholes

In Togo, CREPA (Centre Regional pour l'Eau Potable et L'Assainissement à Faible Côut) was encouraging the liberalisation of water services in 2001. As a consequence, six domestic micro finance institutions were preparing micro credit scheme for a shallow borehole (3000 USD) or rainwater-harvesting tank (1000 USD) for at least two households from a certain area. The loans are originally dedicated to households, which act as small private provider selling water in bulk or in buckets. However the funds are directly disbursed to the private (drilling) companies. In the period from 2001 to 2006, roughly 1200 water points were built and are hence used for small business activities by the households participated in that programme.

Loans for urban services upgrading and shared facilities in low income areas

According to UN-Habitat, by 2020 the number people living in the urban slums of developing countries without adequate WSS services will increase to about 1.4 billion. In this scenario, micro credits could be used as an instrument to finance the upgrade or building of shared facilities in "slum areas".

Chapter- 6

Water Supply and Sanitation in Ethiopia

Access to **water supply and sanitation in Ethiopia** is one of the lowest in the world. While access has increased substantially with funding from external aid, much still remains to be done to achieve the Millennium Development Goal of halving the share of people without access to water and sanitation by 2015, to improve sustainability and to improve service quality.

Some factors inhibiting the achievement of these goals are the limited capacity of water bureaus in the country's nine regions and water desks in the 550 woredas; insufficient cost recovery for proper operation and maintenance; and different policies and procedures used by various donors, notwithstanding the Paris declaration on aid effectiveness.

In 2001 the government adopted a water and sanitation strategy that called for more decentralized decision-making; promoting the involvement of all stakeholders, including the private sector; increasing levels of cost recovery; as well as integrating water supply, sanitation and hygiene promotion activities. Implementation of the policy apparently is uneven. In 2005 the government announced highly ambitious targets to increase coverage in its Plan for Accelerated Sustained Development and to End Poverty (PADEP) for 2010. The investment needed to achieve the goal is about US$ 300 million per year, compared to actual investments of US$ 39 million in 2001-2002. While donors have committed substantial funds to the sector, effectively spending the money and to ensure the proper operation and maintenance of infrastructure built with these funds remain a challenge.

Water resources and use

Ethiopia has 12 river basins with an annual runoff volume of 122 billion m3 of water and an estimated 2.6 - 6.5 billion m3 of ground water potential. This corresponds to an average of 1575 m3 of physically available water per person per year, a relatively large volume. However, due to large spatial and temporal variations in rainfall and lack of storage, water is often not available where and when needed. Only about 3% of water resources are used, of which only about 11% (0.3% of the total) is used for domestic water supply.

The capital Addis Abeba's main source of drinking water is the Gafsara dam built during the Italian occuption and rehabilitated in 2009. Wells and another dam complement the supply. The city of Dire Dawa is supplied exclusively from groundwater which is highly polluted. The situation is most dramatic in Harar where "a steady decrease of the level of Lake Alemaya has resulted in the complete closure of the treatment plant". Due to supply shortfall water vendors sell untreated water with extremely high prices. The lake dries up because of local climate change, changes in land use in its basin and increased irrigation of Khat, a mild drug that is being grown for local consumption and export. A pipeline is expected to bring water over a distance of 75 km from a well field near Dire Dawa to Harar.

The great majority of the rural community water supply relies on groundwater through shallow wells, deep wells and springs. People who have no access to improved supply usually obtain water from rivers, unprotected springs and hand-dug wells. Rainwater harvesting is also common.

Access

According to data from the Joint Monitoring Programme for Water Supply and Sanitation of WHO and UNICEF, which are in turn based on data from various national surveys including the 2005 Ethiopia Demographic and Health Survey (DHS), access to an improved water source and improved sanitation was estimated as follows in 2008:

- 38% for improved water supply (98% for urban areas and 26% for rural areas)
- 12% for improved sanitation (29% in urban areas, 8% in rural areas)

In 1990 access to improved water supply was estimated at only 17%, and access to improved sanitation was estimated at only 4%. There thus has been a significant increase in access for water supply and sanitation, which spans both urban and rural areas.

In communities that lack access to an improved water source, women bear the brunt of the burden of collecting water. For example, according to an article by Tina Rosenberg for National Geographic, in the mountain-top village Foro in the Konso district of southwestern Ethiopia women make three to five round trips per day to fetch dirty water from the Koiro river. Each roundtrip lasts two to three hours and water is carried in "50-pound jerrycans".

Service quality

Rationing and service interruptions are frequent. There are no wastewater treatment plants in Ethiopia, so all wastewater collected in sewers is discharged without any treatment to the environment.

Responsibility for water supply and sanitation

In order to understand responsibilities in the sector it is necessary to provide a brief overview of local government in Ethiopia. Ethiopia is a federal state consisting of the following subdivisions:

- nine ethnically based regions or Kililoch with a population between 200,000 and 25 million each;
- 68 Zones with a population between 100,000 and a few million each;
- 550 Woredas or districts, with a population between 10,000 and more than 300,000 each;
- A large number of Kebeles, which constitute the smallest administrative units in Ethiopia.

In addition to the nine regions there are two “chartered cities”, (Addis Ababa and Dire Dawa), where the lower-level administrative units mentioned above do not exist. There is wide disparity in development and institutional capacity between regions and also within regions. The Amhara, Oromia, Tigray regions as well as the small Harari region are relatively developed. About 70% of Ethiopians live in these four regions. The Southern Nations, where about 20% of the population lives, is very heterogenous. In the more pastoralist and remote “emerging” regions Somali, Afar, Gambella and Benishangul-Gumuz, where about 10% of the population lives, capacity tends to be lowest.

Policy and regulation

There are strong national water supply and sanitation policies and key agencies have clear roles and strategies. National policies are set by the Ministry of Water Resources (MWR) for water supply and by the Ministry of Health for sanitation. In October 2006 a Memorandum of Understanding has been signed by both Ministries, as well as by the Ministry of the Environment, to clearly define the roles and responsibilities of each Ministry. Regional Water Bureaus and Woreda Water Desks are in charge of investment planning, monitoring and technical assistance to service providers. Their capacity to fulfill these tasks is sometimes limited.

Water supply

Formally the MWR's mandate covers only water resources management and it has no legal mandate concerning drinking water supply. Nevertheless, de facto it is the entity in charge of setting policies for water supply and to channel donor funds in the sector to local government entities. MWR has 737 employees in eight departments and 10 "services". One of the eight departments is the Water Supply and Sewerage Department. Since 2006 Asfaw Dingamo is the Minister of Water Resources.

In 2001 the government adopted a National Water Strategy prepared by the MWR. The overall strategy includes a water resources strategy, a hydropower development strategy, a water supply and sanitation strategy, and an irrigation strategy.

Concerning water supply and sanitation, the strategy aims at:

- More decentralized decision-making
- Promoting the involvement of all stakeholders, including the private sector
- Increasing levels of cost recovery
- Integrating water supply, sanitation and hygiene promotion activities.

The strategy document does not include a diagnostic of the current situation. The water and sanitation part of the strategy alone includes 44 recommendations concerning technical, institutional, capacity building, social, economic and environmental issues. There is no priorization between the recommendations and the strategy does not establish mechanisms to monitor the implementation of the strategy.

Sanitation

The Ministry of Health is in charge of policies related to sanitation and hygiene promotion. It has adopted a Sanitation and Hygiene Promotion Strategy. De facto sewers in urban areas are under the responsibility of the MWR, while the promotion of on-site sanitation is the responsibility of the Ministry of Health. The Sanitation and Hygiene Promotion Strategy has re-focused government resources on the promotion of pro-poor, low-cost practices.

Service provision

In the capital the Addis Ababa Water and Sewer Authority provides water and sewer services. In other cities and small towns Town Water Boards are responsible for service provision. They are expected to contract out service provision to private operators. In rural areas community water and sanitation committees operate water systems and promote sanitation. Not all the local committees are registered, which is a prerequisite to open a bank account to hold funds collected from users. Local committees are supported by Woreda Water Desks.

Other

Regional water resources development bureaus play an important role in planning investments at the regional level and in capacity building.

The Ethiopian Social Rehabilitation and Development Fund (ERSDF) – a Social Fund established in 1996 - is also an important actor, especially in rural areas. It has financed almost 2,000 rural water projects serving about 2.5 million people. However, the government has decided to phase out the ERSDF and to re-deploy its staff to other institutions.

History and recent developments

Until 1995 the national government had been responsible for centrally planning and implementing water and sanitation projects. Under the 1995 constitution Ethiopia became a federal state, which implied the decentralization of many functions to lower levels of government. This process has now been under way for more than a decade, but decentralization has been hampered by the limited capacity of local government to carry out its new responsibilities.

Also in 1995, a Ministry of Water Resources was created, taking over many of the responsibilities of the water resources department of the former Ministry of Public Works.

In 1999 the government adopted a National Water Resources Management Policy, which was followed by the establishment of a Water Resources Development Fund (2002) and a Water Sector Development Program. The latter includes a water supply and sewerage development program (nota bene the focus on sewerage and thus the absence of on-site sanitation from the program).

The government's Plan for Accelerated Sustained Development and to End Poverty (PADEP), covering the period 2005-2010, aimed at increasing access to an improved water source to 84% and access to improved sanitation to 80% by 2010. These ambitious targets go well beyond the water and sanitation targets of the Millennium Development Goals, which aim at halving the share of people without access by 2015. Since in 2008 access to an improved water source was 38% and to improved sanitation 12% it seems that these targets cannot be met.

Tariffs and cost recovery

On average cost recovery is too low to recover operating costs, not to speak of providing adequate maintenance of facilities. Recurrent expenditures - estimated at US$ 29 million in 2001-02 - were financed primarily through user charges (64%), as well as by subsidies from the regional governments (31%) and the federal government (5%). Despite this overall bleak picture, a few service providers recover all operating costs and generate a modest cash surplus.

The National Water Resources Management Policy aims at full cost recovery for urban systems and recovery of operation and maintenance costs for rural systems. It is not clear if progress has been made to achieve this ambitious objective since the policy was adopted.

Investment and financing

Investment

There are no reliable estimates of actual investment levels in the sector, and available estimates vary greatly. A detailed estimate of investment and financial flows in the Ethiopian water sector was carried out by the World Bank's Water and Sanitation Program (WSP) for the financial year 2001-02. It estimated total sector investments at US$ 39 million or less than half a dollar per capita, being one of the lowest recorded sector investment levels in the world.

The government estimates that annual investments in the 2006-2015 period will reach about US$ 100 million per year, or about two and a half times their level in 2001-2002. This projection is based on funding commitments made by donors and the government. It thus does not take into account bottlenecks in implementation due to limited capacities or other potential pitfalls. The World Bank projects the 2008 investment level at US$ 100 million, including resources from a 5-year US$ 100 million World Bank loan for urban water supply and sanitation approved in 2007.

The World Bank has estimated that the annual cost of achieving the government's targets to increase coverage until 2010 are about US$ 400 million "in the first few years" and falling to US$ 200 million "in later years". A detailed estimate by the government as part of its MDG Needs Assessment Report estimated investment needs at US$ 297 million per year for the period 2006-2015, roughly in line with the World Bank estimate.

Financing

Sources. According to the WSP estimate quoted above, in 2001-2002 only 9% of sector investments were funded by the federal budget, 55% through the regional budget, 33% off-budget by NGOs, 2% by the ERSDF and 1% by other sources. This estimate does not include community in-kind contributions, which are high for rural water supply and sanitation. A high but unknown share of the federal budget and probably also of the Woreda budget devoted to the sector is funded by donors. Concerning projected investments for 2006–2015, it is estimated that 12% (US$ 12 million) will be funded by the government with its own resources, 15% (US$ 16 million) by communities and 73% (US$ 75 million) by donors. It is not clear if this estimate includes off-budget support by NGOs. Because of the different categories used, a comparison between the historical and projected sources of financing is not possible.

Processes. The financing system has evolved in line with the policy of decentralization. Thus, for example, the country's 550 Woredas now receive block grants from the central government and then can decide autonomously how to use these grants within broad criteria set by the Water Resources Development Fund (WRDF). The WRDF is administered by a Board that is responsible to the MWR and is funded through budgetary allocations and donor funds.

External cooperation

Donors finance numerous projects in water supply and sanitation in Ethiopia – some through the Federal Government and some directly to regions, towns and communities. The donors have established a technical working group (TWG) on water as part of a core donor group called the Development Assistance Group. A Multi-Stakeholder Forum is also supported through the European Union Water Initiative. Despite improved coordination, donors still use different implementation arrangements. As a result, according to the World Bank, transaction cost are high.

Important donors in the sector are the African Development Bank, CIDA, the British DFID, the EU, FINIDA, AFD from France, Germany (through GTZ and KfW), JICA, the Netherlands, UNDP, UNICEF and the World Bank. There are also about 500 local and foreign NGOs, many of which are active in water supply and sanitation.

The African Development Bank provided a US$64 million grant for rural water supply and sanitation approved in 2005

WaterAid is engaged in Ethiopia since 1983. It works closely with established local non governmental organisations (NGOs). In Oromia Region, water projects tend to be spring-fed gravity schemes, some of which are very large, providing water for tens of thousands of people. In Southern Nations, Nationalities, and People's Region schemes have included deep boreholes as water is sometimes only found below 200 metres. For example, in the village of Orbesho residents - mainly women - built themselves an access road to allow drilling equipment to be brought in, dug trenches for pipes and collected stones for structures. In Amhara and Tigray the main technologies have been hand-dug wells and spring development. In Benishangul-Gumuz rope pumps are also used. In sanitation, WaterAid supports the construction and use of latrines. Hygiene education has increasingly focused on the close links between proper handwashing at critical times, like before eating and after going to the toilet, and improved health. In all cases WaterAid works closely with communities from the start. Particular attention is now being paid to engaging women. Since 1998 WaterAid has also been engaged in the slum areas of Addis Ababa. Projects include establishing communal water points linked to the city's piped systems, as well as shower and latrine blocks.

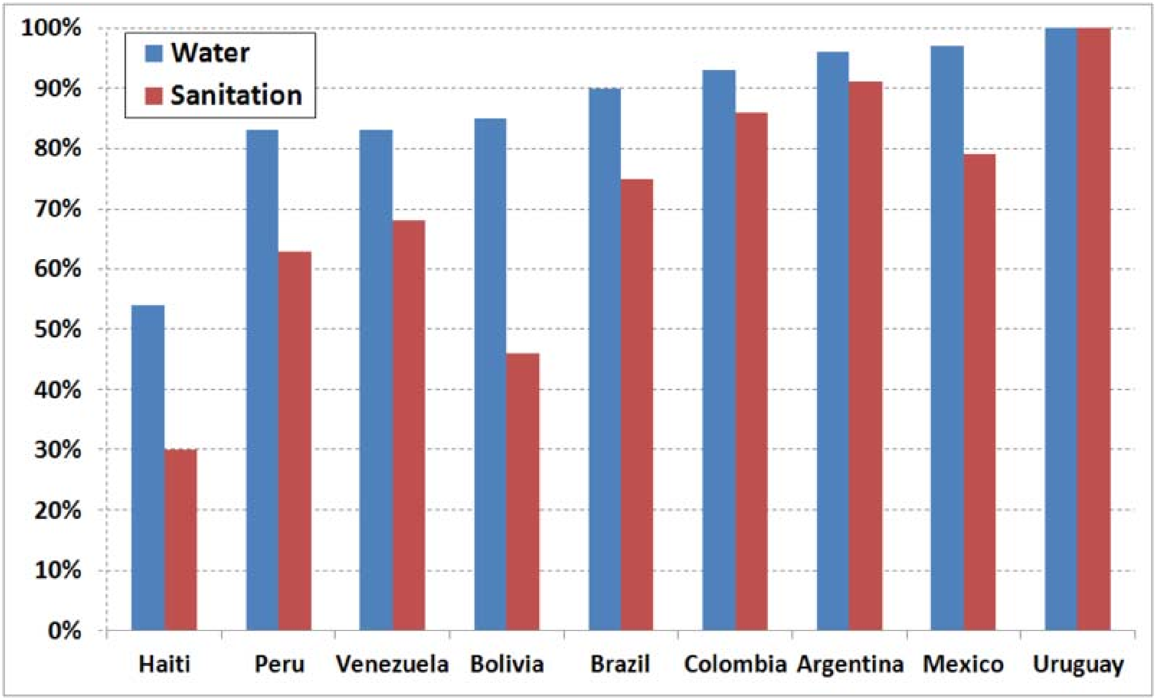
The World Bank provided a US$ 100 million credit/grant for urban water supply and sanitation approved in 2007. and a US$ 100 million credit for water supply and sanitation in 2004. In March 2010, the World Bank approved additional financing of US$ 80 million for the 2004 water supply and sanitation project. According to the World Bank, until 2010 the original project had financed the construction oft 1288 hand dug wells, 835 protected springs, 576 shallow wells, 99 deep wells, 75 rural piped systems and 35 rainwater harvesting, as well as conducting hygiene and sanitation promotion. In rural areas alone, according to the World Bank the project facilitated access to clean water and improved sanitation facilities to about 1.4 million people. In urban areas, the project provided "immediate service improvement" in 87 towns which benefited about 143,000 people.

Chapter- 7

Water Supply and Sanitation in Latin America

Water supply and sanitation in Latin America is characterized by insufficient access and in many cases by poor service quality, with detrimental impacts on public health. Water and sanitation services are provided by a vast array of mostly local service providers under an often fragmented policy and regulatory framework. Financing of water and sanitation remains a serious challenge.

Access



Water and Sanitation Coverage (broad definition) in selected Latin American countries in 2004. Source: World Health Organization (WHO)/UNICEF (2006): Meeting the MDG drinking water and sanitation target : the urban and rural challenge of the decade.

Access to water and sanitation remains insufficient, in particular in rural areas and for the poor. It also differs substantially among and within countries. According to the Joint Monitoring Program of the World Health Organization and UNICEF, in 2004 the share of population which was connected to an improved water source varied from 54% in Haiti to 100% in Uruguay. All together, 50 million people or 9% of the population of Latin America and the Caribbean did not have access to improved water supply, and 125 million or 23% did not have access to improved sanitation. Increasing access remains a challenge, in particular given the poor financial health of service providers and fiscal constraints on behalf of central and local governments.

As far as sanitation is concerned, only 51% of the population has access to sewers. Only an estimated 15% of the collected wastewater finds its way into wastewater treatment plants, which often are not properly functioning. 26% of the population has access to forms of sanitation other than sewers, including septic tanks and various types of latrines., a level that is about as high as in the United States and almost twice as high as in Central Europe. The highest water use can be found in some utilities in Chile and Argentina, where water resources are abundant and water use is almost 500 liter/capita/day. The lowest water use is in Aguas de Illimani serving La Paz, the capital of Bolivia, with less than 50 liter/capita/day. In rural areas water use is sometimes even lower than this level.

Quality of service

Even for those having access to water supply, poor quality of service is often experienced, in the form of intermittent supply, low pressure and poor drinking water quality. However, differences in service quality between countries and between cities in Latin America are vast, and some service providers achieve a quality of service on par with developed countries.

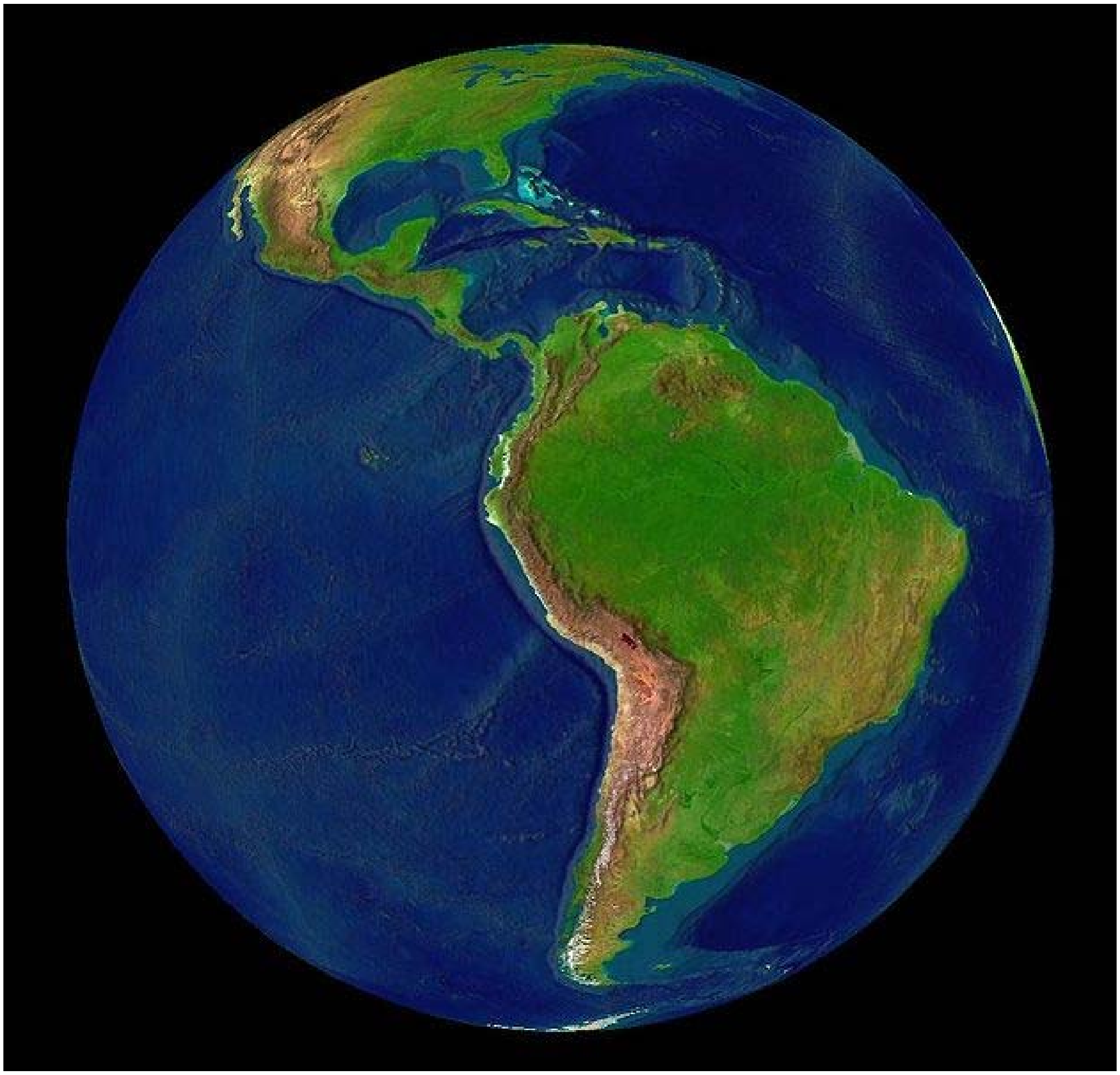
Institutional responsibility

Service provision

Responsibility for water supply and sewerage service provision in Latin American countries is vested either in municipalities, or in regional or national companies. Municipalities are in charge of water and sanitation service provision in Brazil, Colombia, Ecuador, Guatemala, Mexico and Peru. In some countries, such as in Colombia and Mexico, municipalities took over this responsibility from national service providers during the decentralization of the 1980s. Subsequently, especially the larger municipalities have often created specialized municipal (and sometimes inter-municipal) public utilities, whose finances are kept separate from the city's finances. While in most cases the companies are public, in a few notable cases they are mixed or private companies operating under concession, lease or management contracts. Chile and Venezuela are examples of countries that have created regional water companies; however, in the case of Venezuela, the United Nations reports that Venezuela remains one of the poorest in water service provision in this region. State-level regional water companies also exist in all 26 states of Brazil, where they provide services on behalf of some (but not all) municipalities in each state. National public water and sewer companies, which have for the most part been created in the 1960s and 1970s, still exist in Costa Rica, the Dominican Republic, El Salvador, Haiti, Panama, Paraguay and Uruguay. About 90% of urban water and sanitation services in Latin America are provided by public entities. Many private concession contracts signed during the 1990s in Latin America have been either renegotiated or cancelled. The most notable cancellations include the concession for Aguas Argentinas in Buenos Aires, Argentina, and the concessions for Cochabamba and La Paz, Bolivia. Private and mixed companies, however, continue to provide services in many cities of Colombia, in most of Chile, some Brazilian cities, and in Guayaquil, Ecuador.

In rural areas, the provision of water services is usually the responsibility of community organizations (Juntas de Agua). While the infrastructure is funded primarily by transfers from the national governments, typically community labor and sometimes cash contributions are mobilized. When communities are associated in the choice of service level and other key choices, this instills a sense of ownership that makes it more likely that communities will maintain the infrastructure.

Policy and regulation



A terrain map of Latin America

At the level of national governments, responsibility for policies in water and sanitation is typically fragmented between various Ministries, making the development of coherent policies in areas such as transfers to local service providers a challenging undertaking. The economic regulation of service providers is sometimes entrusted to Ministries and sometimes to autonomous regulatory agencies. These agencies sometimes cover only water and sanitation or multiple infrastructure sectors; they can be either at the national (as in Chile, Colombia and Peru) or at the state level (as in Argentina and in some states of Mexico). Their functions vary and may include tariff approvals, monitoring of service quality and handling of complaints. Environmental regulation is entrusted to environmental agencies and the regulation of drinking water quality to Ministries of Health.

Supporting community organizations

Supporting the numerous community organizations that provide water and sanitation services in Latin America - mainly in rural areas - is a key public function that is often underestimated and neglected. Responsibility for this function, if it is defined at all, can be assigned to a government Ministry and its regional branches, a Social Fund or municipalities. Often NGOs also carry out this function, either on their own initiative and with their own resources, or under contract by the government.

In Honduras support to community organizations (Juntas de Agua) is entrusted to the Social Fund FHIS, in cooperation with a national agency for technical assistance in water and sanitation (SANAA). In El Salvador it is done by the Social Fund FISDL and various NGOs. In Peru it is carried out through NGOs and municipalities with the support of a national program (PRONASAR) implemented by the Ministry of Housing. In Paraguay it is the responsibility of a national agency in charge of promoting specifically water supply and sanitation in rural areas and small towns (SENASA). In Ecuador it is carried out under a national program (PRAGUAS) by consultants working for the Ministry of Housing. In Panama such support is provided by the Ministry of Health. In Haiti such support is provided by NGOs, some of which are under contract with the national urban water agency SNEP and its specialized unit for rural areas. There thus is a wide variety of institutional arrangements to support community organizations, so that one cannot speak of a uniform model for such support in Latin America.

Financial aspects

Tariffs

According to a 2006 World Bank study average water tariffs in Latin America are the highest of any region of the developing world. Tariffs are about four times higher than in South Asia, three times higher than in Eastern Europe and Central Asia and almost twice as high as in East Asia. However, tariffs are less than half as high as in OECD countries. Based on a sample of 23 major cities in Latin America the average residential water tariff for a monthly consumption of 15 cubic meter was US$0.41, equivalent to a monthly bill of only about US$6.

Cost recovery

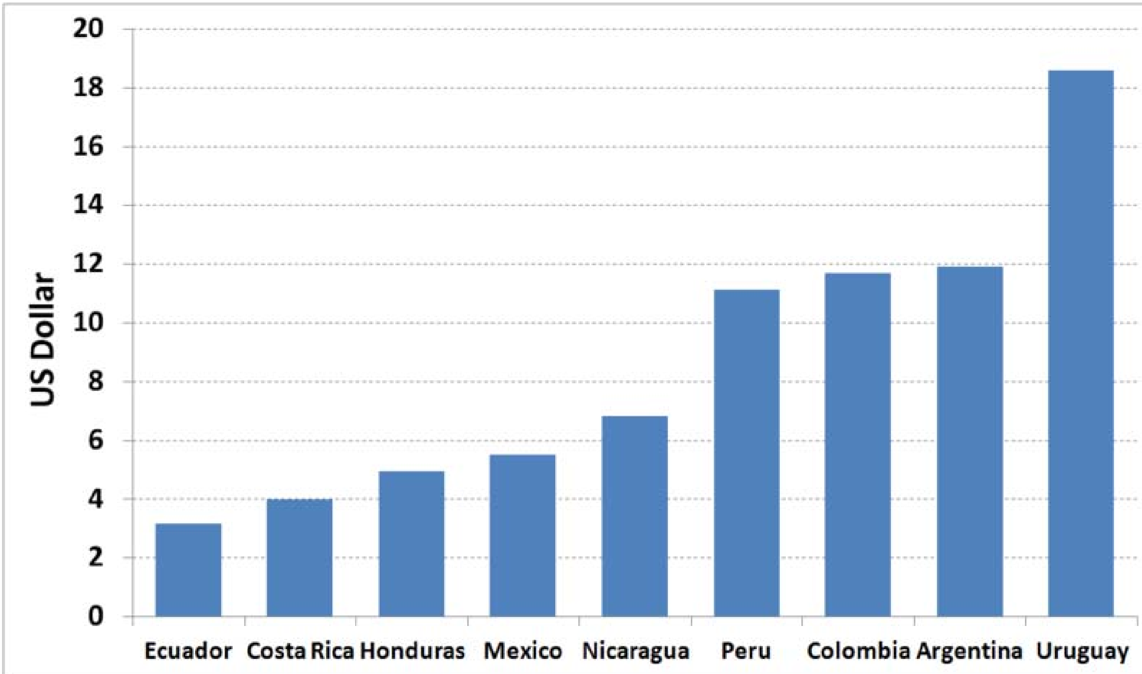
It appears that most utilities in Latin America recover more than their operating costs and thus generate surpluses to self-finance a portion of their investments. The average recovery coefficient of operating costs among a sample of 48 private and public utilities from 8 countries was 1.64. The highest coefficients of more than 2 can be found in utilities in Chile, as well as in Pereira and Manizales in Colombia.

Despite the ostensibly high levels of tariffs and cost recovery estimated based on the sample of utilities analyzed, utilities do not generate sufficient revenue to finance a substantial share of their investments internally, or to be credit-worthy enough to mobilize commercial, long-term credit. The reasons include low levels of operational efficiency, as detailed further below, poor recovery of bills, poor procurement practices and political corruption.

Affordability

There are few studies on the affordability of water and sewer bills in Latin America. The Pan-American Health Organization (PAHO) analyzed multi-purpose household surveys conducted between 1995 and 1999 in 10 countries to assess the share of household income spent on water supply services. These data show that the expenditures on water vary between 0.4% of total expenditures in rural Panama to 3.0% in Kingston, Jamaica. For the households in the poorest income decile expenditures on water are higher, varying from 0.6% in rural Panama to 6.5% in Kingston, Jamaica. However, these figures have to be interpreted with caution. First, it is not clear how water expenditures were defined in the surveys. It seems that in some cases expenditures to buy bottled water and water from tankers were included, while in other cases they were excluded. Second, the sample includes both households with and without access to piped water systems. Therefore, especially in rural areas where coverage tends to be low, the shares are only a poor indication on the affordability of water bills. Third, it is not explicit if sewer bills are included in the analysis, although this is most likely the case, since sewer bills are always a surcharge on the water bill and are thus perceived by most households as part of their water expenditures.

Investment



Annual investment per capita in several Latin American countries in water supply and sanitation (1997-2003 average) in constant US Dollars of 2006

The level of investment in water supply and sanitation in Latin America is tentatively estimated at 0.12% of GDP in the 1990s. A large share of these investments is needed to maintain and rehabilitate existing infrastructure. However, the World Bank has estimated that the investments needed to increase access to achieve the Millennium Development Goals (MDGs) in water and sanitation in Latin America by itself is 0.12% of GDP, not taking into account maintenance and rehabilitation. It can thus be concluded that, on average, a significant increase in investments is needed to achieve the MDGs.

Financing

The modalities of financing water and sanitation infrastructure differ substantially between countries. Some countries that have reached higher levels of cost recovery, such as Chile and some utilities in Brazil and Mexico, rely on commercial credit financing. However, the vast majority of utilities relies on transfers from national governments. These can take various forms: In Colombia municipalities are legally entitled to receive transfers calculated through a formula based on their costs and poverty levels; in Mexico municipalities can apply for matching federal grants provided they fulfill certain conditions that vary by program; in Ecuador municipalities receive transfers based on a formula that takes into account their choice of management model and improvements in cost recovery; and in other countries utilities simply receive transfers that can vary from one year to the other without any conditions. The level of transfers from national governments is highly variable and often far from sufficient to increase coverage and improve service quality. Some countries pass loans from international financial institutions on to utilities in the form of credits. However, these international loans only account for a relatively small share of water and sanitation financing in Latin America.

Efficiency

There are wide differences in the operational efficiency among urban water and sanitation utilities in Latin America. The two most common measures of operation efficiency are labor productivity and non-revenue water (water losses). In terms of labor productivity, the most productive utilities have less than 2 employees per 1000 connections. They include EPM in Colombia, SEDAPAL in Lima, Aguas del Valle in Chile's 4th region, as well as Aguas de Formosa and Aguas de Salta in Argentina. The utility with the lowest labor productivity in the sample is EPSEL from the Lambayeque Region in Peru with more than 15 employees per 1000 connections. The average of the sample is about 5 employees per 1000 connections.

Concerning non-revenue water, the average of Latin American utilities in the sample considered is 40% and thus much higher than estimates of efficient levels, which vary between 15 and 25%. The highest level (73%) is registered by Interagua, the utility serving Guayaquil in Ecuador. The lowest level of any larger utility with a high share of household metering, which is a precondition to accurately measure non-revenue water, is registered in Aguas Cordillera in Chile with 20%.

Strategy to improve services

The Millennium Development Goals (MDG) aim at halving, by 2015, the proportion of people without sustainable access to safe drinking water and adequate sanitation, from a base year of 1990. According to a 2006 World Bank brief, this is achievable for some countries in Latin America and the Caribbean, while it represents a mammoth task for others. According to the World Bank even those countries on track to achieve the MDG targets face tremendous challenges in improving service quality, in particular to attain continuity of supply and to increase wastewater treatment. To meet these challenges Latin American and Caribbean countries, according to the World Bank, would have to advance on several fronts, including:

- **Improving the efficiency of service providers** to allow them to generate more internal resources to cover costs and fund investment. This includes better collection of bills, reduction of administrative losses (clandestine connections, under-metering) and physical losses, better procurement practices, the use of low-cost technologies and a reduction of overstaffing.
- **Increasing investments in water and sanitation** from the current low level of 0.15 percent of GDP. Investment needs are estimated to exceed 0.2 percent of GDP.
- **Introducing innovative mechanisms for commercial financing**. This includes tapping domestic capital markets where feasible and the judicious use of

guarantees and guarantee facilities, while managing contingent liabilities prudently.

- **Targeting subsidies better and improving cost recovery**. Implicit and explicit subsidies through low tariffs mostly benefit the better-off. Increasing tariffs is often a necessity. But in order to make this more equitable, such measures would have to be complemented by actions to enhance collection efficiency, reduce the incidence of illegal connections, increase the share of metered connections, revise tariff structures and introduce means-tested subsidies where feasible.
- **Expanding access to water and sanitation services, especially to the poor**, while ensuring that these services are accessible, efficient, and sustainable. Low-cost technologies such as condominial sewers can play an important role in that respect, as can legalizing land tenure and finding innovative ways to provide services to those without land titles.
- **Improving service quality**. Without continuous supply, reliably good drinking water quality, and the prevention of sewer overflows, health is endangered and – especially if customer service is poor and billing complaints not resolved swiftly – it is difficult to justify a higher degree of cost recovery.
- **Strengthening the capacity of service providers**. This is essential, especially given the high turnover of senior staff in municipal utilities as a result of frequent changes in municipal governments. It is important to make municipal service providers more autonomous, to insulate them as much as possible from political influence, and to provide training and a career path for utility employees.
- **Redefining the role of the private sector in service provision**. Private sector participation in water and sanitation in Latin America and the Caribbean has had mixed results. Some international operators have lost interest in the sector, sometimes citing governments' failure to abide by contracts. However, local private operators continue to play a major role in the sector, helping to improve efficiency and service quality, especially if state supervision is adequate.
- **Strengthening information systems and impact evaluations**. Utilities often have only very limited information available on the quality of their services and their assets. Regulators and governments often have even less, and there are frequently only rudimentary data available on how projects and programs have influenced coverage and service quality. The strengthening of local and national information systems and impact evaluations is therefore a priority for the region.
- **Improving regulatory frameworks.** A regulatory framework that ensures that the interests of both the consumer and the investor are adequately represented is essential. However, experience with utility regulation in the region is sobering, given the limited autonomy and resources of many regulators, as well as the limited ability of many service providers to fulfill norms set by regulators.

Chapter- 8

Water Supply and Sanitation in Argentina

Water supply and sanitation in Argentina

Data	
Water coverage (broad definition)	96%
Sanitation coverage (broad definition)	91%
Continuity of supply	Mostly continuous
Average urban water and sanitation tariff (US$/m3)	0.48 (water) and 0.31 (sewerage) in 2000
Share of household metering	Low
Institutions	
Decentralization to municipalities	Substantial, since 1980
Water and sanitation regulator	At provincial level
Responsibility for policy setting	Ministry of Public Works
Number of urban service providers	1,650

Water supply and sanitation in Argentina is characterized by relatively low tariffs, mostly reasonable service quality, low levels of metering and high levels of consumption for those with access to services. At the same time, according to the WHO, 21% of the total population remains without access to house connections and 52% of the urban population do not have access to sewerage. The responsibility for operating and maintaining water and sanitation services rests with 19 provincial water and sewer companies, more than 100 municipalities and more than 950 cooperatives, the latter operating primarily in small towns. Among the largest water and sewer companies are Agua y Saneamientos Argentinos (AYSA) and Aguas Bonarenses S.A. (ABSA), both operating in Greater Buenos Aires, Aguas Provinciales de Santa Fe, and Aguas Cordobesas SA, all of them now publicly owned. In 2008 there were still a few private concessions, such as Aguas de Salta SA, which is majority-owned by Argentinean investors, and Obras Sanitarias de Mendoza (OSM).

Most service providers barely recover operation and maintenance costs and have no capacity to self-finance investments. While private operators were able to achieve higher levels of cost recovery, since the Argentine financial crisis in 2002 tariffs have been frozen and the self-financing capacity of utilities has disappeared. Roughly two-thirds of provincial water and sanitation spending since 2002 has come from general transfers from the federal government, the remainder coming from various national programs directed specifically to the sector.

Services are regulated by the 23 Provinces, in the case of 14 through regulatory agencies that have some limited autonomy from the government. Overall, however, responsibilities are not always clearly defined, and institutions are often weak, subject to political interference and lacking enforcement powers. The various national institutions with policy-setting responsibilities in the sector are not always well coordinated. There is no coherent national policy in terms of sector financing, subsidies, tariffs and service standards. The federal structure of the country and the dispersion of sector responsibilities between and within various levels of government make the development of a coherent sector policy all the more difficult.

Between 1991 and 1999, as part of one of the world's largest privatization programs covering a range of sectors, water and sanitation concessions with the private sector were signed covering 28% of the country's municipalities and 60% of the population. The highest profile concession was signed in 1993 with a consortium led by the French firm Suez for the central parts of Greater Buenos Aires. After the 2001 economic crisis, many concessions were renegotiated. Many were terminated, as it was the case in Buenos Aires in 2006.

The impact of private sector participation in water and sanitation is a controversial topic. While the public perception of the mostly international concessionaires is overwhelmingly negative in Argentina, some studies show positive impacts. For example, a 2002 study assessed the impact of privatization on child mortality based on household survey data, finding that child mortality fell 5 to 7 percent more in areas that privatized compared to those that remained under public or cooperative management. The authors estimate that the main reason is the massive expansion of access to water. According to Suez, the private concession in Buenos Aires extended access to water to 2 million people and access to sanitation to 1 million people, despite a freeze in tariffs imposed by the government in 2001 in violation of the concession agreement. The government argues that the concessionaire did not fully comply with its obligations concerning expansion and quality, saying that the supplied water had high levels of nitrate, pressure obligations were not kept and scheduled works were not carried out.

Access

Argentina has achieved very high levels of access to an improved water source in urban areas (98%), using a broad definition of access. However, coverage using a narrower definition of access (house connections) is much lower at 83%, since many users still only have access through public standpipes. Also, access in rural areas remains relatively low for a country of Argentina's level of development (80% using a broad definition, 45% for house connections).

Access to improved sanitation, using a broad definition of access including septic tanks and improved latrines, is high at 91%. However, access to sewerage is only 44%.

		Urban (90% of the population)	**Rural (10% of the population)**	**Total**
Water	Broad definition	98%	80%	96%
	House connections	83%	45%	79%
Sanitation	Broad definition	92%	83%	91%
	Sewerage	48%	5%	44%

Source: Joint Monitoring Program WHO/UNICEF(JMP/2006). Data for water and sanitation based on the Census (2001).

According to a study by the *Centro de Implementación de Políticas Públicas para la Equidad y el Crecimiento* (CIPPEC) or Center for Implementation of Public Policies for Equity and Growth, the increase of coverage between 1991 and 2001 was lower in the poorest provinces.

Service quality

Map of Argentina. *Source*: CIA

There are apparently no comprehensive data on water and sanitation water quality in Argentina. In urban areas, service generally is continuos and of potable quality. However, water rationing occurs in some cities during the summer months, and drinking water quality is sometimes sub-standard.

In Buenos Aires, in 2008 there were two water treatment plants and a new one was about to begin.

Concerning sanitation, existing sewage collection systems are insufficient to handle the increasing flows as a growing number of households connect to the sewer systems, leading to frequent sewer overflows.

The level of wastewater treatment varies among the Argentinean regions. According to the Pan American Health Organization, at the national level 10% of the collected wastewater was being treated in 2000. Whereas in many regional capitals, such as Mendoza, Córdoba, Tucumán, Neuquén, Jujuy, Salta and San Juan, most of the wastewater was treated, in the two largest urban areas of the country, Buenos Aires and Rosario, there was practically no treatment at all, resulting in serious environmental problems. However, in 2008 a bidding process was launched to build a wastewater treatment plant in Buenos Aires.

History and recent developments

From 1880 until 1980, the national utility *Obras Sanitarias de la Nación* (OSN) was in charge of providing water and sewer services in the main cities, while in smaller cities it was the responsibility of provincial governments, municipalities and cooperatives.

In 1980 the military government under Jorge Rafael Videla decentralized the provision of water and sanitation services in the main cities served by OSN, except for the metropolitan area of Buenos Aires where OSN continued to provide services. In other cities OSN transferred its responsibilities to provincial governments. Each province chose its model of service provision (municipal, public enterprises, cooperatives or others).

Between 1991 and 1999 under the government of Carlos Menem, as part of one of the worlds largest privatization programs covering a range of sectors, water and sanitation concessions with the private sector were signed in 28% of the country's municipalities covering 60% of the population. The highest profile concession was signed in 1993 with a consortium led by the French firm Suez for the metropolitan area of Buenos Aires. After the 2001 economic crisis, under the government of Nestor Kirchner, many concessions were renegotiated. Some were even terminated and the responsibility for service provision reverted to public entities, as it was the case in Buenos Aires where the newly created public enterprise *Aguas y Saneamientos Argentinos* took over the responsibility for service provision in 2006. At the beginning of 2008, the government of the Province of Mendoza announced that it is interested in increasing its control of the provincial water utility *Obras Sanitarias de Mendoza*, of which it owns 20%, buying another 20% from Saur International.

Impact of private sector participation

So far there has been no comprehensive, objective assessment of the impact of private sector participation in water supply and sanitation in Argentina. However, there has been some partial evidence. For example, a 2002 study assessed the impact of privatization on child mortality based on household survey data, finding that in the 1991-1997 period child mortality fell 5 to 7 percent more in areas that privatized compared to those that remained under public or cooperative management. It also found that the effect was largest in poorest areas (24%). The authors estimate that the main reason is the massive expansion of access to water, which was concentrated in poorer areas that did not receive services before private sector participation was introduced.

The Buenos Aires concession

The largest and best-known case of private sector participation in the Argentine water and sanitation sector was the Buenos Aires concession, signed in 1993 and revoked in 2006. Its impact remains controversial and in early 2008 an arbitration case was still pending with the International Center for Settlement of Investment Disputes (ICSID) of the World Bank Group.

Critics argue that the concessionaire failed to achieve the targets set under the concession contract. When the government rescinded the concession in March 2006, it argued that Aguas Argentinas did not comply with obligations concerning expansion and quality. According to the government, the supplied water had high levels of nitrate, pressure obligations were not kept and scheduled waterworks were not executed by the concessionaire. On the other hand, proponents of private participation state that a freeze in tariffs at the time of the devaluation of the Peso during the Argentinean economic crisis in 2001 substantially reduced the real value of tariff revenues and thus made it difficult to achieve the original targets.

One factor which may have caused the cancellation of the concession contract was the precipitate preparation. Alcazar et al. list some features of the concession which indicate an overhasty process:

1. The regulatory agency ETOSS (*Ente Tripartito de Obras de Servicios de Saneamiento*, Tripartite Entity for Sanitary Services) lacked experience, since it was founded quickly as part of the concession process.
2. The available information in the concession contract about the state of the existing infrastructure was so poor, that the Argentinean government denied taking responsibility for it. This lack of information could have let the bidder to accept the contract in the expectation of future renegotiation.
3. Instead of creating a new and more transparent tariff system, the old one was adopted from OSN.

In addition, the inexperienced regulatory agency was repeatedly bypassed when decisions were taken, for example in the renegotiation of the contract in 1997. In that way, ETOSS was further weakened. The concession contract authorized Aguas Argentinas to demand dollars at the old 1:1 exchange rate after the peso devaluation. Solanes points out that without this practice companies may seek financing in local capital markets to avoid currency fluctuations. He also argues that the needs of the poor were not addressed in the concession. No subsidies were provided for the poor and the tariff system did not encourage expansion of coverage to poor areas, since new connections were often unaffordable and new users also had to pay the costs of expanding the network.

The concessionaire did invest much more than its public predecessor and achieved substantial increases in access to water and sewerage. According to the Argentinean economist Sebastian Galiani, the public company OSN had invested only US$25m per year between 1983 and 1993, while the private concessionaire Aguas Argentinas increased investments to around US$200 m per year between 1993 and 2000.

According to Suez, during the 13 year-duration of its concession it extended access to water to 2 million people and access to sanitation to 1 million people, despite the economic crisis. Between 2003 and 2005 alone about 100,000 inhabitants of poor neighborhoods and slums are said to have been connected through a "participatory management model" piloted by Aguas Argentinas. Aspects of the model have been adopted by the government to extend services to another 400,000 people in La Matanza in the province of Buenos Aires in the project "Water plus work" ("Aguas más trabajo").

An example of local private sector participation: Salta

The government of Salta Province initiated the reform of its water sector in 1996. At the same time many other Argentinean provinces and municipalities brought in the private sector to improve water and sanitation services. While Salta also followed this approach, the process differed somewhat from the one in many other parts of Argentina. First, the provincial government conducted a series of meetings with municipalities and user organizations to discuss the benefits and risks of the concession before it was bid out. This process of consultations was continued by the private concessionaire after the contract was awarded. Second, the government decided from the onset that water and sanitation services in the poor province could not be financed entirely through tariff revenues. It thus decided to finance much of the investments to be undertaken by the private concessionaire with public grants, in addition to providing consumption subsidies. Third, the regulatory agency allowed the concessionaire to provide services at a lower standard in remote or isolated areas that were deemed unprofitable at conventional service standards. Fourth, the provincial regulatory agency granted tariff increases before and even after the 2001 economic crisis. These tariff increases were lower than it would have been necessary without subsidies or flexible service standards. And fifth, the government "ignored the traditional paradigm of only permitting companies with significant previous experience in water supply and sanitation to compete in the bidding process". This provision had favored a few large multinational water firms in other bidding processes. In Salta, however, the bid was won by the Argentinean construction, power and toll road enterprise MECON S.A. which signed a technical assistance contract with the Brazilian Paraná State public utility SANEPAR.

The private concession led to a substantial increase in access to water and sanitation from the time of concession award in 1999 to 2005. It also provided a significant decrease in service interruptions and improved customer service. 13 more municipalities joined the concession contract after it had been signed in order to share in its benefits, bringing the total number of municipalities served by the concessionaire to 56.

While most other private water concessions in Argentina were rescinded in the years after the 2001 economic crisis, the Salta concession has been upheld until 2009 despite a number of problems. In February 2008 the regulatory agency initiated penal proceedings against the concessionaire because one of its wastewater treatment plants discharging to the Arenales River was not functioning. In June 2008 the company was accused of not having complied with contractual targets for the installation of meters, water pressure, continuity of supply, drinking water quality norms, and of applying excessive interests on late payments. In May 2009 Juan Manuel Urtubey, governor of the Province, terminated the concession contract because of non-compliance and created a transition unit to provide services until a state company would be created whose shares would be held by the Province (90%) and workers (10%).

Responsibility for water supply and sanitation

Policy and regulation

Provinces have responsibility for setting rules and policies in the sector for their area. Institutions are weak, subject to political interference and lacking in enforcement powers. 14 out of 23 provinces have regulatory bodies, but they often have limited capacity and unclear institutional responsibilities. In most cases, they act as supervisors of private concession contracts, not covering public and cooperative service providers. This autonomy of provinces resulted in a highly heterogeneous system of water supply and sanitation. Moreover, it hinders to create an overview of the situation at the national level.

Despite recent progress in clarifying responsibilities, the institutional framework at the national level still lacks coherence and coordination among federal actors is weak. The Ministry of Public Works proposes sector policies to the Ministry of Federal Planning, Public Investment and Services which approves them. Within this policy framework the National Agency for Water and Sanitation Works (ENOHSA), a decentralized agency under the Ministry of Public Works, provides financing and technical assistance to service providers. As an advisor to the Ministry of Public Works it de facto influences sector policies. Recently ENOHSA has been also given the faculty to directly execute infrastructure works. There has been some confusion between its position as conceding power (in the Buenos Aires concession) and as policy-maker for the overall sector. There is no coherent national policy in terms of sector financing, subsidies, tariffs and service standards. Nor is there a sector law for water and sanitation. The federal structure of the country and the dispersion of sector responsibilities between and within various levels of government make the development of a coherent sector policy all the more difficult.

Service provision

Provision of water and sanitation supply in Argentina is organized on a municipal or provincial basis by around 1,650 public, cooperative and private entities of various forms. 14 service providers are provincial (Argentina has 23 provinces), but do not necessarily serve the entire province. Some are multi-municipal, some serve a single municipality and others parts of a municipality. There are at least 990 mostly smaller cooperative service providers in Argentina, making Argentina the country in Latin America where this form of service provision is most prevalent.

Financial aspects

Tariffs

Bills of **Aguas y Saneamientos Argentinos**

In 2000, the Argentinean water and sanitation tariff levels were high, given the low quality of services. According to the Panamerican Health Organization (PAHO), the mean tariff for water and sanitation was US$ 0.79 per m3. There are two different tariff systems. The first method is based on the former OSN tariff system. It estimates the consumption of each user according to characteristics such as dwelling size, location of residence and type of dwelling. The second tariff system contains a fixed charge and a variable part which is based on metered consumption. This latter method was made possible by the extensive introduction of water metering, which was included in many concession contracts in the 1990s. The average household expenditure for water supply and sanitation in 2002 was 2.6%, ranging from 2.1% in the highest (wealthiest) quintile to 3.5% in the lowest (poorest) one.

Cost recovery

Most service providers barely recover operation and maintenance costs and have no capacity to self-finance investments. While private operators were able to achieve higher levels of cost recovery and to substantially expand services before the crisis, since 2002 their tariffs have been frozen and their self-financing capacity has disappeared. Service providers thus are almost entirely dependent on federal transfers for investment financing. Roughly two-thirds of provincial water and sanitation spending over the period has come from general transfers from the federal government, the remainder coming from various programs directed specifically to the sector, including for flood protection and water resources management.

When the linkage of the Argentinean peso to the US-Dollar was abandoned due to a serious economic crisis in 2002, the tariffs did not increase but converted 1 to 1 to the devalued peso, resulting in various contract renegotiations. This decision worsened the financial situation of the suppliers. The lack of financial resources results in problems concerning even in maintaining the supply system.

Cutting off water services for non-payment is prohibited in Argentina based on a common interpretation of the constitution.

External support

Inter-American Development Bank

- AR-L1015 : Water Infrastructure: Northern Provinces Development

Approved on January 31, 2007 in the amount of US$240 million, the loan will address specific problems of irrigation, drainage, as well as low access to water and sanitation in the northern provinces of: Jujuy, Catamarca, Santiago del Estero, Tucumán, and Chaco.

- AR-L1034 : PEF:AR-L1031 Potable Water and Sanitation Program

Approved on September 25, 2006 in the amount of US$ 180,000,000, the program will partly finance water and/or sewerage systems for communities up to 50,000 in Argentina.

World Bank

- Infrastructure Project for the Province of Buenos Aires (APL2)

The US$270 million loan was approved on June 28, 2007, and finances 40% sewerage and 16% flood protection for the highly vulnerable and low-income communities in the Province of Buenos Aires.

- Basic Municipal Services Project

The US$175 million loan approved on April 3, 2006, finances water (27%), sanitation (27%), and sewerage (14%) projects in Argentina.

- Urban Flood Prevention and Drainage APL1

The US$190 million loan approved on May 18, 2006, finances flood protection (94%) as well as general water and sanitation sector (2%) in the city of Buenos Aires through the protection of the city's critical infrastructure and the introduction of risk management into the Government investment program.

- Infrastructure Project for the Province of Buenos Aires (APL1)

The US$267 million loan approved on February 15, 2006, finances infrastructure services in sewerage (30%) and flood protection (5%) in the Province of Buenos Aires.

Chapter- 9

Water Supply and Sanitation in Mendoza

The debate about **water supply and sanitation in Mendoza** has been dominated by the controversial private concession for the provincial water company OSM granted in 1998 to a consortium led by Enron. While the concession improved water and sanitation services, it failed to meet all its specified targets. After the collapse of Enron the concession was overtaken by Argentine investors.

Besides OSM water services in the province are provided by the three municipalities of Maipu, Lujan and Tupungatu and 174 small not-for-profit operators.

With 1.6 million inhabitants the province of Mendoza is the 5th most populous province of Argentina. The province has an arid climate and its water supply depends on rivers fed by glaciers from the Andes.

History

Sector reform (1993-1998)

In 1993, in responsive to poor service quality, the provincial Parliament passed a law (Law 6044) with the objective of restructuring the province's water and sanitation sector, introducing a private concession for the provincially-owned company Obras Sanitarias de Mendoza (OSM) and creating a regulatory agency for the sector.

In the same year the provincial government also first submitted a draft law to Parliament to pursue a policy of installing water meters and volumetric billing. More than 120,000 meters were installed in the following five years. However, that law was never passed. Meters were thus not read and fell into disrepair, while bills continued to be issued on a lump sum basis independently of consumption.

Moreover, a culture of non-payment reigned. According to a survey by the newspaper Los Andes, in 1999 one quarter of water users did not pay their water bills.

Early years of the concession (1998-2001)

In 1998 the provincial government launched a bid for a concession for OSM, which was won by a US-French-Argentine consortium led by Enron. OSM's capital was thus held by the following entities:

• 50% by the Enron-led consortium Inversores del Aconcagua • 20% by an operating company called Aguas de Mendoza • 20% were kept by the provincial government • 10% by the company's employees.

Inversora del Aconcagua initially consisted of the US firm Enron (57.5 %), the French firm SAUR International (17.5%), Italgas (5%) and Argentine investors (20%). Aguas de Mendoza is fully owned by SAUR International.

The concession contract was signed for the unusually long duration of 99 years. Investment commitments were US$ 89million over 25 years.

Tariffs were supposed to remain stable for the first five years of the contract. However, there was a 37% increase after the renegotiation of the concession in 2003.

The concession after the economic crisis (2001 onwards)

After the economic crisis of 2001 and the devaluation of the Peso a number of problems became apparent:

- Tariffs were frozen in 2002 by a national emergency decree, in contradiction of tariff increases stipulated in the concession contract. As a result, revenues were insufficient to recover increasing costs;
- There were delays in the execution of works;
- There were problems of bacteriological pollution of drinking water;
- Low water pressure (40% of users do not receive water below minimum pressure);
- Insufficient attention to user complaints;
- Reduction of environmental targets.

In 2002 a process was initiated to renegotiate the concession contract. When Enron went bankrupt in 2003 its part of the shares was initially taken over by its own subsidiary Azurix. In 2004 the shares of OSM were worth only one fifth of their value in 1998. In the same year South Water Argentina SA of the Sielecki Group took over 32% of the shares of OSM from Enron alter the latter went bankrupt.

According to Susana Yelich, director of the consumer group Prodelco, service provision in 2004 was much better than at the time when OSM had been publicly managed. Nevertheless, many consumers were dissatisfied with the services they received and more than 120 law suits were initiated against the private operator.

At the beginning of 2008, the provincial government announced that it is interested in increasing its control of OSM, of which it owns 20%, buying another 20% from Saur International.

Responsibility for water supply and sanitation

Policy and regulation

Sector policy is the responsibility of the provincial governor, assisted by the provincial Minister of Public Works and the Environment.

Economic regulation is the responsibility of a regulatory agency, the Ente Provincial de Aguas y Saneamiento (EPAS), under the Ministry of Public Works and Environment. It was created in 1995 on the basis of Law 6044 of 1993. EPAS remained a weak agency and, as a technical agency with limited autonomy. It was unable to fulfill its role of regulating the concession contract which included both technical and political elements. The regulator has been highly critical of the private concession, requesting it in 2003 to be cancelled due to non-respect of the contractual agreements.

Service provision

There are three categories of service providers in the province of Mendoza:

- OSM with more than 320,000 water and sewer connections
- The three municipalities of Maipu, Lujan and Tupungatu with more than 100,000 water and sewer connections
- 174 small operators, such as cooperatives and neighborhood associations, with more than 38,000 connections.

Financial aspects

Tariffs

In 1998 tariffs of OSM were 30 Pesos (US$ 30) every two months, much more than the national average of 18 Pesos (US$ 18). The average tariff level in 2004 was 60 pesos (US$ 20) for water and sewerage for a period of two months, compared to only 15 pesos (US$ 5) in the case of Buenos Aires. Because of the massive devaluation of the Argentine peso the dollar value of tariffs decreased in this period, although the Peso value of tariffs had doubled in Mendoza.

Note: Tariff data for municipalities and cooperatives are missing.

Sector finances

It is a matter of controversy whether OSM made profits from its concession. In five years OSM paid only 1 million Pesos of dividends. In 2002 and 2003 OSM showed losses of 43 and 17 million Pesos respectively. However, according to the regulatory agency its rate of return was 13%.

Annual fees from the concession were intended to finance the construction of the Potrerillos levee on the Mendoza River, the largest hydraulic infrastructure ever built in the Province. The fees were supposed to be paid by the concessionaire to the Provincial Irrigation Department. However, due to the various problems that afflicted the concession that fee has never been paid. Until 2002 a debt of more than 4 million Pesos had been accumulated.

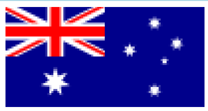
A list of 26,000 needy users (*carenciados*) was established in 2003, for whom the provincial government would pay 40-75% of the water bill. However, not all those on the list were truly needy, since the establishment of the list was influenced by clientelism. Despite requests by the concessionaire, the list has never been updated until 2004. Furthermore, the provincial government has only partially met its payment obligations towards OSM on behalf of the needy users, having accumulated a debt of 13 million Pesos towards OSM by 2000. On the other hand, OSM has not paid taxes, the concession fee and fines imposed on it by the regulator for not having met its investment obligations, equivalent to 13 million Pesos as well.

Media and the water and sanitation sector

Among the province's two main newspapers, Los Andes was highly critical of the concession and of privatization in general. The newspaper Uno was much less critical, which may be explained by the fact that its owner, Daniel Vila, was also a co-owner of OSM through Inversores del Aconcagua. In general the concession contract received negative media coverage, with the media giving ample space to the criticism voiced by politicians, consumer associations and the regulator.

Chapter- 10

Water Supply and Sanitation in Australia

Australia: Water and Sanitation	
	
Data	
Water coverage (broad definition)	100%
Sanitation coverage (broad definition)	100%
Continuity of supply (%)	Mostly continuous
Average residential water use (l/p/d)	191 liter/person/day<(2007)
Average domestic water and sewer bill	A$60/month or US$46/month
Share of household metering	n/a
Annual investment in WSS	A$2 bn/US$1.74 bn (2007–08) or US$81/capita
Share of self-financing by utilities	High
Share of tax-financing	Low
Share of external financing	None
Institutions	
Decentralisation to municipalities	In some states (primarily in Queensland and Tasmania)
National water and sanitation company	State water and sanitation companies
Water and sanitation regulator	No
Responsibility for	Share between states/territories and the

policy setting	Commonwealth (national government)
Sector law	No
Number of urban service providers	> 33
Number of rural service providers	n/a

Water supply and sanitation in Australia is universal and of good quality. As the country's supply of freshwater is increasingly vulnerable to droughts, possibly as a result of climate change, there is an emphasis on water conservation and various regions have imposed restrictions on the use of water. In 2006, Perth became the first Australian city to operate a seawater desalination plant, the Kwinana Desalination Plant, to reduce the city's vulnerability to droughts. More plants are planned or are under construction in Sydney, the Gold Coast, Melbourne, and Adelaide. The use of reclaimed water is also increasingly common. However, some desalination plants were put in stand-by modes in 2010 following above average rainfall levels and floods in 2010.

Governments of Australian states and territories, through state-owned companies, are in charge of service provision in Western Australia, South Australia and the Northern Territory, while utilities owned by local governments provide services in parts of Queensland and Tasmania. In Victoria, New South Wales and Southeast Queensland state-owned utilities provide bulk water, which is then distributed by utilities owned by local government. The Minister for Sustainability, Environment, Water, Population and Communities is responsible for water policies at the federal level.

Water resources and water use

Australia is the driest inhabited continent on Earth, and among the world’s highest consumers of water. Amongst OECD nations Australia is ranked fourth-highest in water use per capita. Total water runoff in 2004–05 was estimated at 243 billion cubic meters (BCM) and total groundwater recharge was estimated at 49 BCM, giving a total inflow to Australia’s water resources of 292 BCM. Over 60 per cent of runoff occurred in northern Australia. Only 6 per cent of Australia’s runoff was in the Murray-Darling Basin, where 50 per cent of Australia’s water use occurs. Australia’s total large dam storage capacity was 84 BCM. While surface water is well known, groundwater resources are not well known. In 2004–05 the National Water Commission undertook water balance assessments for 51 priority geographic areas across Australia. Of these water management areas six were overused (consumptive use was greater than sustainable yield) and seventeen had a high level of consumptive use as a proportion of inflows (consumptive use greater than 30 per cent of inflows). Two water management areas (Great Artesian Basin and Mereenie Sandstone — Alice Springs) had consumptive use greater than total annual inflow. Total water use in Australia in 2004–05 was nearly 80 BCM, with about 75 per cent of this water returned to the environment following in-stream uses such as hydroelectric power generation. Consumptive use of water in the Australian economy in 2004–05 was 18.8 BCM (6.4 per cent of resources), with the agriculture sector the largest user (65 per cent), followed by household use (11 per cent). Residential water use declined from 243 liter/person/day in 2003 to 191 in 2007.

According to the Prime Minister's office, as the impact of climate change intensifies, Australia faces increasingly acute long-term water shortages with lower rainfall, rivers drying up and dam water levels falling. In most parts of Australia, surface water stored in reservoirs is the main source for municipal water supply, making water supply vulnerable to droughts; only a much smaller share comes from groundwater. Non-conventional water sources, such as seawater desalination, play an increasing role in Australia's water supply, with one desalination plant commissioned to supply Perth and others being built in Sydney, the Gold Coast, Melbourne, Adelaide, and another is planned to be built at Port Augusta.

The use of reclaimed water — the non-potable reuse of treated wastewater for irrigation of green spaces, golf courses, agricultural crops or industrial uses — is common and increasing in Australia. Among the 20 largest water utilities in Australia, the largest volume of recycled water supplied was by SA Water in Adelaide (25,047 ML or 29.6% of sewage collected), while the lowest volume of recycled water was by ACTEW in Canberra (2,104 ML or 7.4% of sewage collected).

Adelaide

The Happy Valley Reservoir stores water for supply to Adelaide.

Adelaide receives its drinking water from five sources:

- the River Torrens, flowing from the Adelaide Hills through the city into the sea, with storage provided in the Warren Reservoir, Millbrook Reservoir, Kangaroo Creek Reservoir and a reservoir in Hope Valley;
- the Onkaparinga River south of Adelaide with storage in the Mount Bold Reservoir, downstream of which water is diverted by the Clarendon Weir via a tunnel to the Happy Valley Reservoir on the Field River;
- The Barossa Reservoir, the South Para Reservoir and the Little Para Reservoir north-east of Adelaide;
- Most years the flow to these reservoirs is supplemented by water pumped from the River Murray through two pipelines, one from Mannum to the reservoirs on the River Torrens and the South Para Reservoir and Warren Reservoir, and the other from Murray Bridge to the reservoirs on the Onkaparinga River;
- The Myponga Reservoir on the Myponga river about 60 km south of Adelaide, supplying about 5 per cent of the city's water supply.

The amount of water required from the River Murray varies from about 40 per cent of Adelaide's water needs in a normal rainfall year to as much as 90 per cent in a dry year. At full capacity the above-mentioned reservoirs hold about 200 million cubic meters of water, or a little less than 1 year's supply for metropolitan Adelaide.

A desalination plant in Port Stanvac has been approved, which will provide up to one-third of Adelaide's water needs when built in 2012. A smaller plant near Port Augusta has also been proposed, which will supply almost all the residential water needs of towns on the Spencer Gulf.

Brisbane and Gold Coast

Water storage, treatment and bulk supply for Brisbane is handled by SEQ Water, which sells on to Brisbane Water for distribution to the Greater Brisbane area. Water for the area is stored in three major dams; Wivenhoe Dam on the Brisbane River, Somerset on the Stanley River and North Pine on the North Pine River. Water is also provided by a number of smaller dams that are connected via the South East Queensland Water Grid. The Wivenhoe Dam is shared with the Gold Coast, which has two more water sources, the Hinze Dam and the smaller Little Nerang Dam, both on the Nerang River. Groundwater from North Stradbroke Island is also transferred to the mainland to supplement the area's water supply. Gold Coast Water has commenced construction of a desalination plant at Tugun which was commissioned in 2009. A Southern Regional Pipeline is also under construction that will share Gold Coast water with the rest of South East Queensland. The construction of Traveston Crossing Dam and an associated long-distance pipeline as well as a pipeline from the existing Boondooma Dam have also been proposed to provide the growing population of Southeast Queensland with water.

The AUS$ 2.5bn Western Corridor Recycled Water Project whose construction began in 2006 includes the construction of three new wastewater treatment plants, 200 km of pipelines and 12 pumping stations. It will provide reclaimed water to industrial users, agricultural users and to supplement drinking water supplies in Wivenhoe Dam.

A severe drought in 2005-2007 triggered major investments, including the Tugun desalination plant and the Western Corridor Recycled Water Project. When rainfall became abundant in 2008-2010 and reservoirs were full, the state government decided in 2010 to put the Tugun plant in stand-by mode, operating at less than 10% of capacity, and to close down a new advanced wastewater treatment plant on Gibson Island in order to save power and chemicals.

Canberra

Canberra draws its water supply from three separate catchment systems: The Cotter River catchment, within the ACT; the Googong system on the Queanbeyan River in New South Wales; and the Murrumbidgee River, at the Cotter Pump Station. All these rivers drain into the Murray River.

Melbourne

The Silvan reservoir supplies water Melbourne.

Some 90% of Melbourne's drinking water comes from uninhabited mountain ash forests high up in the Yarra Ranges east of Melbourne. More than 157,000 hectares has been reserved for the primary purpose of harvesting water. These water supply catchments have been closed to the public for more than 100 years. Melbourne's water supply system is based on the principle that it is better to start with the highest quality source water than having to treat it to reach required standards. According to Melbourne Water, Melbourne is one of only about five cities in the world that has such protected catchments. Water from the forests flows through streams in reservoirs, which provide security of supply for times of drought. One of these reservoirs is formed by the Thomson Dam on the Thomson River located about 130 km east of Melbourne in Gippsland, from where water flows through a 19 km long tunnel through the Great Dividing Range into the Upper Yarra Reservoir and then onto Silvan Reservoir for distribution as drinking water in Melbourne. In recent years, drought has resulted in depletion of much of the water in the reservoir of the Thomson Dam.

In June 2007, the Victorian State Government announced a new plan to provide water security for Victoria's growing population and economy by diversifying and boosting water supplies, networking the State's water resources in a Victorian Water Grid and enabling a rapid and flexible response to changing future water needs. The plan includes A$4.9 billion of projects to secure Melbourne and Victoria's water supplies for the long term, including

- the 150 billion litre per year, A$ 2.2 billion Melbourne desalination plant in Wonthaggi which would be the largest desalination plant in Australia, supplying 30% of Melbourne's water needs, for which a Build-Operate Transfer (BOT) contract was awarded in mid-2009 to a consortium led by the French multinational SUEZ;
- a major irrigation upgrade in the Food Bowl in Northern Victoria to deliver water savings to be shared equally between irrigators, the environment, and Melbourne; and
- a major expansion of the Victorian Water Grid with pipelines to connect Melbourne's water system with the desalination plant and Northern irrigation upgrades.

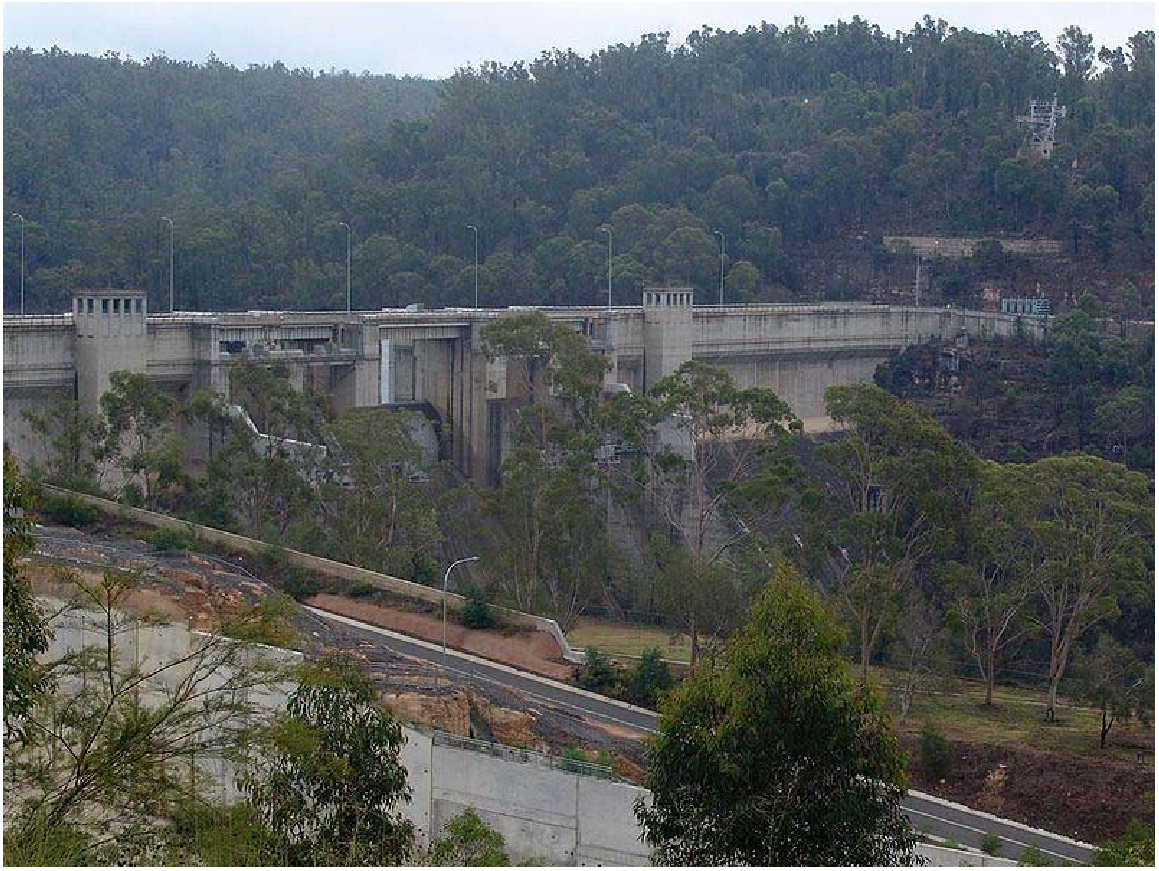
These projects are expected to deliver a 50 per cent boost to Melbourne's water supply within five years and allow water to be moved where it is needed most.

Perth

The New Victoria Dam, shown here at 30.6% of capacity, supplies water to Perth.

Perth receives most of its water from a series of reservoirs. Since 2001, southern Western Australia has suffered severe drought conditions. Average inflows to Perth's metropolitan dams have dropped to less than 90 gigalitres a year compared with 340 gigalitres in 1975. In 2006, Perth became the first Australian city to operate a reverse osmosis seawater desalination plant, the Kwinana Desalination Plant, which as of 2007 supplies 17% of the city's drinking water supply. To mitigate the drought, a second seawater desalination plant is envisaged in Binningup near Bunbury.

Sydney



Warragamba Dam is the main source of water supply for Sydney.

More than four million people in Sydney, the Illawarra, the Blue Mountains and the Southern Highlands rely on the catchments of the Warragamba, Upper Nepean, Blue Mountains, Shoalhaven, and Woronora river systems to supply their drinking water. This is about 60 per cent of the population of New South Wales. These catchments cover an area of almost 16,000 square kilometres. They extend from north of Lithgow in the upper Blue Mountains, to the source of the Shoalhaven River near Cooma in the south — and from Woronora in the east to the source of the Wollondilly River west of Crookwell. The catchments are the source of the raw bulk water stored in reservoirs, which is then supplied to Sydney Water, Shoalhaven City Council and Wingecarribee Shire Council. Given low water levels in reservoirs due to drought Sydney Water announced in 2007 it would build the Kurnell Desalination Plant, powered by wind energy, that would supply up to 15% of the drinking water supply to Sydney, the Illawarra and the Blue Mountains. It is the largest water supply project for Sydney since the Warragamba Dam was opened in 1960.

Map of the catchment areas managed by the Sydney Water Corporation

Responsibility for water supply and sanitation

Policy and regulation

The Constitution of the Commonwealth of Australia states that natural resource policy, including that relating to water, is a responsibility of the States: "The Commonwealth shall not, by any law or regulation of trade or commerce, abridge the right of a State or of the residents therein to the reasonable use of the waters of rivers for conservation or irrigation." (Section 100) However, this legal position has become less clear as a result of decisions by the Australian High Court. The Commonwealth Government has taken a much greater role in the Australian water sector in the early 21st century. The Ministry for Climate Change and Water is in charge of water policies at the federal level.

An example of the expanding role of the Commonwealth in the management of water resources is the federal takeover of the Murray-Darling Basin. In April 2007, amid a major drought, John Howard, then Prime Minister of Australia, announced that the region was facing an "unprecedentedly dangerous" water shortage and that water might have to be reserved for "critical urban" water supplies. The Federal Government proposed a A$10 billion Commonwealth take-over of the Murray-Darling Basin, arguing that effective management could not be undertaken by competing state governments. While the states of New South Wales, Queensland and South Australia as well as the Australian Capital Territory accepted the proposal, the state of Victoria initially refused to co-operate, arguing that its irrigators would be disadvantaged and that it would challenge the takeover in the High Court. Legislation to create the Murray-Darling Basin Commission was passed in both the House of Representatives and the Senate in August 2007 in the form of the Water Act of 2007. In March 2008, Premier John Brumby indicated that the Victorian government would participate in the program, in return for $1 billion to upgrade irrigation and continue water security for farmers.

National Water Initiative. In 1994 the Council of Australian Governments (COAG) agreed on a Water Reform Agenda to work towards reform in the water industry at the national level. In 2004, this was succeeded by the formation of the National Water Commission and the adoption of the National Water Initiative (NWI). The NWI "aims at increasing the productivity and efficiency of Australia 's water use and establishing clear pathways to return all water systems – rivers and groundwater – to environmentally sustainable levels of extraction". The government has also established Drinking Water Guidelines as part of a National Water Quality Management Strategy.

The Government of former Prime Minister Kevin Rudd had announced that it would invest in greater use of recycled water, water desalination and stormwater through a $1 billion urban water infrastructure fund. The Government also announced that it would assist households to install water and energy efficient products, with rebates for rainwater tanks and solar hot water.

State-level regulation. Various state agencies regulate water supply and sanitation in each state, with different arrangements found throughout Australia. State agencies with responsibtilities in the sector include Water Commissions, Environmental Protection Agencies and Competition Authorities. They operate under different Departments (Ministries) such as Natural Resources and Water Departments and Trade Departments. For example, in Queensland under the Water Act 2000 water policy is the responsibility of the Queensland Water Commission, which is under the Department of Natural Resources, Mines and Energy and the Minister of Trade.

Service provision

At the local level, commercialisation and corporatisation of many Australian urban water businesses has led to management responsibilities being vested in commercial utilities, in contrast to earlier arrangements where services were provided directly by an arm of government. The role of the utility's board members is to provide commercial skill and focus, as well as to buffer the organisation from arbitrary political interference. The private sector is involved primarily through Build-Operate-Transfer (BOT) contracts for major treatment plants, including desalination plants.

The institutional arrangements for service provision vary among States and Territories. In parts of Queensland and in Tasmania, for example, local government is responsible for the provision of water services. In other states and territories, different arrangements have evolved. In New South Wales, Victoria and Southeast Queensland, there are separate municipal retail service providers and state bulk service providers that cover large parts of each state. In other states, such as South Australia, Western Australia and the Northern Territories integrated state-level water utilities are in charge of both bulk water supply and retail distribution.

South East Queensland has reformed its water sector in 2008. Under the new structure four state-owned authorities (Seqwater, WaterSecure, LinkWater and the SEQ Water Grid Manager) are in charge of bulk water supply:

- Seqwater supplies water from conventional sources such as dams, weirs and treatment plants.
- WaterSecure supplies water from non-conventional sources such as the Gold Coast Desalination Plant and the Western Corridor Recycled Water Project.
- LinkWater owns the transport infrastructure, and
- the SEQ Water Grid Manager operates the transport infrastructure.

There are three retail utilities , each owned by a group of local governments:

- Queensland Urban Utilities, which distributes water in five council regions (Brisbane, Ipswich, Lockyer Valley, Scenic Rim and Somerset).
- Unity Water serving the Sunshine Coast and Moreton Bay.
- Allconnex serving the Gold Coast, Logan and Redlands.

In **Sydney**, New South Wales, a catchment authority (Sydney Catchment Authority) has been established to supply water in bulk to the retail water and wastewater utility Sydney

Water, a statutory State owned corporation, wholly owned by the New South Wales Government.

In **Melbourne**, Victoria, three government-owned companies (City West Water Ltd., South East Water Ltd., and Yarra Valley Water Ltd.) are the retailers and the wholesaler is a government-owned corporation, Melbourne Water. The wholesaler also controls the catchment for most of its supply.

In **Adelaide**, South Australia (SA), water and sanitation services are provided by SA Water. In 1996 the SA Government awarded United Water a 15-year contract to manage and operate the metropolitan Adelaide water and wastewater systems on behalf of SA Water. SA Water retains ownership of all infrastructure, sets service standards, and implements the government's pricing policy. SA Water also maintains control of all asset investment decisions, billing and revenue collection.

In **Western Australia** the Water Corporation, a government-owned corporation, provides urban water services.

Canning Dam, one of Perth's major dams, at 34.4% of capacity

In **Canberra**, and the Australian Capital Territory generally, a public-private multi-utility partnership (ACTEW) provides services. A government-owned multi-utility, the Power and Water Corporation, provides services to the larger and less remote communities in the Northern Territory, including Alice Springs and Darwin.

Most organisations providing urban water services in Australia have experienced some degree of organisational reform in the 1990s, which has clarified accountabilities by separating policy, regulatory and commercial (operational) functions. The accepted wisdom is that this separation provides urban water businesses with clear commercial goals of customer service, while safeguarding public health and achieving environmental compliance in a sound business operation, free of other conflicting objectives.

For a brief profile of each of the 33 of the largest water companies in Australia see: WSAA Members

Community consultation

The Water Reform Agenda, agreed in 1994, adopted the principle of public consultation by government agencies and service providers when change and/or new initiatives were being contemplated involving water resources. Subsequently the Australian Drinking Water Guidelines emphasised the right of communities to participate in the development of policies relating to their water supply. The Guidelines also provide advice on how customers should be involved in considering options for effective and acceptable monitoring and reporting on performance of their water supply, and on the frequency of such reporting. The Water Reform Agenda also mentions the need for the public to be informed of the cause and effect relationship between infrastructure performance, standards of service and related costs, with a view to promoting levels of service that represent the best value for money to the community.

Water tariffs

In Australia, most water businesses have changed from a charging system based largely on property value to one based on actual water consumed (a user-pays policy), in line with the Water Reform Agenda. Hunter Water in the Newcastle area of New South Wales pioneered this policy in Australia in the 1980s and reported a fall in household water consumption of 30 per cent over previous trends. This experience encouraged other water authorities to adopt the policy with a view to managing demand for water.

However, low-income households in Australia spend in proportional terms much more on utility services than high-income households. The implication is that increases in the price of utility services, if not accompanied by other compensation, will have a regressive and disproportionately negative impact on low-income households. It is generally expected that with the advent of expensive desalination water tariffs will have to increase in Australia.

Across Australia, the average typical annual residential bill for water supply and sewerage services was A$713 in 2007 (US$557 using the January 2007 exchange rate of 1.28). In South East Queensland the average annual water bill of only A$465 in 2005, but that it could increase to A$1,346 by 2017 due to increasing bulk water costs.

Investment

In the capital cities alone, over A$2 billion of expenditure was undertaken in 2007/2008 (US$1.74 billion using the January 2008 exchange rate of 1.15). This expenditure is unprecedented in the industry. Urban water utilities invested A$835 million in replacing old and under-performing assets and A$535 million in maintaining asset reliability.

Demand management and water conservation

Demand management measures to encourage consumers to use less water include advertising, education, pricing and appliance redesign. Furthermore, the use of alternatives to conventional water supply such as effluent reuse, rainwater harvesting and greywater use are also being encouraged. Some water businesses in Australia have opted for restrictions on water use to conserve water supplies and minimise capital expenditure. A series of restriction levels, depending on remaining storage capacity in reservoirs, can curb the maximum daily consumption during drought periods. For example, several water authorities in very hot and dry regions of Australia have adopted a cooperative policy with consumers to restrict peak water usage on very hot days or to restrict garden watering to periods in which it is more effective.