Grey Water Treatment and Reuse in Addis Ababa: The Case of Balderas Condominium

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Addis Ababa university

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Addis Ababa University

School of Graduate Studies

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Advisor

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A Thesis submitted to the School of Graduate Studies of Addis Ababa University in partial fulfillment of the requirements for the Degree of Master of Science in Water Supply and Environmental Engineering

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Plagiarism Declaration

This thesis is my original work, was not copied, has not been presented for a degree in any other University, and all the sources of the material used have been duly acknowledged.

Kewser Abdulfetah

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Date……………………………….

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ABSTRACT

Grey water treatment and reuse in Addis Ababa, the case of Balderas condominium

A study was conducted in Addis Ababa, Balderas area. Grey water was collected from residences of Balderas condominium. For this study grey water was classified into four parts based on their sources (typical laundry product, extra ordinary laundry product, bath/shower and hand basin product) to assess their quality. In extra ordinary laundry product of grey water used normal soup and detergent type but in extra- laundry product special detergent such as acidic detergent, whitener and dyes were used. This study identified that the quality of grey water was different in the four production unit. The first two were the most pollutant generators in grey water and hand basin Grey water contain low contaminant compared to the remaining three. However, the concentration of total coliform in hand basin Grey water was higher. In general the qualities of grey water were above recommended limits for reclaimed water quality. Therefore, this indicates that the grey water in Balderas condominium area require further treatment before any use different from drinking. Following this results and professionals judgment, more detailed study of treatment technology was carried out for the determination of optimal treatment technology for grey water by using AHP and GRA. To compute the weight of criteria (economical, environmental, social and administrative criteria) and indices (capital cost, land cost, operation and maintenance cost, social acceptability, job creation, performance, sludge quality, quantity & disposal system, Adaptability to waste water characteristics, Biomass problem, maturity of plant, social acceptability, job creation and professional skill required for operation and maintenance) questioner filled by professionals was used. GRA was used to settle on the relative distance between indices. Finally the overall result indicated that the MBR was found to be the optimal technology in terms of those calculated criteria and indices.

Key words: Grey water, sources, treatment plant, GRA, Analytical hierarchy process

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ACRONYMS

AAWSA	Addis Ababa water and sewage authority
AHP	Analytical hierarchy method
BOD	Biological oxygen demand
COD	Chemical oxygen demand
CI	Consistency indices
CR	Consistency ratio
CWL	The constructed wetlands
DO	Dissolved oxygen
EPA	Environmental protection agency
USEPA	United State Environmental Protection agency
FAO	Food and Agriculture Organization
FFS	Fixed-film systems
GP	Gravel pack
GRA	Gray relational analysis
GW	Grey water
MBBR	Moving bed bioreactor
MBR	Membrane bioreactor
MCDM	Multi criteria decision making
MDGs	Millennium Development Goals
MoWR	Minster of water resource

NRW	Non revenue water
RBC	Rotary biological contactor
RI	Random indices
SBR	Sequential batch reactor
SS	Suspended solid
SSWM	Sustainable sanitation waste management
TOC	Total organic carbon
UASB	Up flow anaerobic sludge blanket
WHO	World health organization
D.S	Disposal system
W.W.C	Waste water characteristics

CHAPTER ONE

1. INTRODUCTION

1.1 General back ground

As stresses on freshwater resources grow throughout the world and new sources of supply become progressively more scarce, expensive, or politically controversial, different researchers and efforts are underway to identify new ways of meeting water needs. Special note are efforts to reduce water demand by increasing the efficiency of water use including reduction of leakage & demand side management and to expand the usefulness of alternative sources of water previously considered unusable. Among these potential new sources of supply is "grey water" (Lucy Allen *et al*., 2010).

Globally known that grey water (also spelled Grey water, Grey water, or Grey water) is waste water that is derived from clothes washing machines, sinks, showers, bathtubs and dishwashers. It can be light grey (Water from all fixtures that have limited food particles entering, like bathroom sinks and showers, clothes washers) or dark grey(water from kitchen sinks and dishwashers) (Light House Sustainable Building Centre 2007). This wastewater is distinguished from more heavily contaminated "black water" from toilets. In many utility systems around the world, grey water is combined with black water in a single domestic wastewater stream (Lucy Allen *et al*., 2010). However, grey water can be of far higher quality than black water because of its low level of contamination and higher potential for reuse.

Grey water, if captured, diverted, stored or treated appropriately, can be reused in gardens and for other domestic chores such as flushing toilets and washing clothes. The most commonly described application for grey water reuse is toilet/urinal flushing which can reduce water demand within dwelling by up to 30% (Karpiscak *et al*., 1990). However, grey water has been considered for many other applications including irrigation of lawns at cemeteries, golf courses and college campuses (Okun, 1997), vehicle washing, fire protection, boiler feed water, concrete production (Santala *et al*., 1998) and preservation of wetlands (Otterpohl *et al*., 1999). The reuse of Grey water for toilet flushing and garden irrigation has an estimated potential to reduce domestic water consumption by up to 50% (Maimon *et al*., 2010)·

Addis Ababa Water and Sewage Authority (AAWSA) have around 394,636 customers and produce 374000m^3/d of potable water. From this water 228,140m^3 are reaching to the customer and around 109,507are remove as Grey water after reach to the customers. If the people have habit and option of treating and recycling of this water it is possible to save considerable amount of water and other resource. The main obstacle for wider and faster distribution of grey water treatment and reuse systems at community level is the lack of knowledge and experience in that field, especially in developing countries. Scientific knowledge is sparse regarding grey water characteristics and adequate grey water treatment systems allowing a proper and safe disposal or reuse of grey water. However, this has to be accomplished without compromising community health, causing unacceptable environmental impact, or downgrading the amenity of our residential areas.

Grey water must be reused in a beneficial manner for landscaping rather than simply disposal at a depth, which would not benefit landscaping and pollute ground water. The application of grey water systems is therefore of particular importance in assisting developing countries in addressing Goal 6: Ensure clean water and sanitation of the Sustainable Development Goals (SDGs). Specifically, grey water recycle augments existing water use efficiency. The equitable use of this resource can aid in halving the world's population without access to safe water and sanitation and therefore in achieving Goal 6 of the SDGs.

When grey water is reused either onsite or nearby, it has the potential to reduce the demand for new water supply, reduce the energy and meet a wide range of social and economic needs. The existing practice of using rigorously treated high-quality drinking water for toilet flushing is certainly environmentally unsustainable. Although the use of treated Grey water can reduce the pressure from the main's supply and offer considerable environmental benefits (Memon. *et a*., 2005)

In Ethiopia, the government invest in millions of dollar to satisfy the water need of the people and this water are used for domestic and industrial purpose including for drinking, cooking, toilet flash, gardening, washing of different equipment and clothes, fire fitting and for other purpose.

If the people use Grey water for external purpose, such as for toilet flash, gardening, washing of different equipment and clothes, fire fitting and other external uses we can increase our economy and solve power fluctuation problem.

1.2 Statement of the problem

As fresh water supplies dwindle and become more expensive in many areas of developing countries, using water once and then ‘throwing it away 'is becoming too costly, both financially and resource wise. Demands on water resources for household, commercial, industrial, and agricultural purposes are increasing greatly and worldwide water usage has been growing at more than the population growth. In most countries human populations are growing while water availability is not.

On the meeting held in Addis Ababa in 2007 E.C. with ministry of urban development and growth, the minster pointed out three hot issues in the current urban development and growth. One of them was lack of efficient use of water in the city of Addis Ababa. His Excellency mentioned about how much finance is invested to supply the city with clean water, yet 39.6% of clean water is lost before it reaches to each meter and 1/3 of the domestic water is used for toilet flush. From the above discussion it is understood that the country is experiencing unfair use of clean water. Furthermore, the practice of throwing sweet water in to toile flush in a country like Ethiopia where clean water coverage is about 30% needs to be examined and came up with better alternative practice which will maximize efficient use of available water resource.

Globally reuse of wastewater is considered to be an alternative source of clean water. It is also believed that it supplements the existing water sources and helps to prevent excessive diversion of water from other alternative, such as surface an sub surface water sources. in addition it also reduce the amount of wastewater discharge into receiving environment. Thus reusing greywater could potentially solve the current problem on un efficient use of clean water resource.

In our context the main obstacle to reuse grey water is lack of well developed treatment technologies that suits the existing graywater quality. furthermore, lack of well developed optimal treatment selection method and fund (AAWSA & MoWR, 2009). Now a days to select an optimal treatment technology the authorized institutions use simple cost benefit analysis. one of the drawback of this method is its bias arising from subjective judgments and random effects could occur. To avoid this problem. another alternative decision making method should be considered which would be more accurate and maximize efficiency.

1.3 Scope

This research was conducted by considering only light Grey water (not include water from kitchen sink and dishwashers). Dark Grey water was not considered because of lack of time and large space and treatment cost it requires. The study addressed the reuse of Grey water for different purpose and provides appropriate treatment technology. Most of the data that are important for this study were collected from different offices and institutes found in Addis Ababa. Individuals of waste water professionals were also contacted.

1.4 Limitation

The samples were collected from different household in the study area at different time interval and P^H, temperature, suspended solid, ammonia, nitrate, nitrite, phosphate, total coliforms, turbidity, BOD and COD are the only parameters that were considered. The optimal treatment was selected only by considering four criteria and eleven sub-criteria. Only domestic Grey water was considered and industrial and other Grey water were not included. .

1.5 Objective

1.5.1General objectives

The general objective of the research was to select appropriate treatment scheme and treatment selection method that enables households to reuse grey water in order to use the available alternative water resource in sustainable manner.

1.5.2 Specific objective

- To assess the quality of Grey water
- To identify environmentally friendly, optimal and sustainable Grey water treatment technology
- To assess and then recommend decision making method for grey water treatment technology selection.
- To evaluate limited number of treatment alternative using professional idea
- To came up with better alternative for grey water collection and sanitary system
- To document optimal Grey water treatment methodology based on professional opinion

1.6 Research Question

The general research questions are

- Which treatment technologies are suitable to treat Grey water?
- What are the driving forces to reuse Grey water?
- What decision making method are suitable to select optimal treatment technology?
- What qualities have the Grey water in the study area?
- How to treat and recycle Grey water?
- For which purpose the treated Grey water could be use?

1.7 Outline of The Thesis

This thesis is organized in six chapters as depicted below:

Chapter One: - General Introduction and outline

Chapter Two: - Reviews the literature of chemicals, pathogens and other constituent present in Grey water, characteristics of Grey water, Grey water treatment technologies regarding operation, affordability and efficiency.

Chapter Three: - Material and Methods used to achieve the objective of the research.

Chapter Four: - Integrated AHP and GRA procedure

Chapter Five: - Result and Discussion

Chapter Six: - Conclusion and Recommendation

CHAPTER TWO

2. LITERATURE REVIEW

2.1. General back ground

Many places, Grey water is being discharged without treatment directly into surface waters or used as irrigation water (Dallas 2005). These practices not only worsen water shortages when water is discharged unused, but lead to a significant deterioration of local soil and water quality when the water is reused without prior treatment (Gross *et al.,* 2007, Maimon et al., 2010, Travis et al., 2010). In developing nations, 75% of industrial wastewater and 90-95% of raw sewage wastewater is discharged into surface water bodies without any treatment (United Nations, 2007). In most developing nations people withdraw drinking water from the same water body they use for excreta disposal (United Nations, 2008). According to AAWSA, In Addis the Grey water is not treated for the purpose of reuse simply the Grey water is mixed with black water and discharged to the drainage system or nearby river also at the time of rain the people simply release the waste water including Grey water in the road and this may cause the degradation of the receiving water bodies, such as lakes, rivers, streams, etc. and this depend on volume of the discharge, the chemical and microbiological concentration of the effluents. It also depends on type of the discharge for example whether it is amount of suspended solids or organic matter or hazardous pollutants like heavy metals and organo-chlorines, and the characteristics of the receiving waters (Owili, 2003). Eutrophication of water sources may also create environmental conditions that favors the growth of toxinproducing cyanobacteria. Chronic exposure to such toxins produced by these organisms can cause gastroenteritis, liver damage, nervous system impairment, skin irritation and liver cancer in animals (EPA, 2000; Eynard *et al.,* 2000; WHO, 2006). In extension, recreational water users and anyone else coming into contact with the infected water is at risk (Resource Quality Services, 2004). Much of the water used by homes, industries, and businesses must be treated before it is released back to the environment.

2.2 Composition of Grey water

Composition of Grey water is varies household to household depending on the life style of each households and the chemical or detergent that use for washing clothes, shower, hair, hand and toothpaste. In general, it contains often high concentrations of easily degradable organic material, i.e. fat, oil and other organic substances, residues from soap, detergents, cleaning agents, etc. and generally low concentrations of pathogens (Ridderstolpe 2004) and also release of 9-14%, 20-32%, 18-22% and 29-62 % of N, P, K and organic matter respectively (Kujawa-Roeleveld and Zeeman, 2006) and in some cases the concentrations of phosphorus (P) is high this can lead the problems of algae growth in receiving water. Average phosphorous concentrations are typically found within a range of 4–14 mg/l in regions where non-phosphorous detergents are used (Eriksson et al., 2002) and they can be as high as 45–280 mg/l in households where phosphorous detergents are utilized (Friedler, 2004).

The pH value of Grey water, which strongly depends on the pH value of the water supply, it should show the range between 6.5-8.4 for easier treatment and to avoid negative impacts on soil and plants when reused (FAO, 1985; USEPA, 2004). When the house hold use sodium hydroxide-based soaps and bleach used for the purpose of laundry the PH rang of Grey water is increased within the range 9.3–10 (Christova Boal et al., 1995) . The BOD and COD concentrations of Grey water strongly depend on the amount of water and products used in the household especially detergents, soaps, oils and fats and COD values range from 100 to 645 mg.L-1 in light Grey water (Antoine and Stefan, 2006). The BOD loads observed in Grey water in different low and middle income countries amount to 20–50 g/p/d (Friedler, 2004; Mara,2003).

Grey water from bathroom are contaminated with large quantities of oils, body fats and chemicals originating from soap, shampoo, hair dyes, toothpaste, nutrients and from other cleaning products (Loh and coghlan 2003; Poyyamoli et al.2013). It also contains traces of fecal contamination (NSW 2008) and Grey water generated from washing requirements is generally more contaminated than bathroom Grey water (Jeppesen and Solley, 1994; christova-Boal *et al*,.1995) and may contain oils, trace elements and chemicals from detergents, soaps and nutrients and can also contain fecal contamination in traces. Kitchen wastewater is considered dark Grey water and is often excluded from Grey water reuse systems because it can contain higher loads of chemical oxygen demand (COD) and nitrogen as well as greater numbers of pathogens (Li *et al.* 2009). According to Friedler (2004), the Grey water from kitchen and dishwasher should be excluded as they contribute nearly 50 percent of its COD requirement.

The nutrient content in Grey water is generally low compared to normal mixed wastewater. But the quality and microbial state can change substantially within the course of a couple days of storage at 19 to 26 ºC (Dixon et al., 1999) and biological degradation produces malodorous compounds, causing an aesthetic problem (Christova-Boal et al., 1995; Dixon et al., 1999), pathogen growth (Christova-Boal et al., 1995; Rose et al., 1991; Dixon et al., 1999) and mosquito breeding (Christova-Boal et al., 1995), which are a health threat.

Table 1. Quality of Grey water based on Jeppersen and Solley 1994

Parameters	Unit	Grey water	
		Range	Mean
Suspended solid	mg/l	45 - 330	115
Turbidity	NTU	22 -> 200	100
BOD5	mg/l	90 - 290	160
Nitrite	mg/l	<0.1 - 0.8	0.3
Ammonia	mg/l	<1 - 25.4	5.3
Total kjeldahl Nitrogen	mg/l	2.1 - 31.5	12
Total phosphorous	mg/l	0.6 - 27.3	8
Sulphate	mg/l	7.9 - 110	35
P^H		6.6 - 8.7	7.5
Conductivity	mS/cm	325 - 1140	600
Hardness (Ca & Mg)	mg/l	15 - 55	45
Sodium	mg/l	29 - 230	70

2.3 Quantity of grey water

Water use has a tendency to increase with increasing income and decreasing household occupancy (Laine, 2001). This suggests that the amount of Grey water produced is dependent on individual homeowners and how they use water. Grey water is a large source of water with a low organic content and it represents up to 70% of the total consumed water, this including dark Grey water or kitchen waste water but contains only 30% of the organic fraction and from 9 to 20% of the nutrients (Kujawa-Roeleveld and Zeeman, 2006). Supplementary according to WHO 2006 and Friedler 2004, over 2/3 (60-70%) of household wastewater generated is Grey water. From this Grey water bathroom sources accounts for about 50–60 percent of total Grey water (Loh and

Coghlan 2003; Poyyamoli *et al*., 2013), the Grey water from Laundry washing requirements account about 25–35 percent of the total Grey water (Poyyamoli et al.2013 and Rafat Khalaphallah 2012) and hand wash basin accounts for 5-10% of the average household water use (Golda *et al*., 2013). golda Grey water amount for each fixtures was shown in figure 1below .

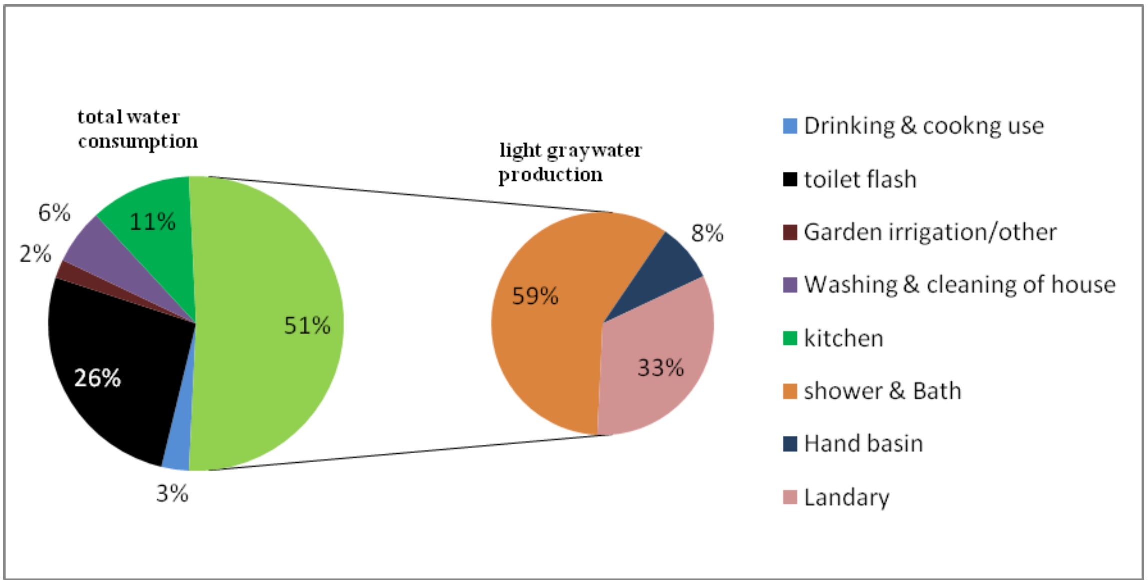

Figure 1 Quantity of Grey water (source: - Golda *et al*., 2013)

2.4 Treatments Technology of Grey water

Treatment is a prerequisite for reuse of used water; treatment requirements vary based on biological and chemical characteristics and intended use of treated Grey water. The aim of treatment is to overcome on all problems, which are caused by pathogenic microorganisms such as *P.aeruginosa, E.coli* and coliphage, chemical compounds such as organic matter (soluble and solid), nitrogen, phosphorus, to meet reuse standards.

There is no universally accepted design for Grey water treatment and it is largely designed in accordance with Grey water source, quantity, quality, site specifications, reuse options and patterns (Finley *et al*., 2009) One thing that is well established is the fact that Grey water intended for treatment and reuse should not be stored for longer periods of time as this encourages the growth of microbial population present in it (Winward *et al*.,2008)**.** But a wide variety of technologies for Grey water treatment have been evaluated including physical treatment (such as sedimentation, sand filtration, and membrane filtration), chemical treatment (including coagulation and disinfection), and biological treatment systems (including rotating biological contactors, sequencing batch reactors, and constructed wetlands) (Li *et al.* ,2009) .

Grey water treatment systems, range from simple low-cost devices that divert Grey water to direct reuse, such as in toilets or outdoor landscaping, to complex treatment processes incorporating sedimentation tanks, bioreactors, filters, pumps, and disinfection and most grey-water treatment plants include a one or two-step septic-tank for pre-treatment (Otterpohl *et al*., 2003). But treatment technologies that are commonly used in municipal wastewater treatment on Grey water is sand-bed filtration, membrane bioreactors (MBR), and biological contactors (Friedler *et al*. 2006). The grey-water treatment needs both physical and biological processes for removal of particles, dissolved organic-matter and pathogens (Jefferson *et al*., 1999). Many treatment systems have been proposed to condition Grey water. For instance, high-rate aerobic systems, such as the rotating biological contactor (Nolde,1999), fluidized bed (Nolde, 1999), aerobic filter (Jefferson *et al*., 2000), membrane bioreactor (Jefferson *et al*., 2000), or by application of low-rate systems, like slow sand filter (Jefferson *et al*., 1999), vertical flow wetlands (Otterpohl *et al*., 2003).

All the treatment wetlands and biological systems found in the research effectively treated Grey water to a high quality (< 20 mg/l BOD, <20 mg/l TSS, and <10 cfu/100ml *E.coli*). The types of biological treatment include sequencing batch reactors, membrane bioreactors and biological aerated filters. While all these particular technologies effectively treated Grey water, systems that incorporated a form of physical and biological treatment resulted in the highest water quality (Robert, 2012)· An interesting note about biological treatment of Grey water as analyzed by Jefferson et al. (2001) is the effectiveness of biological treatment. When tested with both Grey water and blackwater, it was found that membrane bioreactor were able to treat the blackwater to just as high of quality as the Grey water. Nolde (1999), show that the effectiveness of RBCs to treatment Grey water with high performance, low energy consumption, simple to maintain and operate, low energy consumption, ability to withstand shock or toxic load, freedom from odors and good sludge settling properties also reducing the inlet BOD7 from 250 mgL^{-1} down to below 5 mgl^{-1}. Friedler (2006) has shown a pilot RBC to yield good quality effluent with a removal of 98% and 95% of turbidity and BOD5, respectively. The removal rates for BOD 5 were 84 .5%, COD 71%, TOC 71%, SS 75%, total nitrogen 40% and ammonia 25% (Sack and Phillips,1973) good sludge settling properties. it requires less maintenance and operational skill.

The constructed wetlands reported in the literature showed good ability to treat Grey water. The process takes place without input of energy in addition, there is no production of excess sludge, because there is a balance of biomass growth and decomposition. To compensate the low energy demand a higher footprint is needed, but CWL have proven to be a good alternative for small and medium sized wastewater treatment plants (Kadlec, 2009). Marc Pidou1 2006 described that CWL have poor removal of micro-organisms.

SBR application has been proven successful in the treatment of both domestic and industrial wastewaters. (Brenner, 2000) Also proven to be a viable alternative to continuous-flow systems in carbon and nutrient, COD and phosphorous removal also achieve nitrification and de nitrification (Artan *et al*., 2001 and Kargi and Uygur, 2003). In areas where there is a limited amount of space, treatment takes place in a single basin instead of multiple basins, allowing for a smaller footprint and flexible to operate an control but Higher level of maintenance (compared to conventional systems) associated with more sophisticated controls, automated switches, and automated valves (EPA 1999).

Fixed-film systems (FFS) is simple, reliable, biological process, suitable in areas where large tracts of land are not available for land intensive treatment systems, Effective in treating high concentrations of organics depending on the type of medium used(rock, plastic, wood, or other natural or synthetic solid material), Appropriate for small- to medium-sized communities, Rapidly reduce soluble BOD_5 wastewater, low power requirements and moderate level of skill and technical expertise needed to manage and operate the system(EPA, 2000) .

The effluent from Aerated lagoon systems contains high-nutrient and low pathogen and during the warm season anaerobic decomposition can generate odors also Sludge accumulation rates will be higher in cold climates because low temperature inhibits anaerobic reactions and requires energy input. Therefore wastewater lagoons without mechanical aeration should only be built as temporary plants or in great distance from housing areas and required large area but have low maintenance and reliable treatment performance even at shock (peak) loads. The land area required for intermittent sand filters may be a limiting factor. Regular (but minimal) maintenance is required. Odor problems could result from open filter configurations and may require buffer zones from inhabited areas. If appropriate filter media are not available locally, costs could be higher. Clogging of the filter media is possible and produce a high quality effluent (EPA, 1999). Also the incidents of clogging are relatively high and have low quality effluent and required less energy. This type of treatment technology have a problem of odor, vector, Snail and requires regular operator attention(Metcalf & eddy,2003).

Up flow anaerobic sludge blanket (UASB) have high removal of organics and solids, 60 to 90 % BOD; 60 to 80 % COD and 60 to 85 % TSS also low pathogen reduction minimal removal of nutrient (N and P). the main weakness is Requires skilled staff, electricity and is sensitive to variable flows (Swiss Federal Institute of Aquatic Science and Technology). Low odor emissions in case of optimum operation low sludge production, high sludge quality (gate Information Service (gtz) 2001) . The significantly lower level of technology required by the UASB process in comparison with conventional advanced aerobic processes means that they are also cheaper in construction and maintenance. Capital costs for construction can be estimated as low to medium and comparable to baffled reactors (SANIMAS, 2005). Operation costs are low, as usually no costs arise other than the sludging costs and the operation of feeding pump (SANIMAS, 2005). But in the case of oxidation ditches requires a larger land area than other activated sludge treatment options. This can prove costly, limiting the feasibility of oxidation ditches in urban, suburban, or other areas where land acquisition costs are relatively high. Oxidation ditches offer significantly lower operation and maintenance costs than other secondary treatment processes. Compared to other treatment technologies, energy requirements are low, operator attention is minimal, and chemical addition is not usually required. (Ellington, 1999; EPA 2000).

The treatment performance of the MBR is better than in conventional activated sludge process. A high conversion of ammonium to nitrate (>95%) and constant COD removal efficiency (80-98%) was achieved, regardless of the influent fluctuations (Sebastián *et al*.,2011). The advantages of MBR systems over conventional biological systems include better effluent quality, smaller space requirements, and ease of automation. Specifically, MBRs operate at higher volumetric loading rates which result in lower hydraulic retention times (EPA, 2007). In certain situations, however, including retrofits, MBR systems can have lower or competitive capital costs compared with alternatives because MBRs have lower land requirements and use smaller tanks, which can reduce the costs for concrete (EPA 2007, Fleischer et al., 2005). Also Fleischer et al. (2005) compared operating costs of MBR and they obtain the costs of MBR is same order of magnitude as those of alter-native processes, and they compared favorably to those of processes that are chemical-intensive, such as lime treatment and have higher treatment efficiency. The production of sludge, the disposal of which is often difficult, is decreased by a factor of 2 to 3 resulting in a reduction of the overall operating costs.

2.5. Application of treated Grey water

Treated Grey water is recycling for indoor use such as flushing toilets, washing clothes and/or bathing (Christova-Boal *et al.,* 1996; Nolde, 1999;). The second for outdoor use such as irrigating domestic gardens, lawns on college campuses, athletic fields, cemeteries, parks and golf courses, washing vehicles and windows, extinguishing fires, feeding boilers, developing and preserving wetlands and recharging ground water (Christova-Boal *et al*.,1996;Nolde, 1999; Otterpohl, 1999; Okun, 2000; Eriksson *et al*., 2002).

Figure 2 Different application of grey water

The water quality requirements for each application are geo-specific but normally contain criteria based on organic, solids and microbiological content of the water. At its most restrictive the criteria require a BOD_5 of less than 10 mg.L–1, a turbidity below 2 NTU and a non detectable level of either total or faecal coliforms (Jefferson, 2004) . However, standards in other countries are slightly less restrictive and permit higher concentrations of the different parameters or do not include them at all.

2.6 Grey water storage

Storage of Grey water prior to reuse is discouraged because it can affect the pathogen load of both raw and treated Grey water. Dixon et al. (2000) tested a model for predicting quality changes in stored Grey water, based on observed processes of settlement of suspended solids, aerobic microbial growth, anaerobic release of soluble COD from settled organic matter, and atmospheric re-aeration. The study suggests that storage of Grey water for 24h could potentially improve water quality, but storage for more than 48h could seriously deplete dissolved oxygen (DO) levels and lead to what they call "aesthetic problems", including anaerobic processes and associated smells. Rose *et al*. (1991) found a 1-2 log increase in total and fecal coliform counts over the first 48h of Grey water storage.

2.7 Grey water Recycling

To recycle Grey water safely, users must understand the nature of the grey water itself as well as the natural cycles and processes involved in the purification of it. Each set of circumstances requires its own unique recycling system for optimum results. Possible applications identified for the reuse of Grey water at the household level include most commonly toilet flushing, cars washing, and lawn and/or garden irrigation. These reuse applications alone have the potential to significantly reduce domestic water consumption. Potential impacts of these most common forms of Grey water reuse have been outlined by (Christova-Boal *et al.,* 1995). With regard to reuse for toilet flush water, possible hazards include physical clogging of toilet inlet pipes and anaerobic decomposition of insufficiently treated water in the toilet tank. (Lazarova, *et al.,* 2003) nevertheless emphasize the appropriateness of toilet-flushing as an end-use for recycled Grey water in a review that outlines successful examples of water reuse for toilet flushing in large developments around the world.

Table 2 Critical review

Auteur	Title	Methodology
Guangming Zenga, Ru Jianga, Guohe Huanga, Min Xua, Jianbing Lia,	Optimization of wastewater treatment alternative selection by hierarchy grey relational analysis	Hierarchy grey relational analysis
Rafat Khalaphallah	Grey water treatment for reuse by slow sand filtration :study of pathogenic microorganisms and phage survival	Experimental method carried out at laboratory scale process using a slow sand filter (SSF)
Marc Pidou	Hybrid membrane processes for water reuse	Experimental method, laboratory is carried to assess the effluent and influent quality of waste water by using membrane technology
Kewser Abdulfetah	Grey water treatment and reuse in Addis Ababa, the case of Balderas condominium	Experimental method related with AHM and GRA

CHAPTER THREE

3. MATERIAL AND METHODS

3.1 Study area

3.1.1. Study area selection criteria

The study area was selected by the following selection criteria

- Problem :- High use of clean water for car washing and gardening beside toilet flush
- Essay of implement:- Willingness of the community and well organized structure of neighbor hood
- Opportunity/potential:- high amount of greywater production
- Location :- Located around the inner city where potential area for improving quality of life of the city

3.1.2 The selected site

Based on the above criteria the study area was chosen to be a condominium site. Among all the condominium areas that are found in Addis Ababa Balderas area is chosen for its location, opportunity and ease of implementation. Balderas condominium is found in the inner part of Addis Ababa, Yeka Sub-city (Figure 1) which is situated at 9.026 Latitude and 38.78302 Longitude. According to AAWSA (2013), The area is well developed and different kind socio economic activates are performed due to this there are a lot of liquid and solid wastes are generated and the liquid wastes are simple release in to the surrounding green area and to the toilet. Also in the area a huge production of waste water due to the presence of water though out the year and they use potable water for toilet flash for gardening, car washing and for different non potable uses.

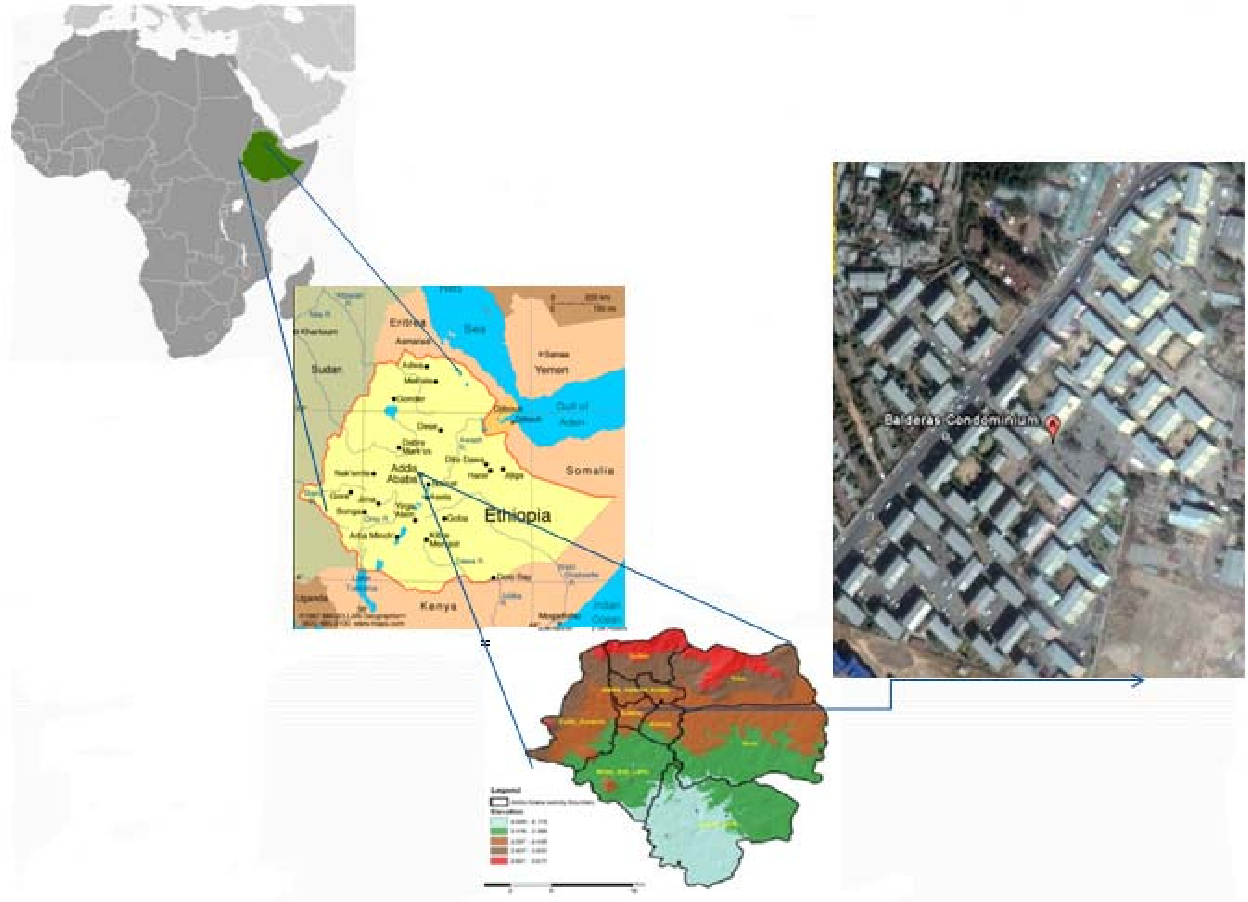

Figure 3 Study area

3.2 Study Design

The study followed both qualitative and quantitative research approaches and also analytical hierarchy process (AHP) related with Gray Analytical Hierarchy method was used as the tool of the study which was supported by laboratory analysis to assess the quality of Grey water. Semi structured questionnaire was used to capture information from professionals in the subject area and the community of Balderas which the data was analyzed using MATLAB and Microsoft excel software.

3.3 Data Collection

3.3.1 Primary data

Primary data was collected from different households and AAWSA & Addis Ababa environmental protection agency and different experts. Some sources of primary data collection mechanisms are discussed below.

3.3.1.1. Questionnaire

Semi structured questionnaire was used to collect information about waste water treatment technology performance parameters within a specific selection criteria and get information about the study area. Two type of questionnaire was used. The first questionnaire was fill by the community live in the study area to get the willingness of the community to reuse the waste water. The second questionnaire (AHP questionnaire) was filled by professionals to put the weight of criteria and indexes. For AHP questionnaire, According to Junn-Yuan Teng (2005) point out that the participant must be experts also the population of the questionnaire is appropriate in five to fifteen people .

The AHP questionnaire was prepared for pair-wise comparisons and filled by relevant experts. In this study 300 residences living in Balderas condominium and eight experts having good knowledge of waste water treatment technologies and related topics were involved including 5 academic staffs of Debre Berhan university.. The remaining three were academic staff of Hawassa University and Addis Ababa University (Table 3).

Table 3 Participant of AHP questioner

Participants			
Number	Education level	Professional background	Institute
2	MSc	Engineering	Hawassa University
1	MSc	Engineering	Addis Ababa university
5	MSc	Engineering	Debre Berhan university

The evaluation of questioner was according to AHP, 1 to 9 scales and the relative importance between two comparative factors is reflected by the element values of judgment matrix. Table 4 shows general form of the measurement scale of AHP (The definition of 1 - 9 scale).

Table 4 The definition of AHP par-wise comparison scale

Importance degree	Descriptions	Explanation
1	Equally important	Criteria i and j are of equal importance
3	Weak important	Criteria i is weakly more important than objective j
5	Strongly important	Criteria i is strongly more important than objective j
7	Very strongly important	Criteria i s very strongly more important than objective j
9	Extremely important	Criteria i is extremely more important than objective j
2,4,6,8	Intermediate values	Midway between the above value

3.3.1.2. Grey water quality laboratory

The quality of Grey water is different in different Grey water production unit. In this paper, for the suitability of analysis, only light Grey water was consider and classified in to four groups (typical cloth washing product, extra ordinary cloth washing procedure, hand wash basin product and shower product). The typical cloth washing product simply follows the common washing stapes and have four stapes as shown in the figure 3 bellow. In the first and second step the cloth inter in to clean water and cleaned by normal soap (the soap can be solid, liquid or powder form) to avoid different oil formed by body flood, and by other means, dust from the environment and different dirty materials from the cloth. The remaining stapes (step 3 and 4) provide for the evasion of soap from the cloth and dirty material that are not cleaned by the previous steps.

Figure 4 Typical Grey water from step 1, 2, 3, 4 and mixture of all steps

The second product is extra ordinary cloth washing procedure; in some way it is similar with typical cloth washing product and the only difference is, in this step the community use different unusual detergent types between the first three step such as acidic detergent and chemicals in the form of liquid or powder, for the purpose of whitening, bleaching, and dyeing the clothes. Due to this one extra step is added. The sampling method was similar with typical cloth washing product in figure 4.

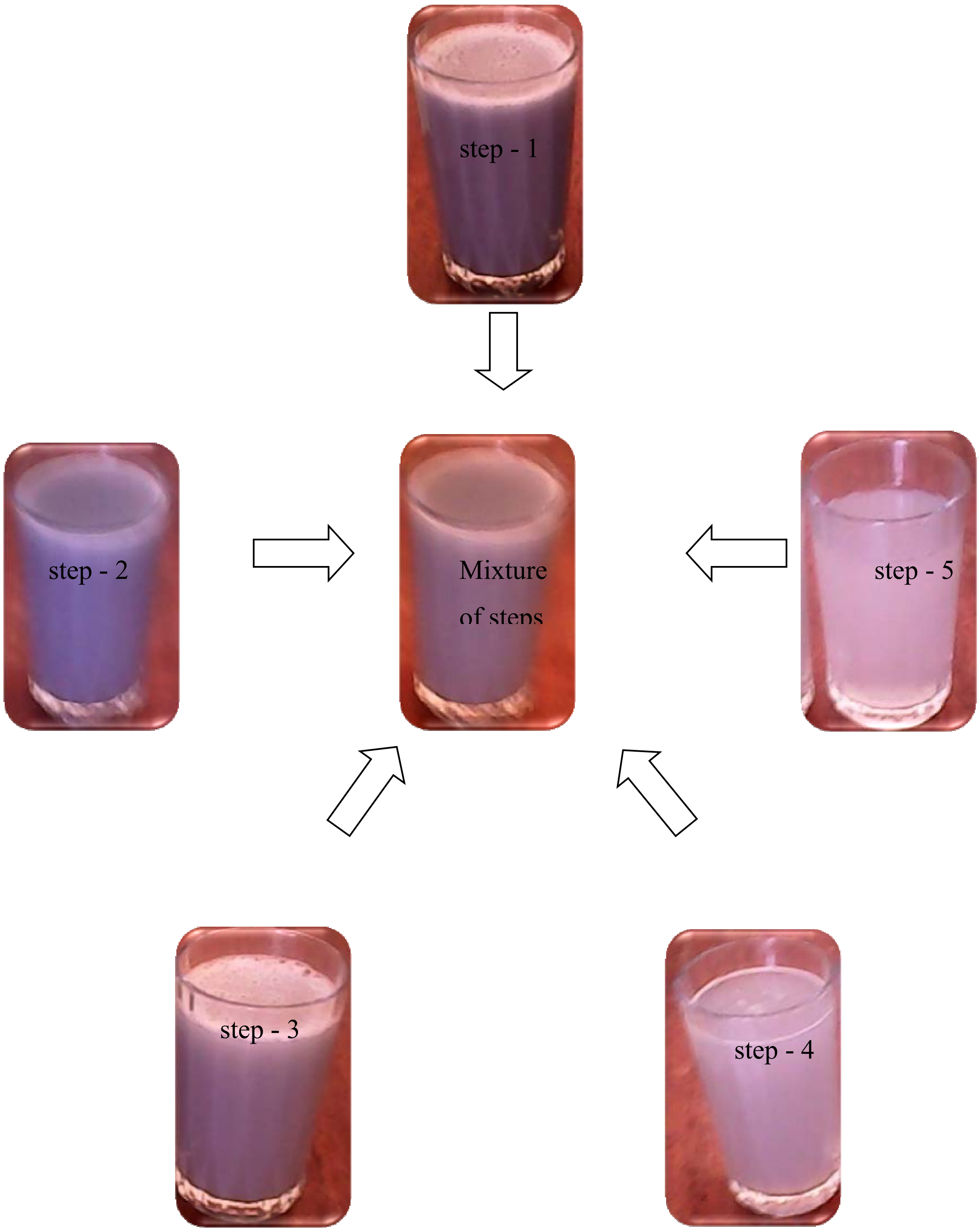

Figure 5 Extra- ordinary clothes washing product

The third one was Hand wash basin products. This product is grouped in to two products the first product represent the water when the people wash their hand, face, mouth and nose at any time but not include washing after using different food and the second product represent the Grey water produced after using different foods and put the product in to two steps as shown in the Figure 5A & B below.

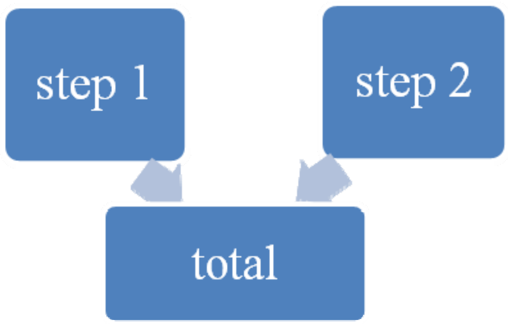

Figure 6 A) Hand basin Grey water for the two steps and mixture of steps Figure 7 B) Photo of the mixture

The last merchandise was shower and bath product. The sample was taken from the bath and shower sink.

Figure 8 Grey water from bath and shower

3.3.1.3. Interview and personal observation

To get information about Grey water quantity and to know the opinions of the community about reuse of Grey water interview and personal observation was one of the tools in this research.

3.3.2 Secondary data

Data on Grey water quality parameters and amount were used to categorize Grey water in the study area (appendix I)), questionnaire formats of analytical hierarchy process (AHP) & gray relational analysis (GRA) and formulas to determine the optimal treatment technology were considered.

3.3.2.1. Literature Review

A broad review of different literatures from different sources on the subject matter was used. Different journals, manuals, magazine, broachers and websites were also used as a source of information with regard to Grey water.

3.4 Grey water sampling

Samples for GW quality assessment were collected from a domestic shower, hand wash basin and clothes and collected from different households in the study area. Equal amount of samples were taken from each step immediately after each washing steps and then mixed according to their category. The samples then taken laboratory for analysis. Before analysis samples were agitated to avoid the spick of the result during replication.

3.5. Data Analysis and Synthesis

Data was analyzed by Excel software and MATLAB. These software's were used to obtain the weight of criteria and indices, to determine consistency indices and consistency ration, primary and secondary gray relational coefficient and to normalize the original data and the two relational coefficients of criteria and indices.

3.6. Result and discussion

After analysis results were drawn based on the collected data and all results and findings were discussed following each methodology.

3.7. Conclusion and Recommendation

Based on results obtained from analysis, a generalized summary was drawn. Finally, a strong recommendation was forwarded. General research process indicated in Figure 8 bellow.

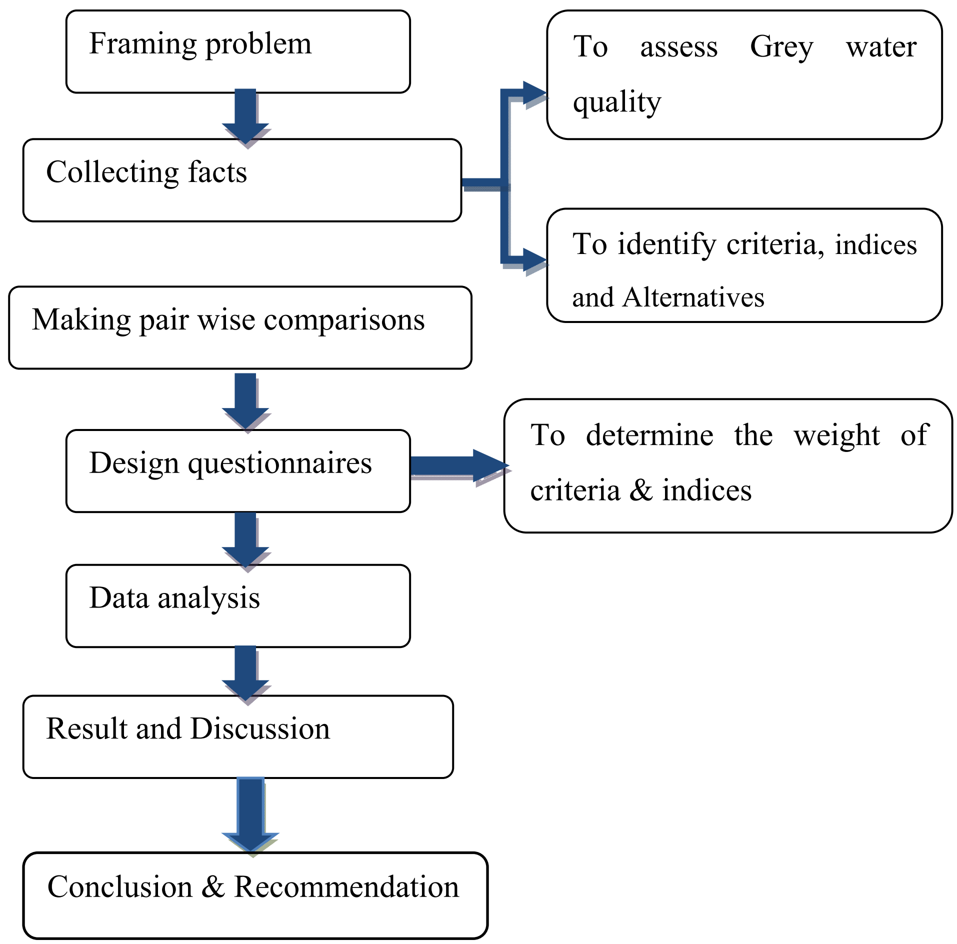

Figure 9 Process of the research

CHAPTER FOUR

4. Integrated AHP and GRA procedure

Analytic hierarchy process (AHP) was introduced by Saaty and afterwards it gained widely acceptance. AHP has been used to solve multiple criteria decision making problems in different areas of human needs and interests and the Grey system theory has been established by Deng (1982). Grey system is defined as a system having partial information. Its nature has ambiguity so it is used to solve the problems consisted of discrete data and partial information. Grey system theory’s distinguish feature is that it can handle smaller data easily and can be achieved in good results. It performs this by putting the data in its regular place with proper treatment.

The first part applies conventional AHP to determine the relative weights of the criteria. And the second part applies GRA to rank the alternatives and then selects the optimum site for treatment plants. The different priorities given to the criteria by experts or decision makers are reflected through the weights. The hierarchy is constructed in such a way that the overall decision goal is at the top level, decision criteria are in the second level, indices are in the third level and decision alternatives at the bottom as shown in figure 10.

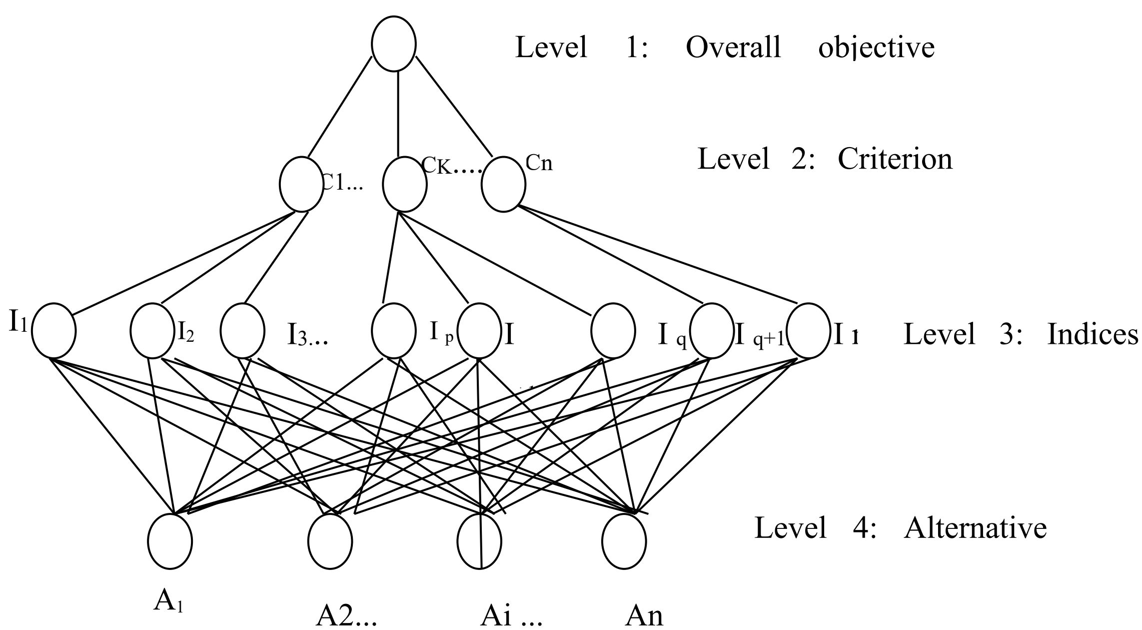

Figure 10 Hierarchy decision model

4.1 Identification of criteria, Indices and alternatives

To select the alternatives, consider around 14 aerobic, anaerobic and anoxic systems have been reviewed by considering the following selection decisive factor: Construction cost, Operation and Maintenance cost, Required space, energy required, Process stability, Operation and maintenance skill required, pollutant removal capacity Sludge quality and quantity, Odor, Noise, patent issue and Vector attraction and also by considering the quality of Grey water in the study area and other country experience select six treatment technologies those are rotary biological contactor, sequential batch reactor, gravel pack, membrane bio-reactor, up flow anaerobic sludge blanket and moving bed bio reactor and this are an alternative level Grey water treatment technology selection system. Based on the available information on various categories of criteria of treatment plant selection through literature study identify three important and significant criteria includes economic, environmental and administrative.

Since the hierarchy has been established for the selection of Grey water treatment technology, after this, the weights of criteria and sub-criteria were computed. These were computed based on decision makers' relative importance of their judgments on alternatives and determine the pair comparison matrix or decision matrix. All of the procedures to select appropriate (optimal) treatment technology according to GRA and AHP are presented below.

1. **AHP Procedure**

The procedures of AHP to solve the problem generally involve three essential steps in order :

a) The pair wise comparison matrix (K) formed:

$$K = (kij) = \begin{bmatrix} k11 & k12 & \dots & k1n \\ k21 & k22 & \dots & k2n \\ \dots & \dots & \dots & \vdots \\ kn1 & kn2 & \dots & knn \end{bmatrix}$$

Where k_{ij} represents the judgment degree of i^{th} factor compared to j^{th} factor.

$k_{ij} = \frac{wi}{wj}$,

$$K = \begin{bmatrix} w1/w1 & w1/w2 & \cdots & w1/wn \\ w2/w1 & w2/w2 & \cdots & w2/wn \\ \cdots & \cdots & \cdots & | \\ wn/w1 & wn/w2 & \cdots & wn/wn \end{bmatrix}$$ ----------------------- **(Equation 1)**

b) AHP allows some small inconsistency in judgment because human is not always consistent. Therefore, a consistency check applied by computing the consistency ratio (CR).

$$CR = \frac{CI}{RI}$$ -- **(Equation 2)**

where RI is the random indices. The values of RI, which change with variations in the dimensions stated in appendix I . CI is the consistency indices, and computed by

Table 5 Linguistic value of random index

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

$$CI = \left(\frac{\lambda max - n}{n-1}\right)$$ ---------------------------- **(Equation 3)**

When CR ≤ 0.10, it means that the inconsistency of the pair wise comparison matrix is in the desired interval and matrix is acceptable.

2. Grey Relational Analysis

The grey relational analysis (GRA) is used to determine the relationship (similarity) between two series of data in a grey system. Its structure has uncertainty, therefore it handles the problems consisted of discrete data and partial information. It operates the grey relational grade to determine the relational degree of factors.

Before calculating the grey relational grade, we must perform data pre-processing. Normalization of series must be done to ensure that all of them are in the same order.

a) Normalization of ‘‘original’’ index data in index level :- All values of sub-criteria (indices) for each alternative moved on the same scale or sequences with various units need to be transformed to have the same numeric order by using the linear normalization method for the purpose of comparison.

For cost indices the normalized data obtained by

$$Xij = \frac{\min(i)\{Si(j)\}}{Si\,(j)}$$ ---------------- ---- ------------- (Equation 4)

While for benefit indices the normalized data obtained by

$$Xij = \frac{Si(j)}{\max(i)\{Si\,(j)\}}$$ --------------- ---- -------------- (Equation 5)

b) The grey relational coefficient which represents the relative distance between the two indices

determined by formula

$$\xi oi(j) = \frac{0.5\max(i)\ \{\max(j)[Xoi-Xij]\}}{[Xoj-Xij]+0.5\max(i)\ \{\max(j)[Xoi-Xij]\}}$$ ----------- (Equation 6)

And obtain primary grey relational coefficient matrix for all indices of the optional schemes, and denoted as $G = \begin{bmatrix} \xi o1(1) & \xi o2(1) & \cdots & \xi om(1) \\ \xi o1(2) & \xi o2(2) & \ldots & \xi om(2) \\ \ldots & \ldots & \ldots & \vdots \\ \xi o1(n) & \xi o2(n) & \cdots & \xi om(n) \end{bmatrix}$

c) Weighed primary grey relational coefficient (δc)

To obtain weighed primary grey relational coefficient vector, weight of index level criteria multiplied by the primary gray relational coefficient as follow

$$\delta c = Wc(1)\ G$$ ------------------ ---- ------------- (Equation 7)

and normalized the primary gray relational coefficient by using equation 4 and 5 then simply get normalized weighed primary grey relational coefficient

d) Secondary grey relational grad (Gc) equation 6 was used to calculate secondary grey relational grade vector.

e) Finally, the integrated grey relational grade vector calculated

$$\varepsilon = Wc\ X\ Gc$$ ------------------ ---- ------------- (Equation 8)

The largest grey relational grade is desired which corresponds to the optimal scheme of Grey water treatment.

CHAPTER FIVE

5. RESULT AND DISCUSSION

In this study the quality analyses of laundry water parameters aimed to identify the contaminants in different Grey water production unit, which could affect human health and the environment adversely if this wastewater is used for different purpose such as for toile flash, garden irrigation, car wash, fire fitting and washing of clothes and different equipment was considered. In general, the laboratory result indicates that the quality of Grey water was different in the four production units (typical cloth washing, extra ordinary cloth washing, hand wash basin and shower/bath product). A summary of the four production units water quality parameters found in this project were presented in table 5. Values from litretures were also indicated for comparison. All values in the table represented average values.

5.1 **Typical and Extra- ordinary cloth washing product**

Typical cloth washing and extra ordinary cloth washing products were signaled as the major pollutants generators from the other two (hand wash basin and Shower/bath product). In earlier works ,to assess the quality of Grey water different researchers were not classifying the laundry Grey water and also there were no previous studies that to classified laundry Grey water in to two parts. Rather, they simply consider the mixture of both typical and extra- ordinary product in to one. This particular research indicated that, the organic pollutant of both products were different with average COD concentration of 6720 mgl^{-1} and 7070 $mgl^{-1,}$ respectively. But a study by Friedler (2004) reported an average COD concentration of washing machine (mixture of typical and extra-ordinary cloth washing product) was1339 mg l^{-1} and average BOD concentration of 462 were measured and this study showed average BOD concentration of typical and extra ordinary washing product was 596 mg l^{-1} and 386 mg $l^{-1,}$ respectively. The variability of the organic pollutant reflects the appropriate variability in lifestyles, customs, installations, product preferences and washing habits of the population (Jefferson *et al*., 2004).

The average value of P^H for the typical and extra ordinary washing products was 9.17 and 10.15, respectively. The two laundry water samples in this project exhibited higher values of P^H than the maximum limits mentioned in previous studies by Bronte (2011). This was clearly related to the composition of the laundry detergents. The laundry water associated with powder detergents was subject to higher levels of p^H than those associated with liquid detergents as supported by Minh (2005).

Results from this study indicated that the concentration of nitrate was high compared to previous studies . Nitrate, in excess, can be a potent water pollutant. Elevated nitrate levels can lead to Eutrophication of surface waters, as well as pose a human health risk (Jagessar and Sooknundun, 2011). According to Braga and Varesche (2014), the maximum nitrate concentration of laundry Grey water was 25.7 mg l^{-1} but this study showed very high value of nitrate for the two Grey water production units (typical and extra-ordinary cloth washing product) 622.5 mg l^{-1} and 307 mg $l^{-,1}$ respectively. This might be coursed by detergents that contain Triethanolamine that could increase the amount of nutrient found in Grey water. Dye and soiled invaded from clothes may have a contribution for the increment of nutrient and organic strength of Grey water. The concentration of phosphate in this study is beyond the usual laundry Grey water phosphate contents. Accordingly, the phosphate concentration of 386 and 413 for typical and extra ordinary cloth washing product were measured, respectively. According to Braga and Varesche (2014), the minimum and maximum concentration of phosphate in laundry Grey water was 9.8 mg/l and 279 mg/l , respectively. Its main source was detergents containing phosphates (Minh 2005 and Eriksson, 2002). In places where the use of these detergents is not allowed, the phosphorus in grey water tends to be 70% lower (Otterpohl, 2003).

5.2 Hand wash basin Grey water

The strength of hand wash basin Grey water was found to be higher as comparison to typical values reported in Friedler (2004) and Jefferson *et al* (2004) ; specially the concentration of BOD, COD and suspended solid. The average concentration of BOD, COD and suspended sold were 384.67 mg L^{-1}, 1133.67 mg L^{-1} and 587 mg L^{-1} respectively. But Jefferson *et al.,* 2004 suggests concentration of BOD (155 ± 49) mg.L^{-1}, COD (587 ± 379) mg.L^{-1} and suspended sold (153 ±226) mg.L^{-1}. Residents and community in Balderas condominium the study area use different type of tooth pastes , hand cleaning detergents and tooth whiteners. These all cosmos may be reasonable causes for increment in the concentration of BOD, COD and suspended solid. Human blood and food particles from cleaning and hygienic practices of residents may also have their contribution for the increment of these parameters. Blood contains red blood cells forming a stable suspension in water that results in high BOD_5 Blood and chemical oxygen demand (COD) (Yordanov, 2010).

5.3 Shower/Bath Grey water

These sources of Grey water tested in the current investigation varied considerably in terms of their organic concentration after Extra-ordinary washing product. For instance, the BOD and COD of the sources were 220 mg L^{-1} and 4525mg L^{-1}, respectively. The chemical reaction between the raw water and different cleaning soaps such as shower gel, shampoo, bathroom cleaner and conditioner may increase the organic concentration of shower Grey water. This fact is in agreement with findings of Marc (2006), which explained, solutions of shampoo provide a significant increase of the organic (BOD and COD) concentration of the Grey water.

Table 6 Comparison of Grey water characteristics

	This study (2015)				Literature			
					Braga & Varesche (2014)	Jefferson *et al.*,(2004)		
Parameters (mg/L)	typical laundry	Extra - ordinary laundry	Hand wash	Bath/shower	laundry (max)	Shower	Bath	Hand basin
Temperature	23.4	24	25	25.3				
Suspended solid	2235	1850	587	1642.5	290	89 (113)	58± 46	153±226
P^H	9.17	10.15	6.68	7.827	6.8	7.52 (0.28)	7.57 ±0.29	7.32 ±0.27
Turbidity (NTU)	2328.125	1989.25	631.18	1537.46	_	84.8 (70.5)	59.8± 43	164 ±171
BOD	596	176	384.67	220	_	146 (55)	129 ±57	155 ±49
COD	6720	7070	1133.67	4525	4796	420 (245)	367 ±246	587 ±379
Nitrite (NO_2^-)	1.6	3.05	0.08	2.5	3.3	_	_	_
Niterate (NO_3^-)	622.5	307	156.69	613.03	25.7	_	_	_
Amonium (NH_3)	3.9	3.5	1.16	5.73	_	_	_	_
phosphate	386.4	413	57.98	47.37	279	0.3 (0.1)	0.4 ±0.4	0.4 ±0.3
Total coliform (NCC/100ml)	228	158.16	228.5	18	_	_	_	_

……..Continued

					literature						
	This study				**Christova (1996)**		**Marie (2011)**	**Friedler (2004)**			
Parameters (mg/L)	typical laundry	Extra - ordinary laundry	Hand wash	Bath/ shower	Bath	Laundry	Shower Grey water	Bath	shower	washing basin	Laundry
Temperature	23.4	24	25	25.3							
Suspended solid	2235	1850	587	1642.5	34 - 380	26 - 400	29.6±15.92	78	303	259	188
P^H	9.17	10.15	6.68	7.827	6.4 - 8.1	6.3 - 9.5	6.85±0.30	7.14	7.43	7	7.5
Turbidity (NTU)	2328.125	1989.25	631.18	1537.46	15 - 270	22 - 350	_	_	_	_	_
BOD	596	176	384.67	220	45 - 330	10 - 520	_	173	424	205	462
COD	6720	7070	1133.67	4525	_	_	_	230	645	386	1339
Nitrite (NO_2^-)	1.6	3.05	0.08	2.5	0.02 - 0.2	0.023 - 0.44	_	_	_	_	_
Nitrate (NO_3^-)	622.5	307	156.69	613.03	0.02 - 0.2	0.023 - 0.44	0.08±0.09	_	_	_	_
Ammonium	3.9	3.5	1.16	5.73	0.1 - 7.8	0.1 - 11	4.97±2.09	0.89	1.2	0.39	4.9
phosphate	386.4	413	57.98	47.37	_	_	1.45±2.07	4.56	10	15	169
Total coliform NCC/100ml	228	158.16	228.5	18	_	_	_	_	_	_	_

This study					Literature Lehr (2005)		
Parameters (mg/L)	typical laundry	Extra-ordinary laundry	Hand wash	Bath/ Shower	Bath/ Shower	Wash basin	Washing Machine
Temperature	23.4	24	25	25.3			
Suspended solid	2235	1850	587	1642.5	76	40	68
P^H	9.17	10.15	6.68	7.827	7.6	8.1	8.1
Turbidity (NTU)	2328.13	1989.25	631.18	1537.46	92	102	108
BOD	596	176	384.67	220	216	252	472
COD	6720	7070	1133.67	4525	424	433	725
Nitrite (NO_2^-)	1.6	3.05	0.08	2.5	-	-	-
Nitrate (NO_3^-)	622.5	307	156.69	613.03	-	-	-
Ammonium	3.9	3.5	1.16	5.73	1.56	0.53	10.7
phosphate	386.4	413	57.98	47.37	1.63	45.5	101
Total coliform (NCC/100ml)	228	158.16	228.5	18	-	-	-

All represent a very high strength. It is not clear why the Grey water had such high concentrations and also all value were substantially above the recommended limits for reclaimed water quality (as shown table 6) for non potable reuse, this indicate that treatment is necessary to meet the effluent standards for reuse of waste water.

Table 7 Recommended limits for reclaimed water quality

	Levi Strauss & Co.				Laosheng *et al* (2009)	EPA (2012) California	Yordanov (2010)
Parameter	Facility Process (Laundry) Water	Landscape Irrigation (Restricted Access)	Cooling Tower Water	Sanitary Toilet Flushing (Restricted Access)	Unrestricted Urban Reuse	Unrestricted Urban Reuse	
P^H	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.5-8.5	-	
BOD	10	30	10	30	20	-	50
SS	10	30	100	30	20		50
Turbidity	2	no limit	no limit	no limit	2	2.0-5.0	
COD							250
Total coliforms						(2.2-23)/100ml	

5.4 Acceptability

Based on the semi-structured questioners distributed though out the study area shows that around 85 % of the community was willing to use the treated grey water for non potable use and 12 % are willing to use for any kind of purpose . The remaining percent of the community was neutral to give any idea about the reuse of grey water as shown in the pie chart below.

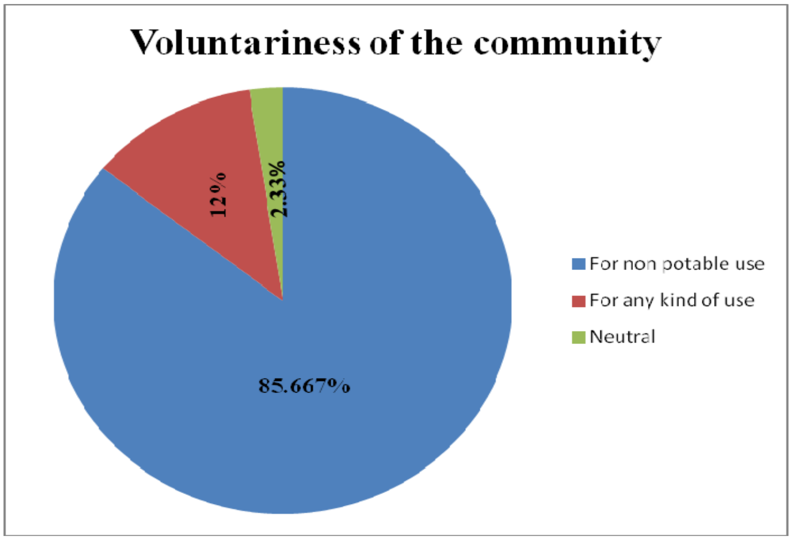

Figure 11 Voluntariness of the community

5.4 Optimal Grey water treatment selection

According to professionals idea analysis using AHP and GRA, the optimal treatment technology for Grey water was MBR. The model of AHP hierarchy involve four core criteria in the first level and 11 indices in the second level and six alternatives which are represented in figure 10 below.

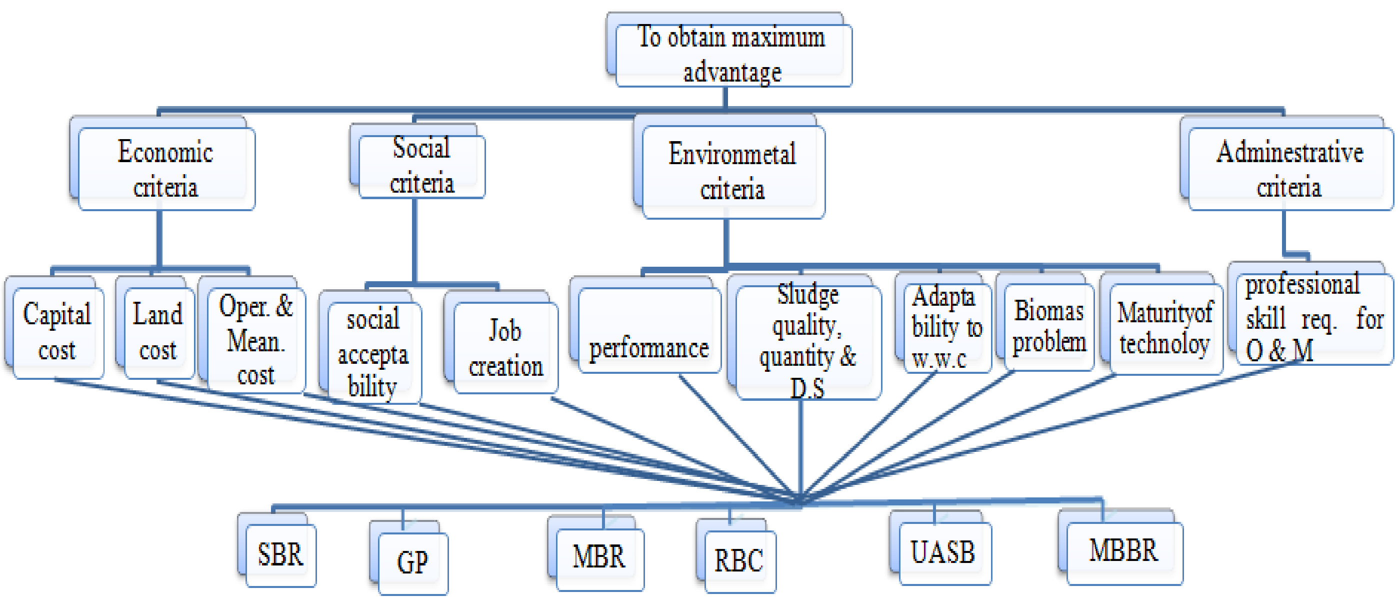

Figure 12 A hierarchy decision model for Grey water treatment technology selection

The decision contains four levels at the top of the hierarchy; the overall objective was obtaining maximum advantage as indicated in figure 9 at the first level (top of hierarchy), it. The criteria level is the second level of the hierarchy and consisted of, economic criteria (C_1), environmental criteria (C_2), social criteria (C_3 and administrative criterion (C_4). The third level is indices level and contains capital cost (I_1), land required (I_2), operation and maintenance cost (I_3), performance (I_4), sludge quality &disposal system (I_5), Adaptability to waste water characteristics (I_6), Biomass problem (I_7), Maturity of technology (I_8), social acceptability (I_9), Job creation (I_{10}) and professional skill required for operation and maintenance (I_{11}).The final is alternative level and this level includes sequential batch reactor (A1), gravel pack (A2), membrane bioreactor(A3), rotary biological contacted (A4), up flow anaerobic sludge blanket(A5) and moving bed bio reactor(A6).

Since the hierarchy has been established for the choice of Grey water treatment selection, after this, the weights of criteria and sub-criteria were computed based on Question.

As mentioned earlier the questionnaire of this study was completed by eight experts and/or professionals. Accordingly, eight engineering lecturers having more than three years of work experiences were involved. All participant use Analytical Hierarchy Process (AHP); the 1 - 9 scale to express their opinion, decision and estimation. In addition, the method of AHP and GRA was analyzed by Microsoft Excel spreadsheet and MATLAB. This soft ware was used to analyze and compute the weight of criteria & indices, standard deviation and to solve different mathematical problems such as Eigen value (used to determine the consistency of professional idea) and dot product of the decision matrix.

Table 8 Weight of indices and criteria

Criteria	Weight	Indices	Indices weight
Economic criteria	0.56	Capital cost	0.672
		Land cost	0.21
		Ope. & M cost	0.118
environmental criteria	0.23	Performance	0.323
		Sludge quality, quantity & disposal system	0.135
		Biomass problem	0.254
		Adaptability to waste water characteristic	0.167
		Maturity of technology	0.121
Social criteria	0.11	Social acceptability	0.77
		Job creation	0.23
Administrative criteria	0.1	professional skills required for Ope. & M	1

As shown above (table 8), experts believe that economic criteria (weight = 0.56) was the main factor in the selection of Grey water treatment. Environmental criteria (weight = 0.23) was the second factor and the third factor was social criteria (weight = 0.11) . Whereas, administrative criteria (weight = 0.1) was the list important factor.

The fist important event in the branch of economical criteria was capital cost (weight= 0.672) of treatments technology. Based on their indices weight, the second and the third important criteria under economical criteria were Land cost (weight = 0.21) and operation and maintenance cost (weight = 0.118), respectively.. Performance of treatment technology (weight = 0.323) was found to be the first important factor in the branch of environmental criteria. Adaptability to waste water characteristics, Biomass problem, sludge quality and quantity and maturity of plant were the second, third, fourth and fifth important factor in sequence. In social criteria the first weighted indices was social acceptability (weight = 0.77) as shown table 7.

According to the computed weight the positive reciprocal matrix (decision matrix) was displayed in table 8 (were by obtain using equation 1).

Table 9 The positive reciprocal matrix (Decision matrix)

	Economical criteria	Environmental Criteria	Social criteria	Administrative Criteria
Economical criteria	1	2.435	5	6
Environmental Criteria	0.41	1	2.1	2.3
Social criteria	0.20	0.5	1	1.1
Administrative criteria	0.2	0.2	1	1

Based on the procedure of GRA and AHP the second step is obtaining the consistency ration. It depends on the Eigen value of the decision matrix (**λ**max= 4.0154) number of criteria (n = 4) and random average consistency indices (RI = 0.9 (Appendix I)). According to equitation 2 and 3 mention in the methodology, the consistency ration (CR) computed was 0.005704. As a rule, a consistency ratio (CR = CI/RI) value of 10% or less is considered as acceptable, otherwise the pair wise comparisons should be revised. However, here the result passed the test of consistency. To solve the complicated interrelationships among the multiple performance characteristics, the optimization of grey relational grades GRA was used. The GRA was started by normalization of ‘‘original’’ data. The original data was then expressed by linguistic value or verbal statements. All the original data (indices) were computed according to professional opinion also literatures have contribution for the computation of indices. the numerical value of all indices are shown in table 9.

Table 10 linguistic value scale

Linguistic value	Quantity
Excellent (E)	0.9
Good (G)	0.7
Moderate (M)	0.5
Poor (P)	0.3
Very poor (VP)	0.1

Table 11 Original data of alternative technology

Goal	Criteria	Sub criteria	Alternative Technologies					
			Opt. 1	Opt. 2	Opt. 3	Opt. 4	Opt. 5	Opt. 6
	Economic criteria	Capital cost	High	Medium	very high	high	medium	M(0.6)
		Land cost	M(0.6)	Medium	L(0.3)	high	High	M(0.6)
		Operation & Maintenance cost	high(0.8)	Medium	very high	medium	medium	High
		performance	G(0.7)	M(0.5)	E(0.9)	G(0.7)	G(0.7)	M(0.6)
		sludge Quality, Quantity & disposal system	medium	M(0.5)	E (0.9)	G(0.7)	G(0.7)	G(0.7)
To obtain maximum advantage	Environmental criteria	Adaptability to wastewater characteristics	0.8	M(0.7)	0.8	0.7)	L(0.3)	M(0.6)
		Biomass problem	0.5	G(0.7)	0.6	M(0.5)	G(0.7)	M(0.5)
		Maturity of plant	0.7	M(0.5)	0.9	G(0.7)	VP(0.1)	G(0.7)
	social criteria	Social acceptability	0.7	0.8	0.7	0.7	0.8	0.7
		Job creation	M(0.5)	M(0.5)	M(0.5)	M(0.5)	M(0.5)	(0.5)
	Administrative criteria	Professional skills required for Operation. & Maintenance	G(0.7)	G (0.7)	VP(0.1)	G(0.7)	VP(0.2)	G(0.7)

The indices consist of cost and benefit indices which are of two different types and not the same numerical order. For the cost indices, the smaller is the better; while for the benefit indices, the larger is the better. Therefore Sequences with various units need to be transformed to have the same numeric order, which is called linear normalization (grey relational generation). The base point adopted during the linear normalization of cost indices is different from that of benefit indices, which will lead to the opposite results and failure of comparison. Therefore two different linear normalization expressions are applied to the indices data. According to formula 4 for cost index and formula 5 for befit index. The value of normalized data presented in table 12 bellow.

Table 12 Normalized values of all sub-criteria

Criteria	Index	Xoj	Normalized data of ''original'' data x_{ij}					
		opt. 0	opt. 1	opt. 2	opt. 3	opt. 4	opt. 5	opt. 6
	I1	1	0.714	1	0.556	0.714	1	0.833
C1	I2	1	0.500	0.6	1.000	0.429	0.429	0.500
	I3	1	0.625	1	0.556	1.000	1	0.714
	I4	1	0.778	0.556	1.000	0.778	0.778	0.667
	I5	1	0.556	0.556	1.000	0.778	0.778	0.778
C2	I6	1	1.000	0.875	1.000	0.875	0.375	0.750
	I7	1	0.714	1	0.857	0.714	1	0.714
	I8	1	0.778	0.556	1.000	0.778	0.111	0.778
C3	I9	1	0.875	1	0.875	0.875	1	0.875
	I10	1	1	1	1	1	1	1
C4	I11	1	1.000	1	0.143	1.000	0.286	1.000

Moreover, additional data needed were prepared for the computation of primary relation coefficients which is the relative distance between indices. It was computed using equation 6 and presented in table 13.

Table 13 Primary grey relational coefficients

Primary grey relational coefficients ζ_{0i} (j)					
opt. 1	opt. 2	opt. 3	opt. 4	opt. 5	opt. 6
0.467	1	0.491	0.5	1	0.6
0.333	0.357	1.000	0.333	0.438	0.333
0.400	1	0.491	1	1	0.467
0.529	0.333	1.000	0.563	0.667	0.429
0.360	0.333	1.000	0.563	0.667	0.529
1.000	0.64	1.000	0.696	0.416	0.5
0.467	1	0.750	0.5	1	0.467
0.529	0.333	1.000	0.563	0.333	0.529
0.8	1	0.873	0.821	1	0.8
1	1	1	1	1	1
1.000	1	0.333	1	0.384	1

Secondary grey relation coefficients is sub-criteria which is the relative distance between indices due to the weight of indices. These coefficients are computed after determining weighted primary gray relational coefficient and normalized weighted primary grey relational coefficients (Appendix I). The value of secondary grey relation coefficients is presented in table 14.

Table 14 secondary gray relational coefficient

Secondary grey relational coefficients					
opt 1	opt 2	opt 3	opt 4	opt 5	opt 6
1	0.33333	0.54417	0.52205	0.37599	0.5754
0.33333	0.35571	1	0.33333	0.46483	0.33333
0.53722	1	0.77289	0.58432	1	0.61891
1	1	0.5	1	0.5	1

Six alternative treatments technologies; Opt. 1 (sequential batch reactor), Opt. 2 (Gravel pack), Opt. 3 (membrane bio reactor), Opt. 4 (rotary biological contactor), Opt. 5 (up flow anaerobic sludge blanket) and Opt. 6 (moving bed bio reactor), were ranked 1, 5, 2, 4, 6 and 3, respectively (Table 15). Therefore, sequential batch reactor as opt. 1 was the optimal alternative among the others for treating Grey water.

Table 15 Integrated grey relational grade for each optional scheme

The integrated grey relational grade for each optional scheme		
Optional scheme (technologies)	Integrated grey relational grade	Rank
opt1	0.795761048	1
opt2	0.478479642	5
opt 3	0.669753728	2
opt 4	0.533287934	4
opt 5	0.477464595	6
opt 6	0.566973132	3

5.5 Cost benefit analysis

5.5.1Coast benefit analysis procedure

SBR, GP, MBR, RBC, UASB & MBBR are the different light gray water cleaning methods identified where cost benefit analysis of each is compared to suggest optimum technique. The analysis was based on generic steps that includes identification of costs and benefits; calculation of costs and benefits and comparison of aggregate costs and aggregate benefit. Since it was difficult to find actual monetary costs of each parameter under cost and benefit column, value set by the Addis Ababa Water and Sanitary Agency is taken for quantitative measurement of both (See table 16).

Table 16 Water cleaning technology selection criteria

S.NO	Criteria	Weighting Factors
1	**Footprint**	48-50
2	**Capital cost**	48-50
3	**Operation and maintenance costs**	38-40
4	**Energy requirements**	28-30
5	**Energy recovery**	28-30
6	**level of skill**	38-40
7	**Adaptability to wastewater characteristics**	6-10
8	**Biomass problems**	6-10
9	**Sludge yield and quality**	6-10
10	**Nuisances**	20-25
11	**Effluent quality**	38-40
12	**Nutrient removal**	6-10
13	**Technical Modification**	28-30
14	**Construction Period**	2-5
15	**Impact of Effluent Discharge on surface water**	28-30
16	**Impact of Effluent Discharge on ground water**	38-40

5.5.1.1 Cost benefit analysis steps

Step 1- Identify costs and benefits of the method

Costs related to alternative cleaning methods

1. Capital cost
2. Operational cost
3. land cost

Benefits related to alternative cleaning methods

1. Performance
2. Biomass problem

3. Adaptability of waste water
4. Professional skill required
5. Maturity of plant
6. Acceptability
7. Job creation
8. Sludge quantity, quality and disposal system

Step 2- Calculation of Costs and Benefits

Table 17 Calculation of Costs

Table 1 Coast Calculation

Method type	Capital coast	Operational coast	Land coast	Value	Rank
SBR	49.5	40	49	138.5	5
GP	48.5	38.5	48.5	135.5	1
MBR	50	40	48	138	4
RBC	49.5	38.5	49.5	137.5	3
UASB	48.5	38.5	49	136	2
MBBR	49	39.5	49	137.5	3

Table 18 Calculation of Benefits

Table 2 Benefit Calculation

Method type	Performance	Biomass problem	Sludge quality, quantity & disposal system	Professional skill requirement	Adaptability to gray water	Maturity of plant	Social acceptability	Job creation	Value
SBR	39.5	8	8	39.5	9.5	9	24	5	142.5
GP	39	9	8	39.5	9	8	24.5	5	142
MBR	40	9	10	38	9.5	10	24	5	145.5
RBC	39.5	8	9	39.5	9	9	24	5	143
UASB	39.5	9	9	38.25	7	6	24.5	5	138.25
MBBR	39.25	8	9	39.5	8.5	8	24	5	141.25

Step 3- Compare aggregate costs and aggregate benefits

Step 3-A Normalization

At this stage calculated values of costs and benefits need to have similar units for ease of calculation. Thus it is important to normalize the obtained values of costs and benefits for comparison and ranking.

Table 19 Normalization of cast and benefit

Normalization of cast and benefit data		
Method type	Cost	Benefit
SBR	0.97833935	0.979381443
GP	1	0.975945017
MBR	0.981884058	1
RBC	0.985454545	0.982817869
UASB	0.996323529	0.950171821
MBBR	0.985454545	0.970790378

Step 3-B Comparison

Table 20 Comparison of cast and benefit

Method type	Value (Coast)	Value (Benefit)	Rank
SBR	0.97833935	0.979381443	4
GP	1	0.975945017	2
MBR	0.981884058	1	1
RBC	0.985454545	0.982817869	3
UASB	0.996323529	0.950171821	6
MBBR	0.985454545	0.970790378	5

CHAPTER SIX

6 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

light gray water from domestic use has high proportion compared to other type of waste water. hand wash, shower and cloth washing are the major sources of light gray water. From this research one can understand that reusing light graywater is a better way of solving the current unfair use of clean water by providing another alternative sources of water for non potable uses.

The results obtained in this study indicate that, the gray water in the study area were highly polluted compared to previous study results. The physical, chemical and microbiological characteristics or quality of Grey water depends on the sources of production. From the four sources (typical washing product, extra ordinary washing product, hand basin product and shower/bath product) ,typical washing product was the major pollutant source for Grey water. Extra ordinary washing product, shower/bath and hand basin product were second, third and the fourth polluted Grey water in order of importance.

Number of total coliform count reached unacceptably high level when compared with standard recommended limits for reclaimed water quality (EPA, 2012). High level coliform counts were observed particularly in the hand basin and typical washing samples. This evidenced the presence of high microbiological contamination and potential presence of pathogens.

Generally this research showed that based on the quality of GW with respect to BOD,COD, SS, turbidity phosphate and Nitrate in the study area; grey water requires adequate treatment prior to household reuse. The wash basins are found low in nitrate, nitrite, ammonia, phosphate, BOD, COD and turbidity compared to the three products. However, it is high in, total coliform. The two cloth washing products were found to be high in nitrate, nitrite, ammonia, phosphate, BOD, COD and turbidity.

The AHP provides a convenient approach for solving complex MCDM (multi criteria decision making) problems. The Grey water treatment alternative selection is a complicated multiple objective decision-making process. Uncertainty, complexity and hierarchy are the most important characteristics. The innovative hierarchy GRA has been performed in this study to compare and evaluate the Grey water treatment plant alternatives. The first part applies conventional AHP to determine the relative weights of the criteria. And the second part applies GRA to rank the alternatives and then selects the optimum treatment technology. The different priorities given to the criteria by experts or decision makers were reflected through the weights, so the bias arising from subjective judgments and random effects was prevented.

Through this process, comparison of treatment plant suggests sequential batch reactor (SBR) to be the most efficient and suitable treatment of Grey water from six alternate (SBR, GP, MBR, RBC, UASB and MBBR) treatment technologies, based on those indicated criteria (Economic, Environmental, Social and Administrative criteria) and indices (Capital cost land cost Operational & maintenance cost, performance, sludge quality and quantity, Adaptability to waste water characteristics, Biomass problem, Maturity of plant, Social acceptability, Job creation and profession skill required).

From the four criteria, economical criteria was an important factor to select an optimal treatment. Environmental, social and administrative criteria have also contributions, but not equally important as economical criteria. From indicated indices, capital cost had the highest weight and this indicates that the capital cost greatly influence the selection of optimal Grey water treatment technology.

GRA with the idea of the hierarchy of the AHP allows for more effective reflection of the actual characteristics of the problem as compared to the mono level-based evaluation. The different levels of importance of the criteria are reflected through the weights to avoid subjectivity and randomness. In addition, the quantified evaluating scale, namely the integrated grey relational grade, makes the wastewater treatment alternative selection more comparable and comprehensive.

The current method of waste water treatment alternative selection has several drawbacks. such as: *potential inaccuracies in identifying and quantifying costs and benefit; increased subjectivity for in tangible costs and benefits; inaccurate calculation of preempt value resulting in misleading analysis and might turn in to a project budget* (N. Plowman 2011). The other drawback of the current method was the aggregation of decision makers' preference based on a simple comparisons. To overcome these drawbacks, a new approach utilizing a pair wise comparisons approach and GRA was developed in order to address imprecision in judgment for weight assignment and preference aggregation of decision makers. Another contribution of this study was proposing a method to mitigate bias judgment and inconsistency in pair wise comparisons. Based on the assessment, it is reliable that the proposed model can provide more accuracy in comparisons with currently used method.

Finally, this research shows that based on the combination of GRA and AHP method, SBR is suitable and optimal technology for light grey water treatment due to the fact that it has relatively lower cost and high benefit compared to the other alternatives listed.

6.2 Recommendation

The authorized person must control the nutrient content of different detergents both import and inside product and aware the community they don't use nutrient reach detergent. because it make the reuse of the Grey water difficult and affect the environment if discharge or release. for example nitrate, under certain natural conditions and forms highly soluble compounds. These are peculiar features that allow nitrate ion to be transported in some groundwater systems to environments where it can be converted into other nitrogen species that either promote surface water Eutrophication or are hazardous to humans, livestock, and the environment.

To select appropriate treatment technology and to solve other decision making required problem the authorize institute shall use the method of the combination of AHP and GRA to get an accurate result and to make the decision making process free from subjective judgments and random effects.

The community simply discharge there Grey water in toilet or reuse as a toilet flash and release to the green area without any treatment. This may affect soil, plant and soil biota also the septic tank may need regular maintenances. This practice must avoid and controlled by certified members of the community. If replace this practice proper reusing (collect and treat) of Grey water may save considerable amount of potable water and protect the environment.

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Appendix

Appendix I

Weighted primary gray relational coefficient

criteria	Weighted primery gray relational cofficent						
	opt 0	opt 1	opt 2	opt 3	opt 4	opt 5	opt 6
C1	1	0.4308	0.865	0.5978	0.524	0.8819	0.5283
C2	1	0.6156	0.5226	0.9582	0.5859	0.6182	0.4789
C3	1	0.846	1	0.902	0.8618	1	0.846
C4	1	1	1	0.333	1	0.3836	1

Normalized weighted primary grey relational coefficients

Normalized weighted primary grey relational coefficients					
opt 1	opt 2	opt 3	opt 4	opt 5	opt 6
1	0.49803	0.72064	0.82214	0.48849	0.81545
0.64245	0.5454	1	0.61146	0.64517	0.49979
0.846	1	0.902	0.8618	1	0.846
1	1	0.333	1	0.3836	1

Appendix II

Addis Ababa University

Institute of Technology Department of Civil and Environmental Engineering

This questioner is develop to obtain useful information for the selection of appropriate Grey water treatment technology and determine the relative weight of each criteria and sub criteria.

Background Information

1. The age of the respondent?
   A) 15-30 B)30-45 C) 45-60 D) Above
2. Sex of the respondent?
   A) Male B) female
3. What is your profession?

4. Year of experience of the respondents

5. Please read the following instruction carefully to fill the following questions

   This questioner is filled for each (SBR, MBR, GP, MBBR, RBC and UASB) treatment technology.

Importance degree	Descriptions	Explanation
1	Equally important	Criteria i and j are of equal importance
3	Weak impotent	Criteria i is weakly more important than objective j
5	Strongly important	Criteria i is strongly more important than objective j
7	Very strongly important	Criteria I s very strongly more important than objective j
9	Extremely important	Criteria i is extremely more important than objective j
2,4,6,8	intermediate values	midway between the above value

Compare the two criteria found in the last column of the table

Major criteria

	Extremely important		Very strongly important		strongly important		Weak impotent		Equally important		Weak important		strongly important		Very strongly important		Extremely important	
conomic riteria	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Environment al criteria
conomic riteria	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Administrati e criteria
conomic riteria	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social criteri
nvironment l criteria	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social criteri
nvironment l criteria	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Administrati e criteria
ocial riteria	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Administrati e criteria

The major criteria includes economic criteria, environmental criteria, social criteria & administrative criteria

sub criteria 1: Economic criteria

Extremely important		Very strongly important		strongly important		Weak important		Equally important		Weak important		strongly important		Very strongly important		Extremely important	
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lan
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	O &

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	O &

Economic criteria include capital cost, land cost & operation and maintenance cost

sub criteria 2: Social criteria

	Extremely important		Very strongly important		strongly important		Weak important		Equally important		Weak important		strongly important		Very strongly important		Extremely important
ility	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

Sub criteria 3: Environmental criteria

	Extremely important		Very strongly important		strongly important		Weak important		Equally important		Weak important		strongly important		Ver stro imp
performance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	
performance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	
performance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	
performance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	
sludge quality & quantity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	
sludge quality & quantity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	
sludge quality & quantity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	

Biomass problem	9	8	7	6	5	4	3	2	1	2	3	4	5	6
Biomass problem	9	8	7	6	5	4	3	2	1	2	3	4	5	6
Adaptability to W.W character	9	8	7	6	5	4	3	2	1	2	3	4	5	6

Environmental criteria includes Performance (effluent quality, nutrient removal and technical modification), sludge quality & quantity, Adaptability to waste water characteristics, biomass problem (such as odor and noise) and maturity of plant

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This questioner is develop to obtain statistically useful information about gray water production capacity and other information of Balderas residential area

Personal Information

1. The age of the respondent?

   A) 15-30 B)30-45 C) 45-60 D) Above

2. Sex of the respondent?

   A) Male B) female

3. What is your profession?

4. what is your income per month

5. How many family members are live?

   A) two B)three C) four D) five E) other (specify)

Socio- Demographic Information

6. How many times the cloth of the family wash per week?

   A) once in a week B) twice in a week C) three times in a week D) Other (specify)

7. By which means the cloth of the family wash?

   A) By machine B) By hand

8. If you select question number 7 A part specify the capacity of the machine and is the machine is automatic or manual?

____

9. If you select question number 7 B part how many litter of water you use ?

____

10. What type of soap you use during wash the clothe of the family?

11. When you discharge the water after washing the cloth?
    A) in toilet B) outside the house C) in the septic tank D) other (specify)

12. How many time the family member wash their body per week? (According to the weather)
    A) once in a week B) twice in a week C) three times in a week D) Daily
13. How many letters of water you use during bathing ?

____

14. How many times you wash your hand per day ?
    A) three B) four C) five D) Other (specify)
15. Which type of soap you use at the time of washing your hand and your body

____

16. If there is no water what u use as a source of water ?

____

17. If there is a shortage of water in the house how do you use the existing water? (water saving habit and recycling without any treatment)

____

18. for which purpose Are you volenter to reuse the grey water?
    A) for non domestic purpose (such as for toilet flash, for car washing for gardening e.t.c)
    B) for domestic purpose (such as for cooking drinking and e.t.c)
    C) For All type of purpose
19. How many birr you pay per month?

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Appendix III

To analyze the gay water quality includes phosphate, nitrate, nitrite, ammonia, COD, PH, suspended solid, temperature, total coliforms and BOD use standard laboratory method. the first five parameters are measured by photo spectrometer and the next three parameters are measured by PH/ conductivity/Temperature/TDS meter

BOD measure by gravimetric method and fecal coliforms is analyzed by membrane filter procedure by using laurel sulfate broth