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Water purification technologies in the LDCs, Lake Naivasha in Kenya

Bachelor Thesis

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I. Declaration

I declare that I have written my bachelor thesis titled “Water purification technologies in the LDCs, Lake Naivasha in Kenya,“ by myself with the help of literature listed in References.

II. Acknowledgement

First of all, I would like to thank my supervisor doc. Ing. Vladimír Krepl CSc. for his expert knowledge, his help with the structure of the thesis, and his help choosing suitable technologies for Lake Naivasha. I would also like to thank my family for supporting me, and also my friends for their advice. To Jan Leopold I owe a particular debt of gratitude for helping me express myself more clearly in English and for proofreading of the text.

III. Summary

Composition of water issues in Kenya and water purification technologies in the LDCs for Lake Naivasha in Kenya.

Kenya is a water scarcity country with poor water management. The majority of the population has no access to clean water while agriculture uses freshwater resources inconsiderately. The poor wastewater management is the most important issue for Kenya. The industry and agriculture frequently use water from lakes and rivers which leads to a long-term decrease in fresh water sources and the increasing scarcity of clean drinking water. This bachelor thesis is aimed at the Lake Naivasha area which is known for its problems of ecosystem degradation and water quality deterioration. This is due to the large areas for cultivation of cut flowers, growing vegetables on large area plantations and population growth in this area. Cultivation of cut flowers leads to accumulation of nutrients in the lake which causes ingrowth of the lake by aquatic weeds. The Naivasha town is the biggest polluter due to untreated sewage water. Therefore, the protection of Lake Naivasha from pollution and improving of the situation of inputs from the rivers Gilgil and Malewa is necessary. This thesis shows protection by water purification technologies used in the sources of pollution. These technologies were selected due to natural, climatic and social conditions. The study also lists technologies proposed for further treatment of water with the possibility of using it as a source of drinking water. This bachelor thesis may be an inspiration for environmental organizations dealing with Lake Naivasha ecosystem, water managing companies or research facilities dealing with water quality in East Africa.

Keyword: Lake Naivasha, irrigation, flower farms, purification technologies, water quality, water pollution, water protection, water scarcity, wastewater treatment, WWTP

IV. Abstrakt

Literární přehled ohledně problematiky vody v Keni a pro technologie čištění vody v rozvojových zemích, zaměřené na jezero Naivasha v Keni.

Keňa je země s nedostatkem vodních zdrojů. Mnoho obyvatel nemá přístup k čisté vodě, zatímco zemědělství využívá sladkovodní zdroje nešetrně. Nejdůležitější otázkou je kanalizační systém a nakládání s odpadními vodami. Průmysl a zemědělství často využívá vodu z jezer a řek, které vedou k dlouhodobému úbytku vody ve sladkovodních zdrojích a zvyšují nedostatek nezávadné pitné vody. Tato bakalářská práce se zabývá okolím jezera Naivasha, které je známé kvůli problému degradace ekosystému a zhoršení kvality vody v jezeře. Je to dáno hojným pěstováním řezaných květin kolem jezera, pěstováním zeleniny na plantážích a zvyšujícího se počtu obyvatel v okolí jezera. Květinářský průmysl má za následek znečištění jezera kvůli nárůstu živin v jezeře, které způsobují zarůstání jezera vodními plevely. Město Naivasha je největší znečišťovatel vzhledem ke špatnému stavu kanalizační sítě a tedy znečišťováním jezera odpadní vodou. Z těchto důvodu je nezbytná ochrana jezera Naivasha před znečištěním těmito zdroji a řek Gilgil a Malewa. Tato práce představí ochranu jezera pomocí technologií pro čištění vody použité přímo ve zdrojích znečištění. Tyto technologie byly vybrány vzhledem k přírodním, klimatickým a sociálním podmínkám. Ve studii jsou zařazeny také technologie zabývající se dalším ošetřením vody s možností využití jí jako pitný zdroj. Tento materiál může být inspirací pro organizace zabývající se životním prostředím, organizace zabývající se ekosystémem jezera Naivasha, nebo ve vodohospodářských institucích a výzkumných pracovištích, zabývajících se kvalitou vody ve východní Africe.

Klíčová slova: jezero Naivasha, nedostatek vody, zavlažování, květinové farmy, kvalita vody, znečištění vody, čistící technologie, čištění odpadních vod, ČOV

V. Contents

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VII. List of Abbreviations

BOD	Biological oxygen demand
CWs	Constructed wetlands
DAF	Dissolved air flotation
DNIP	Draft National Irrigation Policy
EcoSan	Ecological Sanitation
EIA	Environmental Impact Assessment
EMCA	Environmental Management and Coordination Act
E. coli	Escherichia coli
FAO	Food and Agricultural Organization
GBH	Gravel bed hydroponic
GDP	Gross domestic product
GIZ	German Development Cooperation
GTZ	German Technical Cooperation
KWS	Kenya Wildlife Services
LANAWRUA	Lake Naivasha Water Resource Users Association
LNIMP	Lake Naivasha Integrated Management Plan
LNRA	Lake Naivasha Riparian Association
MF	Microfiltration
MOCP	Moringa Oleifera Coagulant Protein
MRL	Maximum residue limits
MWI	Ministry of Water and Irrigation
NAIVAWASS	Naivasha Water Sewerage and Sanitation Company
NEMA	National Environmental Management Authority
NF	Nanofiltration
NTU	Nephelometric turbidity unit
RO	Reverse Osmosis
RWTP	River wastewater treatment plant
SBR	Sequencing Batch Reactor
SIDA	Swedish International Development Cooperation
SuSaNa	The Sustainable Sanitation Alliance
TA	Total Alkanity

TH	Total Hardness
TSS	Total suspended solids
UF	Ultrafiltration
US-EPA	United States Environmental Protection Agency
WHO	World Health Organization
WRMA	Water Resources Management Authority
WSP	Water Service Provider
WWF	World Wildlife Fund
WWTP	Wastewater Treatment Plant

1. Introduction

Nowadays, one of the major global issues is the shortage of drinking water on Earth. It is possible to identify several causes of the problem, namely, the increase in human population, excessive water sources wastage or its industrial using and polluting them. This work deals with preserving the drinking water sources and using technology to improve their quality. The work is focused on Kenya in East Africa, particularly on Lake Naivasha.

Kenya and other African states as well, suffer from water scarcity. Most of the rivers in this area are unnavigable and as in other equatorial countries, this is a major problem during the dry season. In Kenya, there are many lakes. Unfortunately, most of them are salty and therefore not usable for drinking. The lakes, including freshwater Lake Naivasha, are situated in the Rift Valley. Lake Naivasha is very important for its ecosystem and as a freshwater source. However, the amount of the lake water is continually dwindling. This could be caused by irrigation agriculture farms and growing horticultural industry in the vicinity. The flower farms are also big polluters of the lake by nutrients due to the fact that for the fastest production of flowers, it is necessary to use large quantities of pesticides, herbicides and insecticides. Others polluters are the Malewa and Gilgil rivers mainly due to the deforestation in areas around the upper streams. However, the biggest problem would be poor wastewater management in the area. The Naivasha town has more then 100 000 inhabitants, but its sewer system was built for 20 000. The ever growing number of population equals more water consumption and more wastewater at the same time.

The main aim of the work is to introduce the protection of the water in Lake Naivasha with appropriate technology according to the local environmental conditions and to give a brief summary of the water purification technologies for this lake. The wastewater treatment technology would be a solution for improving water quality in the lake because the wastewater treatment technology would purify water in the sources of pollution, therefore it would prevent the infusion of the waste water into the lake and thereby prevent the contamination of the lake water. This study will introduce the summary of the main sources of pollution and for each of these it will propose the best solution of treatment considering the technology and systems which have already been used in the area. The study will also design a solution for water saving in the area during the dry season.

2. The Aim of thesis

The Aim of this bachelor thesis is to submit an integrated survey of pollution sources of Lake Naivasha. With the aid of statistics, information centers and scientific articles, the thesis seeks to find the biggest source of pollution and to suggest technologies and procedures for preventing this pollution. The main aim is the protection of the water in Lake Naivasha by appropriate technology in accord with the local environmental conditions and also to give a brief summary of the water purification technologies for this lake and nearby localities which should be used mainly for the benefit of the population and the wildlife of this area.

3. Methods

This thesis rests upon the analysis of the available literature in English regarding a whole range of problems concerning sources of drinking water in Kenya, information from scientific articles and researches about Lake Naivasha conducted during the last 30 years. The most frequent sources of scientific articles were Hydrobiologia, Journal of Environment and Earth Science and Journal of Agriculture, Science and Technology.

The thesis is based upon the study by George E Otiang'a-Owiti and Ignatius Abiya Oswe, "Human impact on lake ecosystems: the case of Lake Naivasha, Kenya" (2010), and the book "Lake Naivasha: experiences and lessons learned brief" written by Higgins, Odada and Becht (2011). The information about the quality of water in the lake was learnt from the research "Mitigating the Water Footprint of Export Cut Flowers from the Lake Naivasha Basin, Kenya" by Mekonnen, Hoekstra and Becht (2012). Further, the data about the situation of wastewater in Naivasha town were obtained from study "The Water Crisis in Kenya" by Samatha Marshall (2011). Lastly, the determination of suitable treatment technologies was conducted with the help of the research "Treatment of flower farm wastewater effluents use constructed wetlands in lake Naivasha, Kenya" by Kimani, Mwangi and Gichuki (2012) and the thesis by Cornelissen (2014) "Rehabilitation of the former Northern Swamp Lake Naivasha - Kenya".

4. Literature Review

4.1 Background of the Republic of Kenya

4.1.1 Basic information

Kenya is a country located in Eastern Africa, bordering with Tanzania, Uganda, Ethiopia, South Sudan, and Somalia. The official name is The Republic of Kenya and it is a presidential representative democratic republic. From March 2013, the president of Kenya is Uhuru Kenyatta (Commonwealth, 2015).

The total area is 580,370 km^2 (WB, 2014a). The capital city Nairobi is also largest city with more than 3,363 million inhabitants. It is located in the South, 1700 m above sea level (CIA, 2013). The second largest city is Mombasa, on the south coast of the Indian Ocean, with million inhabitants. Mombasa is also the largest port on the East African coast and the most significant trading corridor in the sub-region (AfDB, 2013). The official languages are English and Kiswahili (CIA, 2011). The total population is 45,546,000 (FAO, 2014). Most of them, 75.5% is rural population and 82.5% is Christian. There are six main ethnic groups. The biggest, with 22%, is Kikuyu (CIA, 2011).

4.1.2 Geography

From the geographical point of view, Kenya can be considered as a mountainous country. Most of the country is covered by the Great Rift Valley where the highest mountain in Kenya lies; Month Kenya with an altitude of 5199 meters (Mahaney, 2004). Kenya is also a coastal state with 536 km long coastline which stretches from the northern border with Ethiopia along the Indian Ocean to the southern border with Tanzania (Advameg, 2015). Kenya lies on the Equator. This affects its natural, environmental and living conditions.

In the south are the important Mombasa city and the capital city Nairobi. In the west, the most important geographic point is the Lake Victoria. From northwest to the central part of country there is the Great Rift Valley where large numbers of tectonic lakes are situated. The north is dominated by 250 km long the Lake Turkana (Odada, 2006). The northeast is presented by desert landscape.

4.1.3 The soils

Land in Kenya is divided by landscape with difficult topography, areas of precipitation, natural conditions and of course natural materials of soil. In the west of the country, there are highly weathered soils leached with accumulations of iron and aluminum oxides. The central Kenya‘s and the highlands´ soils contain mainly the nitosols and andosols due to their volcanic origin. The soils of semi-arid area are mostly sodicity, salinity and vulnerability to erosion. Near the coast, the soils are composed by fertile land such as acrisols and luvisols. The Rift Valley soils are predominantly saline with high sodium content (FAO, 2005).

4.1.4 Climate in Kenya

Kenya has climatic conditions typical for tropics even though it lies on the Equator. The climate is best described as monsoonal, which means that there is a rainy season and a dry season. However, in Kenya these seasons are more divided by four distinct times of year. The first one is the Warm dry season which lasts from January to late March and the lowest rainfall is in January, with an average of 40mm. Temperatures range between 11° C to 21° C (WWCI, 2015). The second one is called Long rains. It lasts from March to June and its most intense rain falls in April with the maximum of 250mm. The average temperature is around 30° C. The third one is the Cool dry season. It is from July to September and its weather is typically dry with lower temperatures. The last one is the Short rainy season lasting from October to December. It is wet with balanced amounts of rainfall during these months. However, in particular parts of the country the timing can be slightly different (UNON, 2015). There is a big difference between climate in Nairobi in the South and Marsabit in the North. That leads to variable rainfalls from less than 200 mm in northern Kenya to over 1 800 mm on the slopes of Mt. Kenya. The climate is influenced by the various inter-tropical zones which range from permanent snow area above 4 600 meters on Mt. Kenya to a desert type area in the north of the country. About 80% of the country is arid and semi-arid (FAO, 2005).

4.1.5 Economy

Agriculture is the main sector of Kenya’s economy and its performance influences the total economic growth of the country. In 2014, the Gross domestic product was US$ 62.7 billion with an annual growth rate of 5.7% (IMF, 2014), and agriculture contributed 29.5%, industry 19.8% and services 50.7% to the GDP (WB, 2013a). About 67% of the total population is economically active, female by 62% and male by 72% (WB, 2014). Agriculture employs 75% of the population, contributes 29.5% to GDP and accounts for 50% of export earnings. Main export products are tea, coffee, corn, vegetables, dairy products, beef and fish (CIA, 2013). Annual usage for freshwater withdrawals in agriculture is 79.2%. Just for comparison, in industry it is only 3.7%. Tourism is the largest source of income. The service base contributes around 50.7% of GDP (WB, 2013b).

4.1.5.1 Agriculture:

The rangelands cover the remaining 82 % of the land in Kenya (KLA, 2000). Cattle, sheep and goat breeding are predominant. Therefore, Kenya export consists mainly of meat, milk and wool. Plant production is weaker because Kenya has a very small amount of arable land. Overall crop production is divided into small farms and then large plantations for a market economy concentrated around freshwater lakes such as the Lake Victoria, Lake Naivasha or Lake Baringo. In general, the agriculture is concentrated in the eastern part and central part of Kenya (MoA, 2013).

Floricultural industry is the second largest in the agricultural sector after the export of tea and ensures that the country's income comes mainly from exports (BI, 2012). During the 1980s the floriculture industry blossomed around Lake Naivasha with farms now covering more than 4,000 hectares (Mekonnen, 2012). The floriculture industry earns grossing approximately 40 billion Kenyan Shillings ($425 million) annually (Henley, 2014).

4.1.5.2 Industry

The priority sectors are those whose domestic production is meant to replace expensive imports, i.e. food, textile and leather industry, petroleum products (domestic refinery in Mombasa), paper and printing industries (Bussinesifo, 2012). Industrial production growth rate is 5.1 % (CIA, 2013). The horticulture sector, oil refining; aluminum, steel, lead; cement, commercial ship repair and tourism in services sector are also important (CIA, 2013).

4.1.6 Politic and socio-economic situation

Kenya can be characterized as a developing country which has begun to increase its economic benefits during the past few years. Kenya's economic problems can be derived from the politico-historical situation. Kenya had been a colonized country.

In December of 1964, it became an independent republic. The first president was the leading African nationalist Jomo Kenyatta. Kenyatta was cooperating well with the western nations and improved the economy in Kenya. He died in 1978. After that, the president Daniel Arap Moi was elected (Sundet et al., 2009). He pushed for the centralization of the state and deepening africanization. During next twenty years, there was an economic crisis and political instability. In the 90s, the Forum for the Restoration of Democracy began to take shape (BBC, 2014). In 2010 new constitution was accepted. In 2013 there was another presidential election. Uhuru Kenyatta, the son of Kenya's first president, won the presidential election. After his first year in the presidential office, Kenya revised the way the GDP was calculated, making the economy 25% bigger than previously thought - and the fourth biggest in sub-Saharan Africa. However, the country is still unstable and there have been numbers of terrorist attacks during last several years (BBC, 2014).

4.2 Hydrology and water situation in Kenya

4.2.1 Basic hydrology and water situation

Kenya is classified as a scarcity country with only 466.7 cubic meters of renewable freshwater per capita (WB, 2013c).[1] The reasons are the geographical location and climatic conditions. Due to the continued population growth, it has been estimated that by the year 2025, Kenya's per capita water availability will be 235 cubic meters per year, about half less than today (Mogaka et al., 2005).

Kenya´s average rainfall amount is around 630 mm per year, but in the north of the country, it is only about 200 mm per year (FAO, 2010). As it was mentioned above, the country's economy is focused on agriculture that is sustainable only due to irrigation and agrochemicals. This obviously has a big impact on water quality.

Furthermore, in extensive areas of the country, there is just 61.7% of population with water access. Kenya has potential for improvement, but unfortunately, there is still a big difference in access to clean water between rural and urban populations. In 2012, 55.1% of the rural population had access to safe water.[2] On the other hand, only 82.3% of the urban population had the access to safe water (WB, 2012).

Kenya is known for its poor water management. Even 20 years ago, most of the country budget went into water treatment because water sources and groundwater were in a very poor condition. Waste waters are used beyond their sustainability and this causes contamination of drinking water and accumulation of sewage water which is needed to be pumped out (Higgins et al., 2011).

At the end of 2002, the Water Act was passed after it was approved by the governing body of aquatic resources. It authorized the establishment of the Water Resources Management Authority (WRMA) which is supposed to focus on overall regulation of the country's water resources. Therefore, this Act established that anyone who wants to use water has to pay user fees (Mogaka et al., 2005).

[1] By comparison: 2005 - 647 m^3, 2007 -548,3m^3, 2012 – 473.4m^3, 2013 – 466.7m^3 (WB, 2013c).

[2] In many villages the water is not introduced. Villagers must therefore go for water to distant cities up to tens of kilometers far. Mostly women and children walk for the water. Due to this fact, some children are not attending school. Water is available from public water taps on main streets. Since 2002 the water fee is 5 shillings per 20 liters. Most of the population earns only 250 shillings a day and a half of that is spent on the water (Marek, 2012).

4.2.1.1 Water resources

Water resources in Kenya consist of inland saline or fresh water lakes, the Indian Ocean, permanent and seasonal rivers, wetlands and ponds (KLA, 2000).

In the country there are five main drainage areas involving of 579 770 km^2 which have a total water flow of over 14,836 million m^3 (KLA, 2000). The first one is the Lake Victoria basin which is covering 8% of drainage area. The second one is Rift Valley and inland lakes, covering 22.5%. The third and the fourth are presented by the Athi River and Tana River in the Central East Coast basin and they cover 11.5% and 21.7%. The last and the largest drainage area, covering 36.3%, is Ewaso Ng'iro River (Monroy et al., 2007).

4.2.1.2 Water supply

The largest part of water bodies are Lake Turkana and Lake Victoria. The largest rivers are Tana and Galana in the North and Athi River in the East. Most lakes are located in the Rift Valley. The lakes were formed due to the poor water flow of the rivers.

The renewable surface water resources are estimated at 20.2 km^3 a year. The volcanic and quaternary geological formations are rich in groundwater. "*Underground water supplies are 3 km^3 and about 3.5 km^3 of groundwater is produced annually, the annual safe yield abstraction of groundwater is estimated at 0.6 km^3"* (FAO, 2005).

The total capacity of large and medium dams is about 4.1 km^3. The biggest dams are situated at the Tana River. The Seven Forks Hydro Stations have five main stations with installed capacity of 543.2 MW (GTZ, 2007). There are 9 lakes with a surface area of 10 747 km^2. Most of the lakes are saline with the exception of Victoria, Naivasha and Baringo. The lakes Nakuru and Naivasha have been declared Ramsar sites as wetlands of international importance for conservation of biodiversity (FAO, 2005).

4.2.2 Water quality

The quality of water in Kenya is in a very bad state. The pollution of water in cities is increasing. This situation can be related with the continually rising number of inhabitants and the development of local industries. High population growth is usually connected with an increased usage of water resources. "*The urban population is steadily increasing while access to functioning and affordable wastewater facilities in Kenya is not"* (UNEP, 2010). Even though they are illegal in Kenya, slums arise in the large cities and towns, therefore there are no services being offered and the hygienic conditions are alarming which largely contributes to the water pollution. Generally, the situation concerning waste water is very bad. Even though the usage of the waste water is forbidden, the majority of the impoverished population uses this water for doing the laundry and stock water supply. Generally, Kenya has poor water management and waste water system. The sewage system is missing in villages and slums in the cities (Permatasari, 2004; Marshall, 2011).

The issue of water pollution does not apply only to the slums of the large cities and towns. As it was previously mentioned, Kenya's economy is based on the agriculture (FAO, 2003). On top of that, the illegal gathering of water from the drinking water sources is not included into the statistics. There is another aspect of the influence which the agriculture has on the quality of water. Sewage matter and garbage from agriculture, urbanization and industry continuously pollute water resources in Kenya (KLA, 2000).

Degradation of water resources could be also caused by inappropriate farming methods which lead to soil erosion and permit heavy siltation of the rivers. Pesticide application also contaminates the water. Secondly, the use of water bodies as dumping sites for waste leads to contamination of the water resources by solid pollutant (KLA, 2000).

Table 1:Water quality in Kenya, 1963-2012

Parameter	Desired level	1963	1974	1984	1999	2000	2012
Colour	Colourless	Colourless	Colourless	Slightly coloured	Coloured	Highly coloured	
Turbidity Sediment Load	Clear nil	Clear nil	Clear slight	Turbid moderate	Turbid heavy	Very turbid heavy	Very turbid
Total Dissolved Solids	Normal	Normal	Fair	Moderate	Moderate increase	Very high increase	Unacceptable <1200 (mg/L)
Bacteriological Contamination	No pathogenic bacteria	Little contamin.	Little contamin.	Little contamin.	Gross contamin.	Gross contamin.	Gross contamin.
E. coli					moderate	polluted	Critical
Total coliforms							Critical
Biological oxygen demand	Less than 5mg/l	5-20	10-20	20-40	40-60	60+	30+

Source: (KLA, 2000; Omondi, 2012; Veenvliet, 2014).

4.3 *Background of water situation of Lake Naivasha*

4.3.1 Location and geography

Lake Naivasha lies between 0° 08' to 0° 55' S and 36° 00' to 36° 45' at 1890 meters above the sea level (Harper, 2004; Higgins et al., 2011; P. M. Njogu et al., 2011). It is the second largest freshwater lake in Kenya. It is located in the Great Rift Valley and it serves as the only source of drinking water for population around the lake because the other Rift Valley´s lakes are saline (Higgins et al., 2011). Moreover, it is widely used as the main source of water for irrigation of the abundant vegetable and flower farms. Although its area takes up 145 km^2, the lake a top depth of only 8 meters (Mireri, 2005). This might be the reason why the lake is one of the largest ecosystems in Kenya. There is great fish species diversity, bird diversity and, of course, hippos, giraffes, buffaloes and zebras are just a few of the species that thrive at the lake and its surrounding swamps and grasslands (WWF, 2011).

4.3.2 Climate

The climate is semi-arid and is influenced by the Aberdare Range which lies at an altitude around 3000 meters. The mountain range forms a rain shadow (Mireri, 2005). Although the annual rainfall in the Aberdare Range is 1350 mm, average rainfall in the lake area is 650 mm (Harper, 2004; Higgins et al., 2011). Climate can be divided into the dry and the wet season. The driest times of the year are February and July with the average value of around 20 mm of rainfall (Muthuwatta, 2004).[3]

4.3.3 The soils

As already mentioned, the lake is located in the Rift Valley. The volcanic formation in the Rift Valley is the reason why most of the soils in the area have high sodium content (Higgins et al., 2011). According to the Kenya Soil Survey conducted in 1982, there are mainly the lithosols and sodicity soils around the southern shore of the lake, because they are developed on volcanic ashes mainly composed of fine pumice grains and create majestic pumice layers (KSS, 1982). Therefore, the soils are very permeable, with very-low water-holding capacity. Very frequent irrigation activity led to water seeping down to the groundwater. The high permeability of the soils, the gentle slopes around the lake and rarely occurring surface runoffs may cause that the majority of agrochemicals are transported toward groundwater (Higgins et al., 2011).

4.3.4 Hydrology and water supply

The Naivasha basin ecosystem area is composed of an endorheic fresh water system. "*This lake system consists of a main lake (Lake Naivasha), a semi-separated sodic extension (Oloiden Lake) and a separate sodic crater lake (Sonachi) with a basin approximately 3400 km^2*" (Kuhn et al., 2012). The inflow into the main lake comes from the rivers: Malewa, Gilgil and Karati. The Karati River in the northeast is an ephemeral stream that flows into Lake Naivasha on about 100 days each year (Boar & Harper, 2002). The overall catchment of the area is more than 2000km^2 (Kuhn et al., 2012).

The water inputs to the lake include rainfall, inflows from the rivers and underground water movement from the catchment (Mireri, 2005).The groundwater levels in the vicinity of the lake closely follow its water level variations. The surface inflow recharges the surrounding shallow and deep aquifer systems are the reason that the lake remains fresh (Becht & Nyaoro, 2006).

The water levels of the lake respond to long-term wet and dry climatic cycles in which the water level can change several meters within a few months, causing a horizontal change of

[3] On the 14th of February, Saint Valentine´s Day, the production of the flowers reaches the maximum. February is the driest and warmest period of the year, due to the Valentine´s day intensive irrigation is necessary for rapid and excessive production of flowers. The farms must draw irrigation water from other sources than the groundwater. According to the article "The true price of water" in report of Rozvojovka, the water is pumped from the lake by water pumps (Marek, 2012).

several kilometers. These hydrological dynamics add an extra dimension to the riparian ecosystem as well as to the water resource management issues.

The rapid growth of the flower industry and expanding smallholder irrigation has increased the pressure on the volatile water resources of the Naivasha basin. The total irrigated commercial farm area around the lake is 4 450 ha. Cut flowers account for about 43% of the irrigated area followed by vegetables with 41 % (Mekonnen & Hoekstra, 2010).

Until 1999 the groundwater to the north of the lake was exploited as the water supply for Naivasha town. However, due to the growth of the flower farms, a large area was put under cultivation. Recently, horticultural farms have started operations in the upper catchment taking water from the river (Becht & Nyaoro, 2006).

It will be necessary to raise awareness among the flower farms so that they install the necessary equipment and implement the right measures to use water in a sustainable manner (Mekonnen & Hoekstra, 2010).

4.4 The state of Lake Naivasha

4.4.1 Water quality of Lake Naivasha

Nowadays, this area is very important for Kenya´s economy because during the last 20 years, a very intensive agricultural production of vegetable and cut flowers in large farms has taken place around the lake. That leads not only to loss of water in the catchment, but also to the constant pollution of the lake. However, at the beginning of the 21st century many organizations did their best to facilitate abidance of the Water Act and the Water Management Plan which has led to the maintenance of water quality in the lake. On the other hand, a steady growth of population in surrounding towns and still growing industries may lead to dangerous enlargement of the pollution of the lake due to the poor management of the sewage systems of Naivasha town and the farms, in spite of the many government measures.

In overall, Lake Naivasha still has relatively healthy basis and the water quality parameters are in acceptable condition (Higgins et al., 2011).

4.4.2 Comparison and analysis of water quality conditions

In order to use technologies for improving the quality of the water in Lake Naivasha, it is, first of all, necessary to know the quality of water, the main sources of pollution and the environmental conditions of the lake itself. In general, quality of water can be estimated by the variety of plants and animals which are present in it. Among the parameters defining the trophic status, it is possible to include the total amount of nitrogen, phosphor, chlorophyll-a and water clarity. An excess of nutrients in the lake denotes eutrophication which leads to the ingrowth of the lake. This means organic pollution of phosphorus and nitrogen (Ndungu, 2014). The excess of these nutrients has been the main reason for the invasion of the water hyacinth, *Eichornia crassipes* (Jimoh et al., 2007).

The main water issues of the lake could be water abstraction, agrochemicals and sewage pollution, destruction of riparian habitat, over-fishing and erosion (Becht et al., 2007).

4.4.3 Pollution of Lake Naivasha

To approach the pollution situation of the lake and water loss from the area during the past 40 years, it is necessary to summarize all the reasons and causes that lead to contamination. In general, the situation of the lake today started in 1980, when the main railway line to Uganda was rebuilt. Because there had already been very good conditions for growing vegetables and other crops around the lake, the infrastructure was built and very cheap rent land attracted thousands of European investors who founded businesses there. As it was mentioned before, due to the suitable climate and natural conditions of the area, the floral industry and the number of vegetable farms began to grow rapidly. Furthermore, the lake is attractive for tourists mainly for its beautiful nature, the infrastructural background with social facilities and also because it is a popular and potent fishing ground.

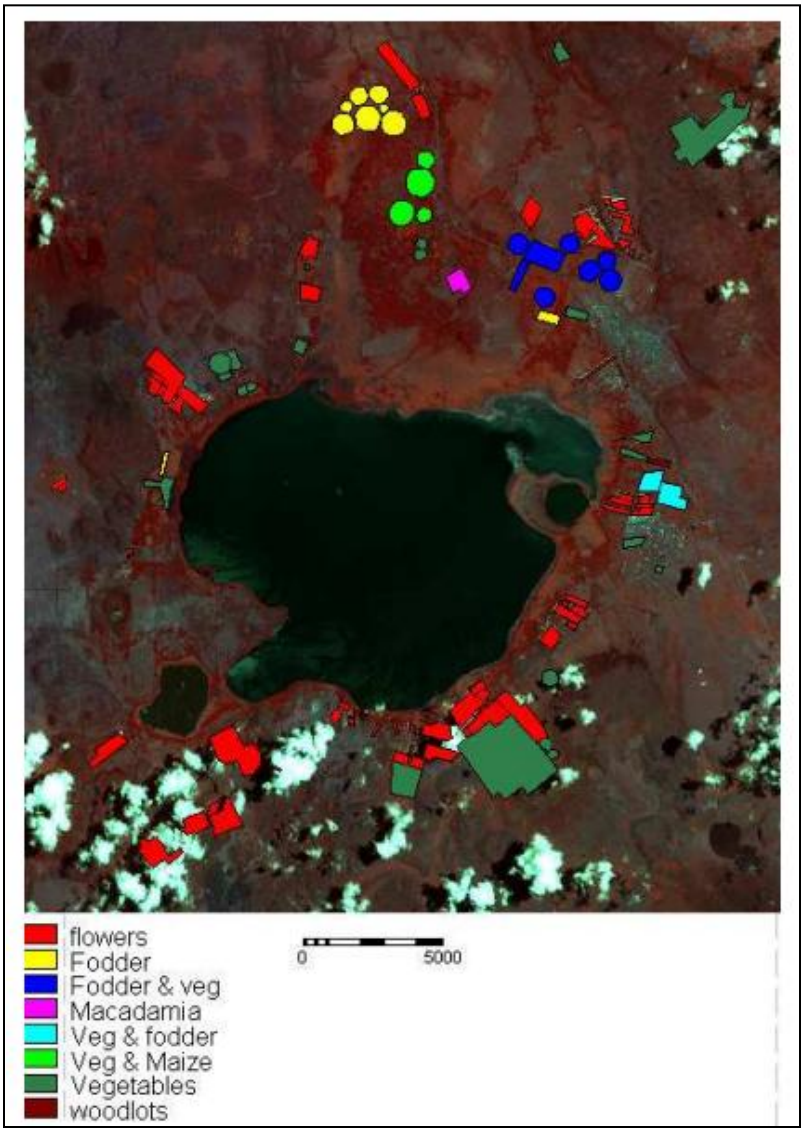
4.4.4 The main sources of pollution:

Many of the authors who concern themselves with the water issues of Lake Naivasha agree on three main causes of the pollution. The first cause concerns the agrochemicals and heavy elements which get into the lake from large horticultural farms. The second source is the sediments brought by the Malewa River and the third reason is rapidly growing Naivasha town with poor securing of waste water. Therefore, the main pollution sources are the horticultural farms, many smallholder farms in the upper catchment and the ever-growing population around the area.

4.4.4.1 Flower farms

The flower industry sector is one of the fastest growing sectors in Kenya today with most of the farmland around the lake practicing intensive irrigated agriculture (Otiang'a-Owiti & Oswe, 2010). Also, the land covered by irrigation crops has increased tremendously in recent years (Becht, 2007).

Figure 1: Irrigation crops around Lake Naivasha.



Source: (Becht, 2007)

The flower industry and agriculture in general are very agro-chemically intensive industry branches. Furthermore, these branches are also very demanding when it comes to water usage. That is why all the farms are concentrated in the vicinity of the water sources, namely: the Lake Naivasha and the Malewa river catchment. Using agrochemicals near the catchment leads to their leakage into the water courses through groundwater or storm run-off during the rainy season.

At the beginning of this century, the studies drawing attention to the pollution of the lake by flower farms started a long-lasting debate on the protection of the ecosystem of Lake Naivasha. In 1996, the Management Plan of Lake Naivasha was adopted by the government (Higgins et al., 2011).

Although the introduction of the Management Plan and Water Act has implied that the lake is still polluted, the elements of pollution were found within the limits set by the World Health Organization (Koaga et al., 2013). These were reflections of the various intervention measures employed by the government. The implementation of these approaches was good for the conservation of the lake and its ecosystem (Koaga et al., 2013).

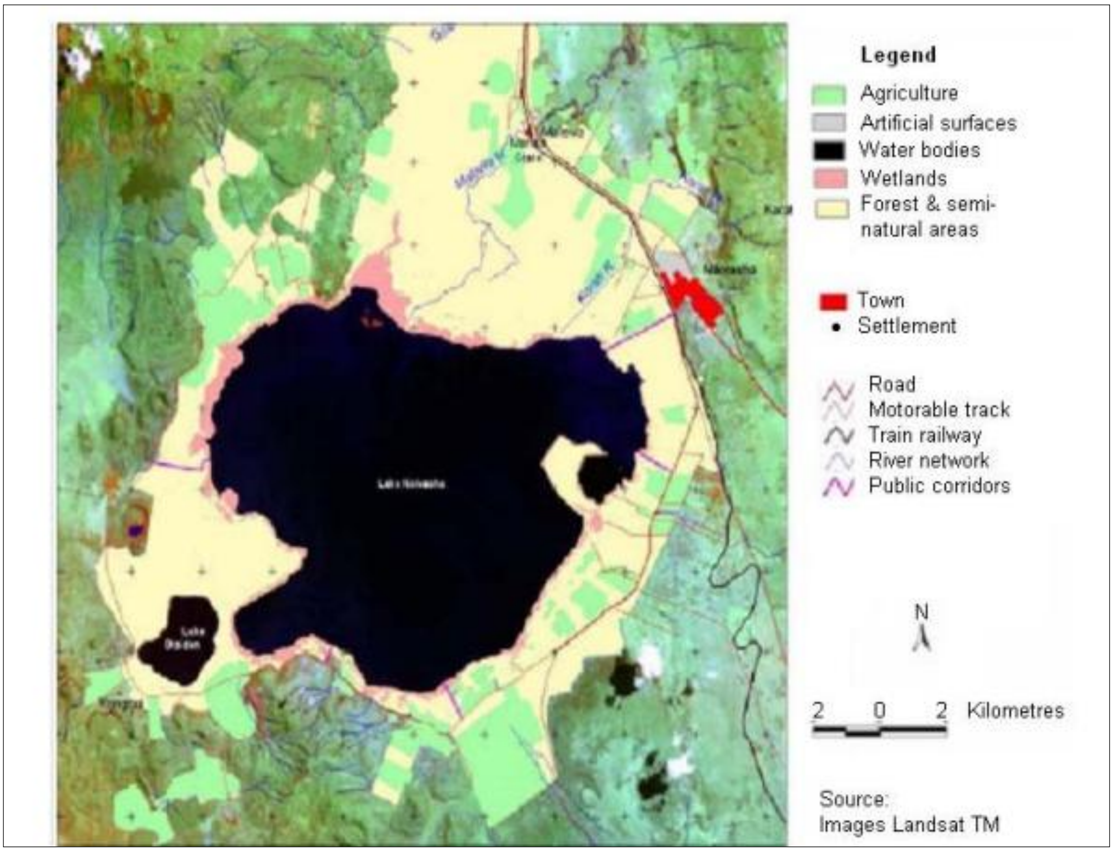
According the study of Becht (2007) and other authors, the risk of agrochemicals ending up in the lake is limited. *"The change to environmentally-friendlier pest control, and better irrigation management, has definitely had a positive effect on the lake´s water quality. However, the agrochemicals contribution of the hinterlands to the lake is higher than the contribution of the farms around the lake"* (Higgins et al., 2011).

Nevertheless, the quickly growing farms offer many job opportunities and for the impoverished local population it is the only way of making a living. The inflow of urban immigration into Naivasha town steadily grows. In 2009, the town had 169,142 inhabitants (Cheserem, 2011), but the areas around lake had 376,243 (Oparanya & Ambetsa, 2009) of which 50,000 worked at the flower farms near the lake (Gårdman, 2008). That leads not only to a great pollution of water sources but, clearly, to larger usage of water. As it was mentioned above, Kenya has extremely faulty water management and in addition to that, the hygienic conditions in the town are alarming. Therefore, we can assume that the town is another important factor influencing of pollution of the lake.

4.4.4.2 Naivasha town

The town of Naivasha is situated 2 km to the southeast from bank of the lake. Nowadays, due to the striking population growth, the town has approximately 200,000 inhabitants. The population growth leads to water issues because more people translates into higher water usage and enlarged need of hygienic, social and sanitation background.

Figure 2: Map of Naivasha town location.



Source: (Mageria et al., 2006).

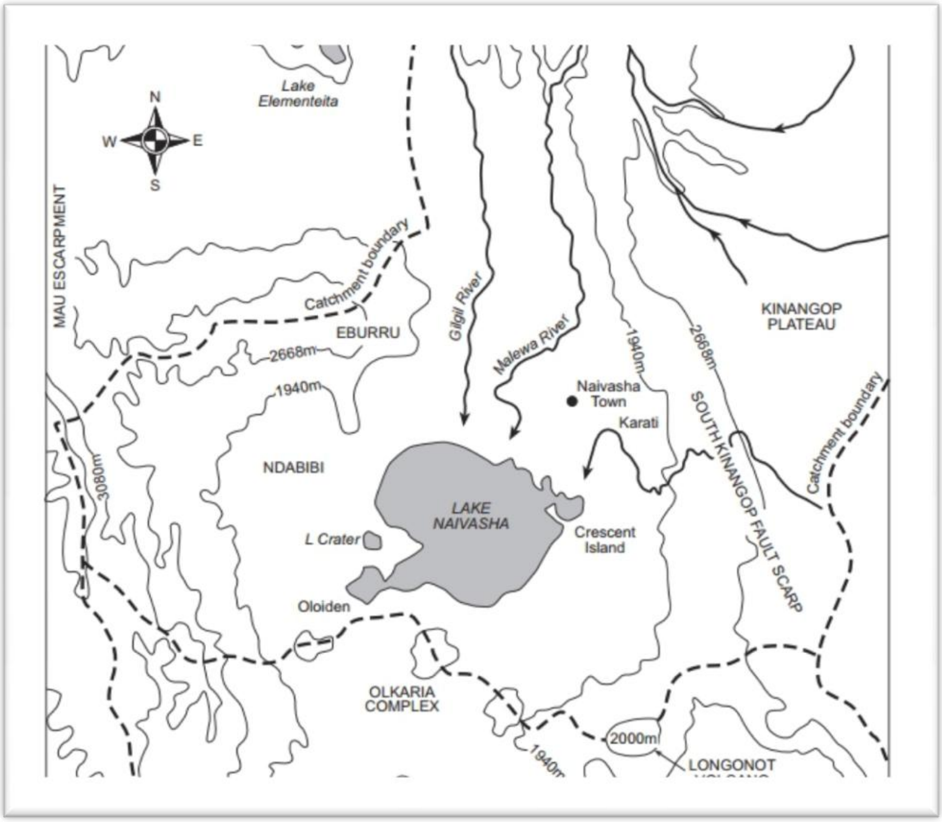
Hygienic conditions are dependent on the adequate supplies of clean and safe water. The town's habitants have limited access to clean water and to basic sanitation services. There are some EcoSan latrines, six clean water production sites with the total of twelve boreholes of quality water. There are also sewerage services and a pipe network (NAIVAWAS, 2015). Unfortunately, canalization is installed only in certain parts of the town (Permatasari, 2004). Similarly, there are only several central water pipes which are located at the main streets and people have to take the water into canisters. Furthermore, there is the situation arising from establishing the Water Act in 2002 that only those who can pay for the water are allowed to use it.

This condition means that people who are living in the slums do not have enough money to pay for the clean water so they use water from the canalization, boreholes and the lake. Therefore, the lake is polluted for example by doing the laundry or doing the dishes. The biggest threat, however, is fecal contamination. Fecal pollution from humans and animals in this area is recognized as the major water pollutant and it has a bearing on public health (Omondi et al., 2013).

The lake provides water for domestic use and shares the same water table with key groundwater aquifers that provide borehole water for the rapidly-expanding human population in Naivasha town and surrounding areas (Otiang'a-Owiti & Oswe, 2010).

The sources of pollutants include semi-treated municipal sewage, agrochemicals surface run-off from Naivasha town and surrounding horticultural farms in the catchment (Otiang'a-Owiti & Oswe, 2010). According to the study by Otiang'a-Owiti and Oswe (2010) the lake has high nutrient levels and it is contaminated with bacterial pathogens, viruses and parasites from partially-treated municipal sewage, animal fecal waste and pit latrines at the settlements that dot the lake shoreline.

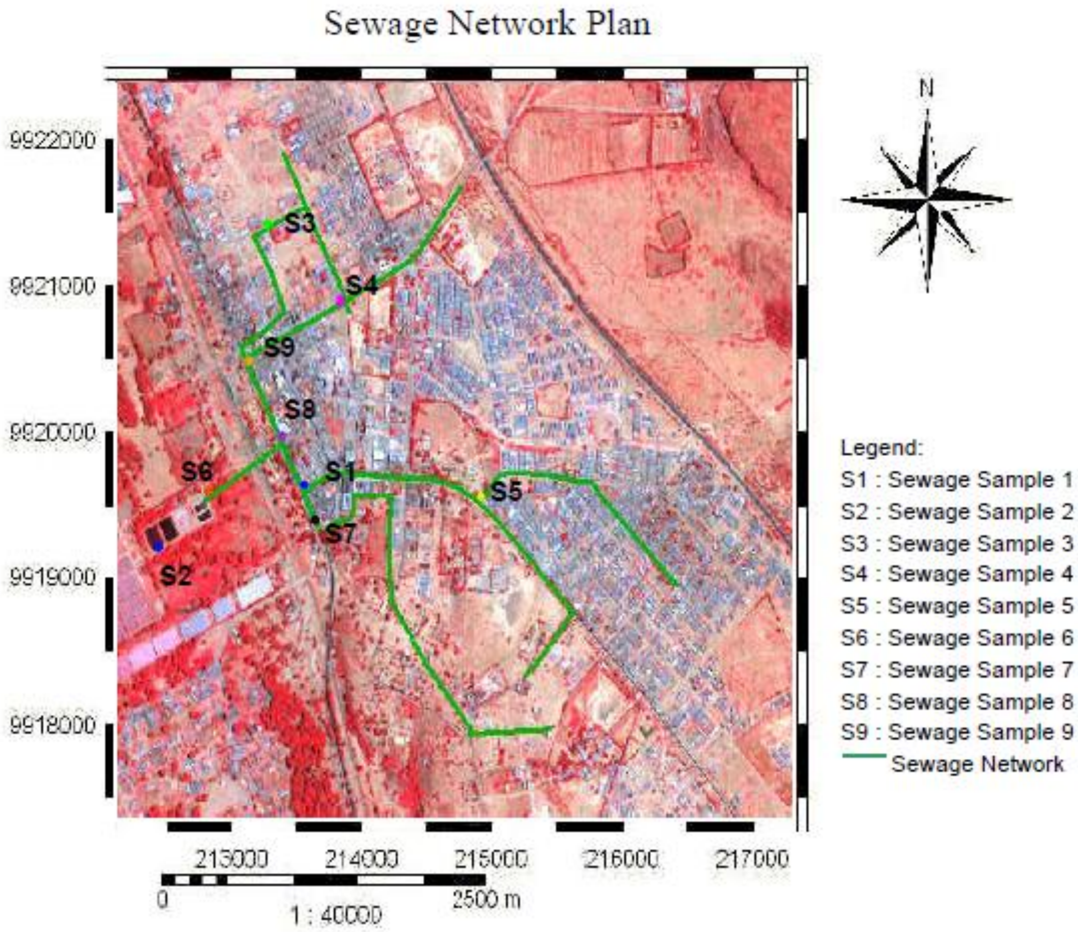
Figure 3:The catchment of Lake Naivasha, showing the direction of its surface water inflows and other physical details.



Source: (Clarke et al., 1990).

The Lake Naivasha catchment has an internal drainage system but no surface outlet. This is typical of Eastern Rift Valley lakes where extensive volcanic activity disrupted the drainage system. That includes the area of Naivasha town with a 40% sewage covering. "*Since presently only 15 % of the population is connected to the sewage system"* (Permatasari, 2004).

Figure 4: Sewage Network Plan the Naivasha town.



Souce: (Permatasari, 2004).

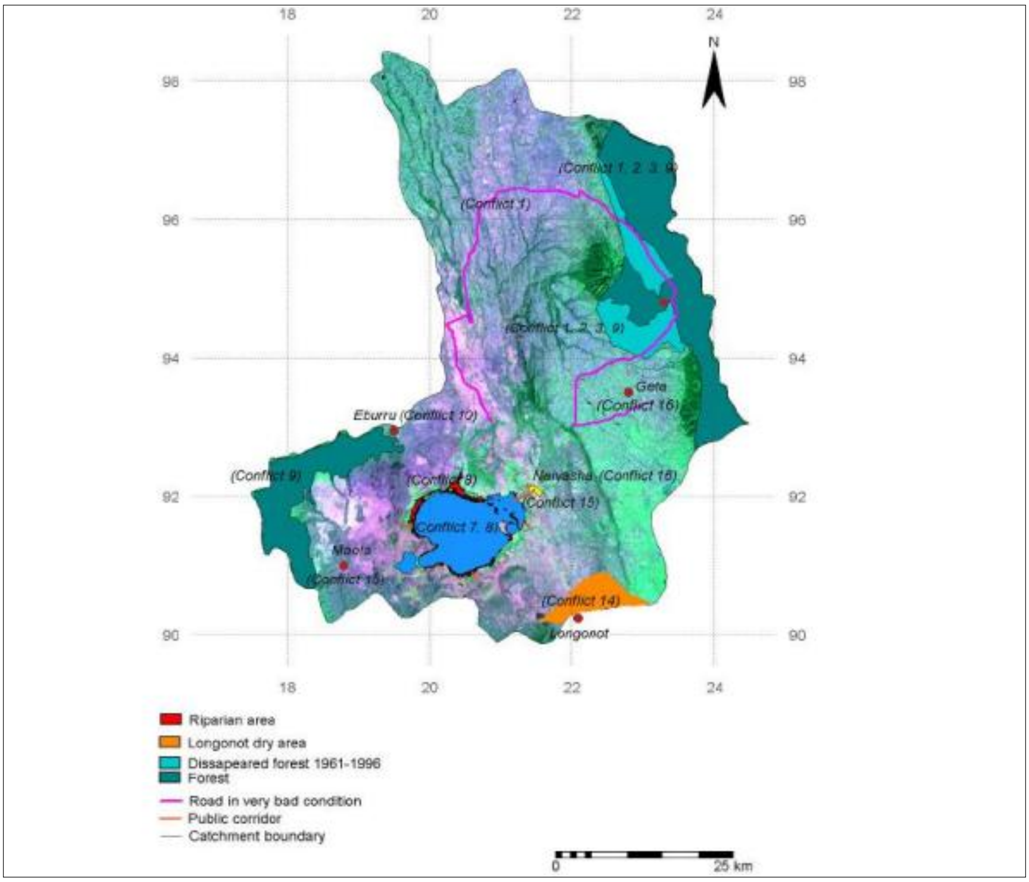
"Naivasha town has a separate system for sewage and drainage. For the sewage system, they have close channel (the water flows through pipe) while for the drainage network there is an open channel (partly the water flow rely on natural channel)" (Permatasari, 2004).

"There is likelihood of contamination of both surface and ground water sources within Naivasha due to inadequate sanitation as communities here depend on bushes, pit latrines and septic tanks for sewage disposal"(Mireri, 2005).

4.4.4.3 The Malewa River

The Malewa contributes to the pollution by two factors - firstly, the settlements along the river and in its catchment and secondly, the presence of vegetable farms along the rivers Malewa and Gilgil. If we look at the catchment of the Malewa River, we learn that the river stems in the Aberdares ranges which are covered predominantly by forests. However, much of the forest coverage has been cleared and transformed into agricultural land. From the environmental point of view, forests are very important for the imbibition of water and its retaining in the ground, a feat managed due to the deep roots of the trees. The forest helps to retain the water beneath its roots and thus it prevents the soil erosion. The deforestation increases the flow rate and clogs the streams with the soil erosion.

Figure 5: Conflict of the area in the Malewa catchment.4



Source: (Fayos, 2002).

[4]"*Consequently, the human activities lead to further siltation as a result of increased sediment yield. Activities including tillage, manure application, cutting down of forests and intensive livestock grazing affect water quality and quantity within the Turasha and Kitiri catchment tributaries of the Malewa River Basin"*(Ogweno, 2005).

In addition, Kenya uses a considerable amount of pesticides to assure higher yield. In the study by Ngundu (2014), it was found out that there are fertilizers present which are based mainly on nitrogen and phosphor. This is confirmed in the research by Becht (2007) in which the primary nutrient associated with sediment transport is phosphorus. Phosphorus also leads to formation of floating mats which is affirmed by the study by Harper (2002). Similar discoveries can be found in the research by Jimoh et al. (2007). By analyzing the samples, they detected very high density of water hyacinth right in the Malewa River. It is possible to assume that the pollutants flow from the river to the lake due to the pollutant sediments in the delta of the Malewa River at the northern end of the lake (Jimoh et al., 2007; Ndungu, 2014). The Malewa River may be the source of pollution due to the density of farms along the river and the deforestation along the upper stream.

The River Malewa is presented as the main source of heavy metal pollution. The study by Njogu (2011) shows, that the Malewa catchment and the point of entry of the river into the lake contain high contents of copper, lead and cadmium. The metals are supposed to originate from the farms upstream, downstream and from traffic pollution from the Nairobi — Nakuru, mainly at Turasha and Malewa highway bridge.

In the study by Ndungu (2014) writes: *"The effluent from the WWTP and direct return flow from greenhouses or agricultural plots have limits effect on the average concentration of the whole lake."*

4.5 *Improving the quality of water in Lake Naivasha*

Lake Naivasha is a large area comprising of 3400 km^2 of water body. As it was mentioned above, this thesis is focused on improving the quality of water in Lake Naivasha by using water purification technologies. In order to do it, it is necessary to target the sites with the highest levels of pollution. The thesis identified the flower farms around the lake, the town of Naivasha and the mouth of the river Malewa as the three primary pollutants of the lake.

This thesis adumbrates a proposal for solving water pollution problem by using water purification technologies. Before any project can be launched, it is necessary to establish the data about the total pollution conditions of area, for example, the ecosystem situation, the number of cities, the growth of the number of inhabitants, the climate and the rainfall change, soil conditions and others factors. In the area of Lake Naivasha, the biggest waste producers are the cities and farms. The most serious issue is an inefficient wastewater treatment system. In developing countries, the most frequent way of disposing of the waste is transporting it and releasing it into a river. Therefore, waste water treatment system must be installed in the sources of pollution in order to improve the water situation in the rivers. The wastewater system and water purification technology system will be chosen according to the following parameters: the amount and the type of pollution, the size of the area which is available for water treatment, the distance from the source of pollution, the treatment effect, the ability to maintain and operate WWTP, and ecological risk assessment of the surrounding ecosystem (VUPP, 2005). If the farms do not have the option of connecting to canalization, the solution would be establishing wastewater treatment every farm separately which means that every farm would treat its waste water by itself using a technology suitable for the given type of pollution.

4.5.1 The technology for purifying the water at flower farms

The flower farms partake in the polluting mainly by releasing of an excessive amount nutrients into the lake, namely of nitrogen and phosphorus. This causes the ingrowth of the lake. Another issue is the contamination of the lake by pesticides and herbicides used at the farms. According to the studies written by students from Moi University (Mburu et al., 2013) and the study from Wageningen (Ohayo-Mitoko & Grace, 1997), pesticides and herbicides belonging in WHO class I. and II. are also used at the farms. Among the agrochemicals being used, there are several which are dangerous for human health for example paraquat and organophosphates.

Therefore, it is very important to secure the lake so that the toxic materials do not get in. One of the ways of accomplishing this is creating a root zone waste water treatment system.

The largest issue of the lake is the outflow of herbicides into the water due to the agrochemicals being flushed out during the rains. According to the article published by Agrotip (2012), this is heavily affected by the amount of rainfall, the permeability the humidity of the soil, the speed of outflow and the distance from water resources. As it was discovered above, the average annual rainfall in this area is around 650 mm.

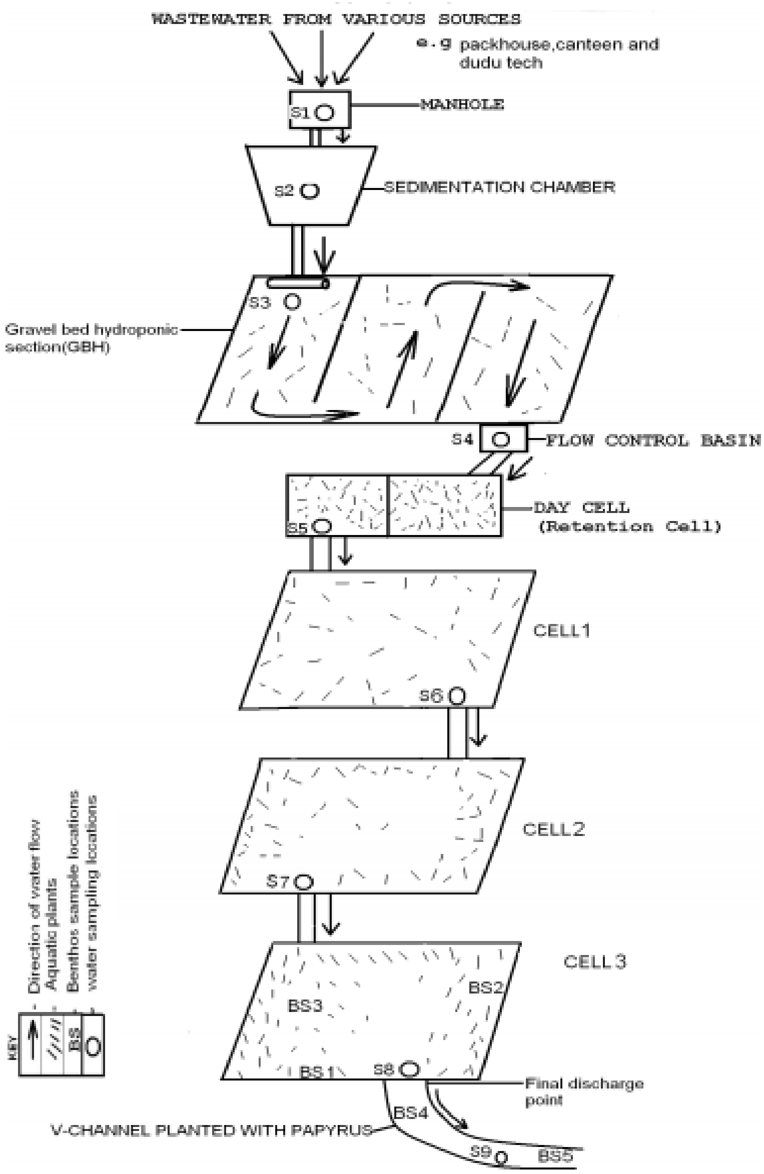
Furthermore, the soils around Lake Naivasha are based on volcanic ashes which have very high permeability due to the large size of its pores. The soils are arid and semi-arid. They are also gritty which means that they are permeable and water is quickly imbibed. The lake is situated in a valley so the entire outflow from the mountainous surroundings is focused into the lake. Because of the rapid water soak it can be assumed that even agrochemicals from farms get into ground water this way. The distance between the lake and the farms is generally in the range of one and two kilometers. All these factors result in a high risk of out-flowing of the pesticides from the flower farms. This could be averted by building clear water storage tanks or underground rainwater storage cisterns. It would be also possible to catch the contaminated water from the farms with the help of an impenetrable foil. However, it is not recommended due to the strong UV radiation in this area which greatly accelerates the attrition of the foils.

Aerobic processes, such as activated sludge, aerobic ponds and lagoon or Sequencing Batch Reactor (SBR), are very effective. The principle is an aerobic treatment tank where the grey water is aerobically treated to encourage the biological treatment of the bacteria. The principle of this technology is based on activated mass of microorganisms capable of aerobic sludge stabilization. This biomass is aerated and maintained in suspension in the reactor vessel. These technologies significantly reduce the level of nitrogen, phosphorus and hazardous substances (GoV, 2007). The disadvantage is that a lot of space is required for digestion tanks. However, for developing countries, it is a suitable technology because of the low cost and simple maintenance.

4.5.1.1 The constructed wetlands technologies:

Kenya now has six working constructed wetlands (CWs) that recycle wastewater and return it clean to surface systems (Raymer, 2011). The constructed wetland technologies used to treat wastewater were constructed in Naivasha area by commercial flower farmers in order to protect the lake against the release of effluents from the flower farms into the environment. One of them is the Kingfisher constructed wetland in Naivasha. „*The Kingfisher constructed wetland was constructed in the year 2005 at approximately $40,000 and was designed to receive approximately 45m^3 of wastewater per day from overall farm facilities. This wetland is a combined (hybrid) system of a subsurface flow system known as gravel bed hydroponics (GBH) section and a surface flow system with three sequential treatment cells*" (Kimani et al., 2012).

Figure 6: The Kingfisher wetland in Naivasha [5]



Source: (Kimani et al., 2012).

[5]S1-inlet, S2-sedimentation chamber, S3-inlet GBH, S4-outlet GBH, S5-outlet day cell, S6, S7, and S8 are outlets cell 1, 2 and 3 respectively and S9-v-channel (Kimani et al., 2012).

Water entering SC1 is, for the first time, exposed to sunlight and air which makes green algae. Then the water overflows by the sedimentation chamber to gravel bed hydroponic section (GBH). The GBH is simply a walled rectangle with alternating wall embankments ensuring that wastewater meanders through the gravel as it is being broken down. "*The large surface area for the microbial attachment provided by the ballast pieces assists in microbial breakdown of organic wastes*. *The GBH top is planted with macro hydrophytes that absorb nutrients and also aids in the transportation of oxygen to the underground bacteria through their rooting systems, hence enhancing the growth of these useful bacterial colonies*. *The same conditions are replicated for wetland cells 2 and 3*" (Khisa et al., 2014). The three surface cells have open surfaces at their midpoints for the purpose of facilitating natural aeration due to exposure to wind and the destruction of pathogenic organisms through ultraviolet irradiation. The constructed wetland in Naivasha has riparian buffer installation which removes agro-chemicals from horticultural farms (Raymer, 2011).

The objective of constructed wetlands is to decrease the amount of nutrients in the wastewater effluents. Accumulation of nutrients could result in eutrophication of the recipient water bodies. However, even though the outflow effluent is filtered, it is still rich in nutrients. The improvement of the treatment efficiency could be achieved through combination of various types of constructed wetlands (Vymazal, 2007; Kimani et al., 2012).

4.5.1.2 Technologies for reducing agrochemicals

Another way to efficiently remove the pesticides from water is using membrane processes such as ultrafiltration (UF), microfiltration (MF), reverse osmosis (RO) and nanofiltration (NF). These methods are based on selective permeability of the membrane which is given by the size of its pores (Tázlerová, 2013). The processes are effective against pesticides mainly due to the fact that molecular weight of the pesticides is between 200 and 400 g/mol (Riungu et al., 2012) and the nanofiltration membrane can filter molecular weight from 200 to 15 000 g/mol (Filter, 2015). Nanofiltration is very effective for removing organic and inorganic substances from surface waters. Reverse osmosis is more useful and effective for removing heavy metals. Ultra filtration is used for treating the groundwater and also for treating of the lake water. As an example of this, it is possible to mention the hydro station Laussanne in Switzerland. Furthermore, there was a test of the efficiency of microfiltration on the water of Lake Brugneto in Italy with positive results; for example, pathogenic microorganisms were eliminated from the water with 100% effectivity and all algae with the 99.2% efficiency

(Honzajková et al., 2010). Nevertheless, the membrane processes are very demanding concerning energy and monetary expenditures – the initial investment into the pumps is very large. Moreover, there is a constant need of maintenance and cleaning of the membranes. Considering all this, it is possible to state that, although the processes are very effective, they are not suitable for the conditions of the area because they are very expensive and technically demanding. Nonetheless, there are Indian companies offering many nanofiltration plants for affordable prices. Among the favorite ones, there is for example the nanofiltration plant made by the company Shivam. It also has some offtake in Africa, e.g. in Egypt (Watertreaters, 2010).

4.5.1.3 Technologies for saving water

If the farms will be very frequently irrigated by water from lake, groundwater or the Malewa and Gilgil rivers, it would be necessary to employ some effective action for saving natural water sources. The total irrigated area is 4467 ha, 55% of that is by lake, 39% of groundwater and 6% of rivers (Becht, 2007; Mekonnen et al., 2012). Nowadays, most of farms use irrigation system such as Sprinkler (36%), greenhouse (27%), pivot (21%) and drip (16%) (Becht, 2007). Draft National irrigation policy of Kenya has a vision of improving the drainage situation in Kenya to 2030. Some of them promote water harvesting, use of wastewater, and exploitation of groundwater for irrigation (DNIP, 2015).

"During the last 20 years the irrigation technology has seen a shift from overhead sprinkler to more sophisticated systems as central pivots and drip irrigation. Also many farmers have moved from outdoor cultivation to greenhouses. The latest trend is hydroponics culture in greenhouses. The changes in irrigation practices definitely help to conserve water" (Becht & Nyaoro 2006).

Budget irrigation systems could be used by Jain irrigation system Ltd. This company offers a Jain Solar water pumping system operating on power generated by Solar Photovoltaic panels. It could be used in combination with rainwater harvesting. Jain Solar water pumping system operates with power generated by Solar Photovoltaic panels. "*The power generated by solar panels is used for operating DC surface centrifugal mono-block pump set for lifting water from water tank for minor irrigation and drinking water purpose. The system requires a shadow-free area for installation of the Solar Panels*" (JAINS, 2015). This system could be built into the farms and water should be used for irrigation or as a source of drinkable water for workers on farm. However, it could be applied only for drinking water supply therefore using rainwater harvesting method could be possible only with using water purification technology.

In Nyatike district, the west part of Kenya the water harvesting was used in combination with the treatment technology by Moringa oleifera seeds. Groundwater harvesting is a method of collecting surface runoff from a catchment's area and storing it in surface reservoirs. This method is interesting because it substitutes the lake water that would be pumped from farms for irrigation by stored rainfall. The massing of the water would be provided by sloped channels which would take it to the retention tank. It is recommended to make the tank of an impermeable material because of high seepage of local soils and to build it into the floor in order to save materials costs (Berdén & Gustavsson, 2010). Purification by MOCP is effective mainly against medium to high pollution levels caused by muddy components, clay and bacteria. It works on the basis abilities ion-exchange of positively charged proteins of seeds which attract the negatively charged particles and bacteria. The mixing action causes them to link together (Huda et al., 2012). However, the treated water could not be stored at storage tanks for a long time, so scientists from Pennsylvania came up the with technology of f-sand which includes an extract of the seed containing the Positively Charged Moringa protein added to negatively charged sand (Folkard, 2001). Moringa-functionalized sand, or f-sand, has the key advantage of using the elimination of organic matter upon which microorganisms can feed, resulting in clean water that can be stored for longer times (Huda et al., 2012). The f-sand technology could be used for water purification in the rainfall harvesting water reservoir. The other option is using f-sand for water treatment in a sand filter.

4.5.2 Wastewater treatment methods in Naivasha city

As it has been written above, the largest sources of water pollution in Naivasha are the slums on the outskirts of the town. Due to the fact that the slums have no sanitation facilities, the streets are covered with waste and excrement. The worst situation could be expected during the rains. The issue of the whole city is waste water treatment.

The biggest problem is poor public sewerage system and deficient wastewater treatment plant. The sewerage was built for 20 000 people, the Naivasha city has ten times more inhabitants now (Chege, 2013). This causes overflowing and sometimes ruptures of sewerage at many places and in those cases the wastewater is discharged into the streets, at markets or at schools.

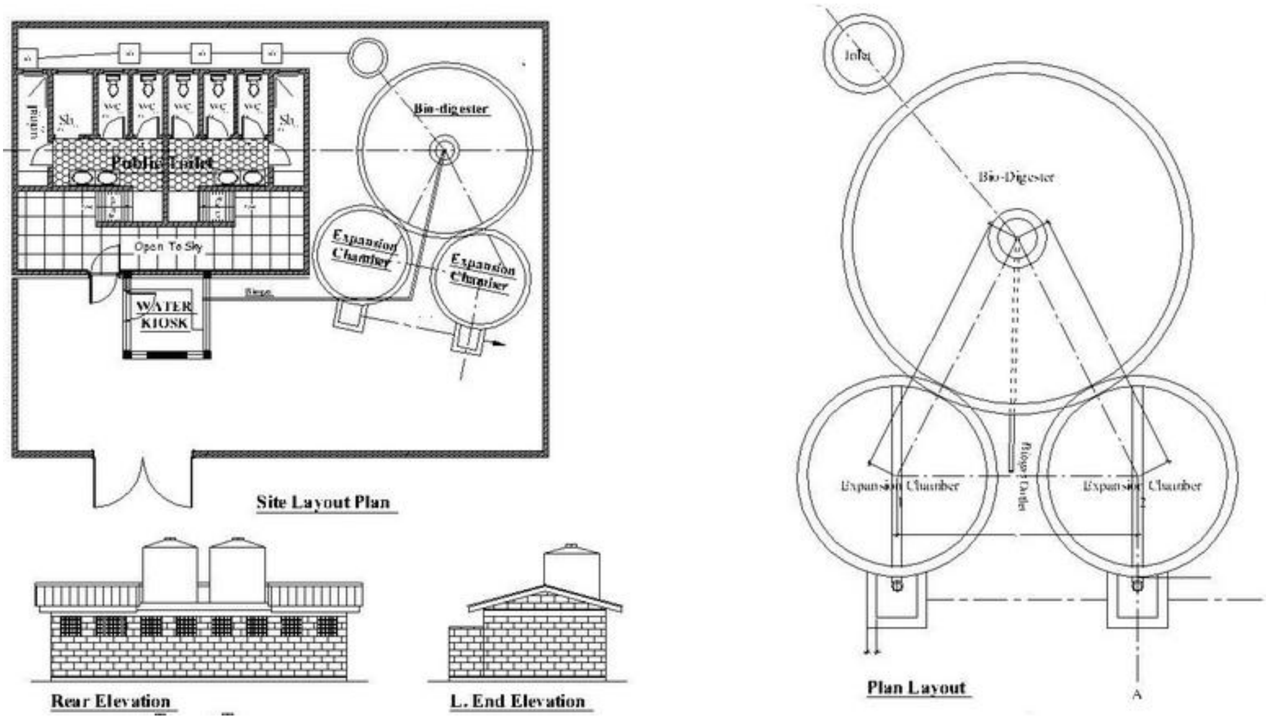
The good news is that recently, several projects such as bio-centers, or EcoSan latrines were implemented. With the water and sanitation problems in Naivasha deals the Water Service Provider (WSP). It is called Naivasha Water Sewerage and Sanitation Company Ltd. (NAIVAWASS). It was formed under the Water Sector Reform Program of the Ministry of Water and Irrigation (MWI) a few years ago (Rieck & Onyango, 2010). Partnership organizations from European Union - SIDA, GTZ, EcoSan organized and realized a pilot public sanitation project which combined a water kiosk, toilets, showers and biogas made in Naivasha.

The town has five public toilets (at markets and bus stops) with flush toilets and sewer connections (Rieck & Onyango, 2010). The public sanitation facility and a water kiosk were constructed adjacent to the bus park in the center of town, because there was a sewer connection available. *"The new facility comprises a sanitation unit (toilets, handwash basins, a urinal and showers) and a water kiosk. The facility is connected to the town water supply network and has three overhead water storage tanks to cater for short supply interruptions. The wastewater from the toilets, showers and hand wash basins is drained into an underground biogas plant that treats the wastewater anaerobically. Treated effluent is discharged to the sewer"* (Rieck & Onyango, 2010).

The principle of water treatment is the same as principle of BioCenter in Nairobi Mukuru slum. *"A biogas toilet consists of a shallow pit, bio digester and a vent pipe equipped with a fly screen for control of odour and flies. The excreta are deposited in the pit which is connected to the bio digester. The waste is digested anaerobically in the bio digester to produce methane gas"* (Schouten & Mathenge, 2010). Further treatment of the wastewater could be done through baffled reactors and anaerobic filtering. Meanwhile the wastewater is discharged into the sewer (Rieck & Onyango, 2010).

Further digested sludge could be used as a fertilizer by nearby agriculture farms. The energy from biogas is used for cooking. The Biocenter could be built mostly from local materials but an expert drafts person is needed to design it. The qualification of workers is not necessary. The maintenance is simple (Kubíková, 2009).

Figure 7: Public toilet with biogas plant and water kiosk Naivasha, SuSanA project, 2010.



Source: (Rieck & Onyango, 2010)

One of the viable solutions of water supplies is rainwater harvesting. This technology is based on collecting water to a storage tank. In Naivasha town, this system could be the solution of the safe drinking water insufficiency. Rainwater could be used for clothes washing or cattle feeding. The working principle of the method is collecting rainwater from roofs to a storage tank. Nevertheless, it is not advisable to use the water for drinking purposes even after boiling. Also, it must be borne in mind that water storage in accumulation tanks is not a good idea because there usually is a secondary contamination and an increase in bacteriological contamination (Kubíková, 2009). Rainwater is for fast consumption.

The rainwater gets to the storage tank through a drainpipe. It is necessary to build the drainage on roofs and also a rainwater storage tank of suitable size with discharge pipes. An impermeable material is necessary. The size of the tank is determined by the quantity and intensity of rainfall which should be in balance with the water usage (Kubíková, 2009).

An even better option could be installing two or more smaller tanks interconnected with each other with isolation between each tank. The replenishing of the last tank should not occur before the utilization of the original volume of water. In order to catch coarse dirt, a strainer or a filter material layer for water purification could be installed. If the water is also used for drinking and cooking purposes, a simple filter can be attached to a water diversion tap though for drinking purposes the water would need further disinfection. It is recommended to cover up these storage tanks in order to hinder water contamination and reduce evaporation from the surface (Kubíková, 2009). F-sand process, which has already been mentioned, or some other sand filtration could be used as purification technologies in this case.

4.5.2.1 Waste water treatment plant

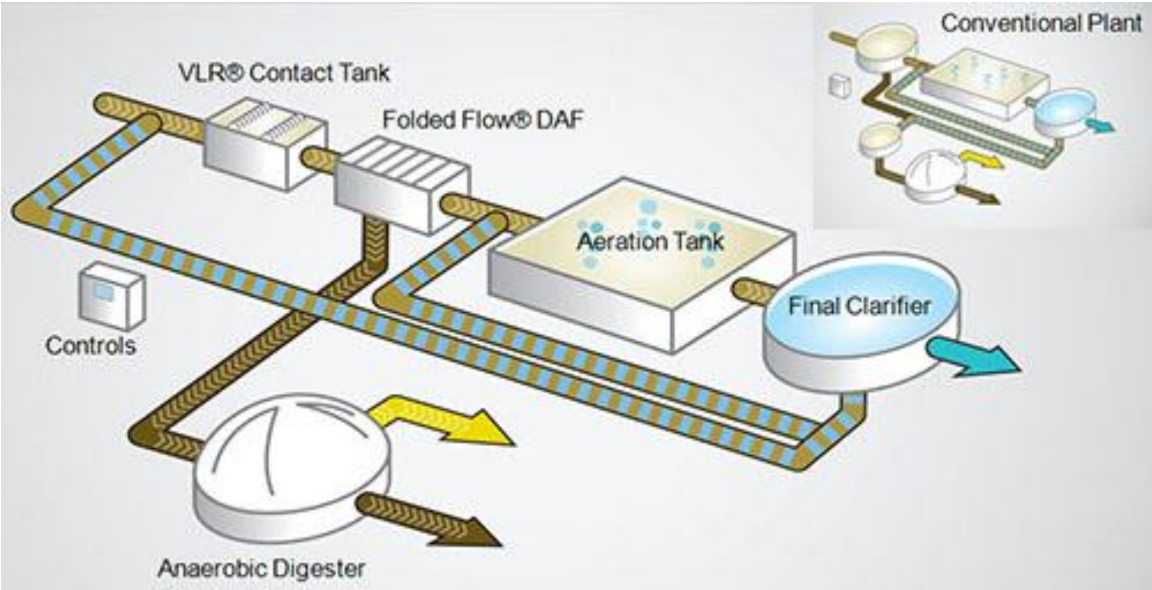
In development countries, it is recommended to use decentralized system of waste water. Nowadays, building up sanitation facilities on different places in Naivasha is in agreement with this opinion about the decentralization of sewage. However, Naivasha basic sewage system was built with a wastewater treatment plant which was meant for 20 000 people and which is probably based on sludge digestion. At present, the sewage is used by a far larger amount people and due to this situation the sewer system overloads. The ideal solution would be building a completely new sewerage system. As an ideal sewer system, it would be possible to discharge the polluted water to a treatment plant by one conduit pipe, while the second conduit would drain rainwater into the recipient, which could be used as potable water. For sewage water, a gravity sewer branched sewer system could be used. The system would lead to a central wastewater treatment plant for Naivasha city. Some relief for the system could be provided by Bio-center systems or Ekosan latrines - i.e. dry toilets.

WWTP system proposed for Naivasha is inspired by systems from development countries with similar environmental conditions. According to this analysis, the most used technologies are lagoon-based technologies, stabilization and treatment ponds and also systems where aerobic and anaerobic processes are used. Lagoon-based and stabilization pond technologies show an apparent disadvantage. They require large areas to work properly. Furthermore, during storm rainfalls, the tanks can overflow. In light of these facts, the above mentioned technologies are not recommended for this particular area. On the other hand, aerobic and anaerobic processes seem to be a suitable solution. Naivasha is bordered with flower and vegetable farms, therefore the main sewage treatment technology could be anaerobic digestion by means of digester tanks. Digestate could be used as a fertilizer, provided the appropriate ratio of carbon and nitrogen (Petráková & Kotovicová, 2012).

An example could be The Captivator™ System. "*The Captivator™ System improves a conventional process by replacing primary clarification and separate sludge thickening with a*

VLR® Contact Tank (oxidation ditch) and a Folded Flow® DAF (Dissolved air flotation) *applied to the liquid stream. Organic matter is extracted from raw wastewater and sent directly to anaerobic digestion. Since less BOD is sent to the biological aeration tanks, less energy is required by the process. Waste activated sludge is circulated to the aerated VLR contact tank at the front end of the plant. The Captivator System reduces capital investments otherwise required for primary clarification, separate sludge thickening, and normal aeration tank volume, The Captivator System is easily combined with other technologies such as a Dystor Gas Holder, a JetMix Hydraulic Digester Mixing System, or a low temperature Sludge Belt Dryer*“ (Evoqua, 2012a).

Figure 8: The CaptivatorTM System



Source: (Evoqua, 2012a)

4.5.3 Protection the Malewa River

Deteriorating quality of water in the lake is caused by an increasing amount of nutrients in the lake, mainly nitrogen and phosphorus. Nowadays the lake is transforming from clear to muddy eutrophic turbid state. Therefore, what is important for the continuous assessment of the water quality is a monitoring program of the lake. According to the study Ndungu (2014) samples were taken from seven sampling sites around Lake Naivasha. One of these sites was the Mouth of the Malewa River. The samples showed the lowest degree of conductivity and highest turbidity (67.17 NTU), low values of total hardness (TH) and total alkanity (TA). Even the levels of nutrients came out very badly for the Malewa River. According to the same study (2014), it turned out that all samples the Mouth of the Malewa River had the highest concentrations of phosphorus and nitrogen. On the other hand, ion concentration was the lowest here. This survey of quality water in the Mouth of the Malewa River shows, that turbidity and TSS were quite high due to the surface runoff of the Malewa catchment which is an agricultural area (Ndungu, 2014).

It has been proved that lake sedimentation increased by nearly 1 cm per year since the 1990s. This is attributed to increased agricultural activities around the Malewa River and Lake Naivasha. Throughout the years, various measures have been carried out to mitigate erosion. These include a pilot project by a WWF-Care-Kenya partnership in 2011 which comprised of the establishment of grass strips to reduce runoff and erosion on steep slopes in the sub-basins of the Malewa River basin (Cornelissen, 2014).

In accordance to the study by Cornelissen (2014) rehabilitation of Northern Swamp around the rivers Malewa and Gilgil by forming wetlands of about 4 km² north of Lake Naivasha would contribute to the mitigation of erosion. The wetland could to retain sediments and prevent them from ending up in the lake. Two alternative solutions were designed by Marula Estates (Cornelissen, 2014).

Bank filtration has proven to be a very effective water purification technology. It has been used in nearby Nakuru[6] (Sharma & Amy, 2009). "*The bank filtration cleans the surface water, mostly from a river system into a groundwater system induced by water abstraction close to the surface water. This water abstraction is commonly done by operating wells. As the water flows through the soil, it is filtered and its quality hence is improved*" (Tratschin & Spuhler, 2010). The bank filtration is appropriate for urbanized areas around surface waters, for example Gilgil town, where the Gilgil River, which also inflows into Lake Naivasha, flows through the town.

4.5.3.1 River water treatment plant

As it has already been mentioned, the Mouth of the Malewa River is a heavily polluted water area. It is necessary to build a river water treatment plant (RWTP). This RWTP would have a mechanical-biological system. The mechanical pre-treatment is usually ensured by screens or bar screens. After the mechanical pre-treatment, there comes another part with biological treatment. In this case, for the Malewa River, activated sludge wastewater treatment could be used, because the sludge would eliminate phosphate, nitrate and pollution caused soil

[6]Nakuru is fourth biggest city in the Rift Valley. From Naivasha is distanced 70 kilometers. Nakuru Lake is not freshwater.

erosion. Amidst the treatment system there would be used biological methods such as active sludge, aeration systems, sequencing batch reactors (SBR), and others. The principle of purification is based on microorganism action. The microorganisms use the unwanted substances as energy sources and dismantle them by natural metabolism of their bodies (vodakva, 2013).

The next step will be the separation of the sludge and the clean water in the settling tanks. The disadvantages of this wastewater treatment system area need for a large area in order to build the plant, the initial investment, and the need for trained workforce and specialized service. Another disadvantage is the interference into the local ecosystem.

However, a possible solution is using the Sequencing Batch Reactors. Firstly, the SBR treatment process is highly effective at treating variable volumes of waste water, so it is suitable for the area with alternating of the drought and rain seasons. Secondly, the SRB is very effective for treatment of nutrients. For these conditions, the suitable system is OMNIFLO SRB System (Evoqua, 2012c).

4.5.3.2 Rehabilitation of Northern Swamp and Gilgil and Malewa wetlands

In order to preserve the ecosystem, the nature water treatment could be the best solution. The Gilgil and Malewa wetlands would be reconstructed. The farmer Marula Estates would like to upgrade these wetlands and improve the treatment technologies. In 2009, he implemented a plan to rehabilitate wetlands. The first part of project was successful and therefore it is possible to prepare the second part of the project, which includes a construction of a dam to buffer water from the Malewa River (Cornelissen, 2014).

"The two alternative rehabilitation alternatives are based on the Wetland rehabilitation project Naivasha – Kenya (Marula Estates, 2013) and differ in the way of landscaping the former Northern Swamp. What both alternative designs have in common is the spillway channel connecting the Malewa River and the former Northern Swamp including the inlet construction to regulate the amount of water to be diverted"(Cornelissen, 2014).

The first part of the Marula estates wetlands project was very successful and dealt with rehabilitation of the northern part of Northern Swamp where the Gilgil enters. The second part includes three components. "*The first component is the construction of an earth dike including a fish ladder functioning as outlet construction. The second component is shaping the landscape for maximizing the wetland biodiversity which will be done on 1.2 km² and includes the construction of small islands of various levels to maximize biodiversity and natural colonization* *of different plants according to the specific water level. The third component is the construction of the Malewa spillway channel including the construction of the inlet construction in the Malewa River bank to divert the water from the Malewa River into the wetland*" (Cornelissen, 2014). However, further research will be needed to design the construction because there could be problems with soil erosion and it will also be necessary to design a management plan for the inlet construction for regulating inflow to the wetland due to a great threat of flooding.

5. Discussion

Kenya is a water scarcity country with water surface comprising only 2.2 % of Kenya´s area. Only a half of rural population has access to clean water. Kenya with 466.7 cubic meters of renewable freshwater per capita in comparison to the world with average 6055.1 cubic meters of renewable freshwater per capita, has to rise to the challenges of water supplies ahead of it (WB, 2013c). In Kenya, it is necessary to protect the water resources with effective technologies. However, for these technologies to be effective, it needs to be ensured that the technologies are sustainable. For developing countries, sustainability means that technologies would not need complicated operation and maintenance. The construction of each protection system affects the environment. Particularly Lake Naivasha protected ecosystem would need to use technologies very well suited to the environment conditions. Natural systems would be preferable (Munang et al., 2010; Raymer, 2011).

Lake Naivasha is a very important freshwater source in Kenya. Its water is used for drinking, for irrigation and for technical purposes. Furthermore, it is a tourist destination and a fishing ground for the local population. The main water issues of the lake could be water abstraction, agrochemicals and sewage pollution, destruction of riparian habitat, over-fishing and erosion (Becht et al., 2007). However, the lake water is self-cleaning due to sand soils. "*Abstraction and ground water seepage keeps the lake water fresh"* (Ndungu, 2014). However, an ever-increasing number of people around the lake and water demand for irrigation water for vegetable and flower farms results in degradation of Naivasha ecosystem. In his study, Harper (2011) confirms the issue of degradation of ecosystem due to intake of phosphorus to lake and it leads to eutrophic status of lake. The eutrophication of the lake can cause death of large fishes and reduction of bird population. The reduction of the population of birds and other animals is ceused by the decline of the amount of their prey. It is caused by a combination of increased turbidity in the lake, floating mats of exotic vegetation and the loss of lagoons behind fringing papyrus caused by lake level decline (Harper et al., 2011). Withal, the papyrus is natural purifier of water and what is more, the plant productivity and the energy contents of papyrus are high (Perbangkhem & Polprasert, 2010).

There is evidence that the lake water level is decreasing, for example when compared to resent data (Hickley & Harper, 2002), the maps published by Ase et al. (1986) show that lake level was approximately 1.75 m lower in 1991 than in 1983, and the study by Awange et al. (2013) also supports the opinion that lake is drying out. However, due to the renewing of the water supply during the rainy season, the drying out is not the main issue. As stated in the scientific literature, the most serious issue of Naivasha is the nutrients pollution of the lake. This agrees with the research of Harret et al. (2007) which has shown, according to the samples taken at various locations of the pollution, that the largest polluters of the lake are the flower farms near the lake. The samples from the surroundings of the farms showed high quantity of chlorophyll-a, highest nutrient inputs and high coverage of water hyacinth density (Harret et al., 2007). This also confirmed the study by Mekonnen. et al. (2012), according to which, the flower farms are responsible for the lake pollution due to nutrient load (Mekonnen et al., 2012). It leads to ingrowth of the lake which is the main cause for the degradation of the lake (Harper et al., 2011). Also, the flower farms generate a large part of degradation of the lake due to their using of agrochemicals. The study of students from Kenyatta University shows that the samples from plantations, farms and the horticultural sector were found to be the most significant source of heavy metal pollution – namely by copper, lead, cadmium and zinc (Njogu et al., 2011). "*The Karati delta where most water enters the lake also shows high nickel content indicating inflows from River Malewa"* (Njogu et al., 2011). Study by Ogendi et al. (2014) agreed that the highest levels of lead were recorded in the Malewa River mouth samples. "*River Malewa is a major of source of heavy metals into this lake. The river drains through an agricultural area where pesticides and animal feeds are used intensively*" (Ogendi et al., 2014). This is thought to be due to the intensive use of agrochemicals containing heavy metals as active ingredients (Njogu et al., 2011). On top of that, many studies conducted during several past years show presence of organochlorine pesticide residues in Lake Naivasha (Becht R., 2007; Jimoh et al., 2007; M´Anampiu, 2011; J. Koaga, 2013). Other study by Njoroge et al. (2013) shows, that the number of pesticides that had been used along the shore of Lake Naivasha was 141. About 18.6 % of these were extremely hazardous and some pesticides that were being used are very toxic to humans and even the quantities of pesticides used were categorized as being high or very high (Njoroge et al., 2013). It would also confirm the thesis by Ndungu (2014), where the turbidity, nitrogen and phosphorus concentration of the lake was the highest in the region around the Malewa river delta. In order to prevent further contamination of the lake, it will be necessary to limit the pollution coming from the inflows from the flower farms which contain pollutants such as phosphor or nitrogen.

However, according to the study by M´Anampiu (2011) the organochlorine pesticide residues are generally below the maximum residue limits (MRL) set by FAO/WHO bodies

(M´Anampiu, 2011). According study Ogendi pollution of metals such as cadmium and cooper exceeded the WHO recommended guidelines (Ogendi et al., 2014). In overall, Lake Naivasha still has relatively healthy basis and the water quality parameters are in acceptable condition (Higgins et al., 2011).

There does not appear to be any other possibility, for Lake Naivasha to preserve its ecosystem and clean water but to protect the lake before continuously growing pollutions. Protecting the sustainability of Lake Naivasha water source also requires other measures, for instance good water management, using purification technologies or budget irrigation technologies aimed on water protecting constructions. This technology could be used mainly at the sources of pollution such as the flower farms, the Malewa River and Naivasha town.

In recent years, Kenya actively addresses the issue of water resources which is confirmed by the fact that it adopted the Water management plan in 1996 or Water Act in 2002. Many ecological organizations are interested in protection of the lake. One of the most involved is Lake Naivasha Riparian Association (LNRA). The lake water is protected by virtue of The Lake Naivasha Integrated Management Plan (LNIMP), The Lake Naivasha Environmental Management Plan, Environmental Management and Coordination Act (EMCA), National Environmental Management Authority (NEMA) and others government regulations. Furthermore, the protection of the Naivasha Ramsar and catchment area is provided by non-governmental organizations such as WWF or by programs for development cooperation financed for example by German Development Cooperation (GIZ). In Naivasha town, there was established Naivasha Water Sewerage and Sanitation Company Ltd. (NAIVAWASS). It was formed under the Water Sector Reform Program of the Ministry of Water and Irrigation (MWI) (WRMA, 2009). There are even more organizations trying to save the lake ecosystem. However, the Government of Kenya should prescribe some actual guidelines for wastewater management and waste disposal which would be used to instruct the local populations. According the study by Harper (2011) "*The highly complex socio-political situation at Naivasha is, on the one hand showing increasing organisation at the formal level, spearheaded by the LaNaWRUA, KWS and now the Prime Minister's Office and on the other hand showing a rise in initiatives at the grassroots level*" (Harper et al., 2011).

In 2010 International Conference on Aquatic Resources of Kenya was deliberately held at the KWS Training Institute in Naivasha. Proposed actions include: restoration of lake-edge vegetation; removal of illegal developments in the riparian zone; setting and enforcing of abstraction limits; expansion of the municipal sewage treatment works; and fast-tracking the development of the Lake Naivasha Integrated Management Plan (LNIMP) (Harper et al., 2011).

All of that shows interest in protecting water quality in Lake Naivasha by Kenyans. This can be seen in their approach to solving water scarcity issues and wastewater treatment. For example, there were build several sanitation facilities such as the public toilets with biogas plant and water kiosk in Naivasha town, the Kingfisher constructed wetland in Kingfisher flower farm. Furthermore micro irrigation technologies such as Sprinkler were installed at several farms; the rehabilitation of the Gilgil wetland was started and so forth (Rieck, 2010; Cornelissen, 2014; Khisa, 2014). Building wastewater treatment plants in the sources of pollution would be efficient, however not only are acquisition costs still too high to be financed, but the work of experts would also be necessary. Developing countries have limited budgets hence buying a very expensive technology is impossible. This thesis endeavored to gather information about natural and social conditions of the polluted areas in order to ascertain using the fittest purification technology. The individual pollution sources were analyzed according to the degree of contamination of hazardous materials and the water quality. The comprehention of the pollution was gaine from the researches by students from the universities of Leicester, Nairobi, Twente, Bonn and Egerton. Possible solutions of the treatment were suggested.

Although the flower farms are very economically important for Kenya, using the agrochemicals and very frequent irrigation leads to the destruction the Lake Naivasha ecosystem. The Becht and Nyaoro said: "*During the last 20 years the irrigation technology has seen a shift from overhead sprinkler to more sophisticated systems as central pivots and drip irrigation. Also many farmers have moved from outdoor cultivation to greenhouses. The latest trend is hydroponics culture in greenhouses. The changes in irrigation practices definitely help to conserve water*" (Becht & Nyaoro 2006).

However, to reduce the effects of farms on the quality of water it would be ideal to incorporate a small wastewater treatment plant into each farm. This WWTP would eliminate especially unwanted substances such nitrates, phosphates, pesticides and herbicides. According the Bachelor thesis by Tázlerová the pesticides is possible eliminated by membrane technology (Tázlerová, 2013). The suitable technologies for eliminating agrochemicals could be a membrane process or a storage tank with f-sand (Folkard, 2001; Huda et al., 2012). Due to their very high cost, these water purification technologies would have to be subsidized by the state budget in the context of environmental programs for smallholders. Mass production by foreign investors has obligation protect nature resource by purification technology at their own expense (UNCTAD, 2012).

"*Environment-related requirements Investors in Kenya are required to comply with environmental standards. Developers of projects involving manufacturing or processing, or any project sited by a body of water or in a conservation area, are required to carry out an environmental impact assessment (EIA) and obtain an environmental impact assessment license, prior to project implementation*" (UNCTAD, 2012). According The Constitution of Kenya: "*Every person has a duty to cooperate with State organs and other persons to protect and conserve the environment and ensure ecologically sustainable development and use of natural resources*" (KLR, 2010). This implies that, according to the new constitution of Kenya, the owners of the large farms are bound to protect the natural resources and also preserve them as long as they use them. If the flower farms pollute the lake, they are bound by law to eliminate the pollution.

Naivasha town is another polluter of the nearby lake. The town has very ineffective waste management and sewer system (Mireri, 2005). Due to an increase in population growth, the capacity of the sewerage is no longer sufficient (Chege, 2013). "*From the results implied that obtained all the physicochemical parameters from all the water sources were within the recommended standards by WHO, US-EPA and NEMA for drinking water*" (Omondi et al., 2013). "*Fecal contamination is a source of pathogenic micro-organisms linked to the high incidences of waterborne diseases (typhoid, bacillary dysentery and other diarrhea diseases) reported from medical institutions around Naivasha"* (Otiang'a-Owiti & Oswe, 2010).

It is necessary to build new separate sewers with drainage wastewater system and rainwater system. The water from these systems would be brought to central wastewater treatment plant. "*The wastewater system and water purification technology system will be chosen according to the following parameters: the amount and the type of pollution, the size of the area which is available for water treatment, the distance from the source of pollution, the treatment effect, the ability to maintain and operate WWTP, and ecological risk assessment of the surrounding ecosystem" (VUPP, 2005).*

Nevertheless, building WWTP is very high-priced in regard of the construction but also in regard of the maintenance. In order to build the canalization network, it is necessary to hire experts and to rebuild a large part of the city. Such a project takes a very long time. Therefore it would be good to focus on small projects such as EkoSan latrines or Bio Centers.

The Malewa River has a high content of heavy metals (Njogu et al, 2011), and nutrients, mainly nitrogen and phosphorus pollution (Harper et al., 2002; Becht, 2007; Jimoh et al., 2007; Ndungu, 2014). In addition to this, there is also the pollution caused by deforestation in the upper part of the stream (Ogweno, 2005). Around the Malewa River, there are many vegetable farms, however, there is no largely populated area. The intake of phosphates and nitrates into Lake Naivasha causes ingrown and its nutrients are increased. To maintain the quality of water in the lake it is necessary to use technology that will purify the water from phosphates, nitrates and sediments, soil erosion. According the study by Ndungu *"The reducing the inflow of pollutants can be done by restoring the swamp in the north of the lake such that most of the pollutants and sediments are retained in this area"* (Ndungu, 2014). In order to preserve the lake ecosystem it would be fitting to use natural water purification. Some of the solutions for the protection of the water in the lake would be the Malewa and Gilgil wetlands in combination with construction of an earth dike including a fish ladder functioning as outlet construction further shaping the landscape. Furthermore, it is possible to mention the construction of a colony of islands to maximize biodiversity, the construction of the Malewa spillway channel including inlet from the Malewa River into the wetland (Cornelissen, 2014). It is estimated that the wetland treatment should reduce the inflow of suspended matter and phosphorus up to 80 % and over 50 % respectively. The sediment inflow into Lake Naivasha will then be reduced to 18 % (Cornelissen, 2014). However, the project is still in an unfinished form.

The ecosystem of Lake Naivasha is a unique biotope with freshwater. Considering the water scarcity in Kenya, the protection of this ecosystem is very important, mainly because it provides drinking water for the inhabitants of the local cities. It is necessary to mention that the lake is an ecosystem which is interconnected with its surroundings. Therefore, it is needed to look at Lake Naivasha as an issue comprising of several subsequent problems. In order to solve main issue we should focus on each of these particular problems separately. The pollution of the lake alone cannot be dealt with, it is necessary to prevent it. In order for the lake to preserve its quality of water, the inflow of contaminants from all possible sources must be limited. Considering the number and types of contaminants, we cannot use just one improving technology at one location of pollution. It is necessary to focus at each place separately. Thus the highest effectivity would be achieved. Nonetheless, we approach the fact that Kenya cannot afford paying for such expensive technologies. As it has been mentioned before, the flower farms should provide the cleanup of the waste at their own expanse. Therefore, the state funding and the development aid should be focused on the city of Naivasha. The fecal contamination is the largest threat to the inhabitants of the area both regarding the living environment and health. Furthermore, the poor sanitary conditions lower the attractiveness of the location for tourists who are the source of income for many of the local populace. The government of Kenya should focus on improvement of the wastewater management and also on improving the possibility of access to drinking water in the cities and villages. It should be done especially in those which are the sources of pollution of drinking water.

6. Conclusion

Lake Naivasha is a very important freshwater source with fairly good water quality. However, during recent years the lake has issues with ingrowth which is caused by an inflow of nutrients from the surrounding flower farms. Furthermore, the ever-growing populace of nearby towns increases the degree of fecal pollution. In order to keep the lake water clean and to preserve the water for the next generations, it is necessary to use protective technologies. These technologies would be used at the sites of the worst pollution and by that the leakage of dangerous substances into the lake would be prevented.

In the thesis, there were detected three largest sources of the pollution according researches by students from the universities in Kenya and Netherlands. According to the water quality indicators, these are flower farms, the Naivasha town and the Mouth of Malewa River. The thesis suggested effective and at the same time sustainable technologies for the sources of the worst pollution, i.e. flower farms, Naivasha town and the lower stream of the river Malewa.

Flower farms pollute the lake by their output of nutrients. If we want to eliminate input of nutrients to the lake, wastewater treatment will be necessary for every farm. The most sustainable solution is a Nanofiltration plant built in farms. A cheaper option is the Constructed wetland.

To the Naivasha town, it is recommended to build a new canalization network with a detached sewer system which would lead to the central wastewater treatment plan based sludge system with water filtration with oxygen. Thereby modified water would either go straight to the lake or a filter would be used to return the water into the circulation and use it as drinking water. These technologies would use energy from anaerobic digestion which would be included in the wastewater treatment plant.

The Malewa River pollutes the lake by nutrients, phosphorus and heavy metals. The effective solution could be Sequencing Batch Reactor which would eliminate nutrients. It is also effective at treating variable volumes of waste water. For preservation of the Lake Naivasha ecosystem, the most suitable course of action is the usage of natural technologies in combination with considerate handling of the soils in agricultural establishments. That will avert the soil erosion. The reconstruction of Gilgil and Malewa wetlands is very auspicious project due to fact that it would reduce the amount of phosphorus by over 50% and the sediments to 18%.

Because water is being used for irrigation, it is necessary to use micro-irrigation technologies or safe water technologies. Considering the financial demands of these technologies, it would be necessary to alter the system of state funding so that they would cover a part of the smaller farmers' cost for building the technologies.

It is very important to prevent pollution. It is more difficult and expensive to treat dangerous substances in the lake than to eliminate the polluted inputs. If the treatment projects in the sources of pollution are not realized, the damage the lake will be irreversible.

The treatment systems would furthermore be supported by technologies such as BioCenters or EkoSan toilets. In general, it is necessary for Kenya to improve the water and waste management. During the following years, treating the waste water and building canalization in larger cities should be a priority for the entire country.

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8. Appendix

Flower farm wastewater treatment.

Constructed wetland system and rainwater harvesting, Van den Berg Flower Farm

Source: Green-water.org, 2015

Nanofiltration plant Shivam

Source: Watertreaters, 2007

Improving sanitation facilities in Kenya

Rainwater Harvesting in Kenya

Source: Rainmaster, 2014 (right); stormsaver, 2014 (left);

Water Kiosk and public toilets in Naivasha town, Bus station, SuSanNa.

Source: (Rieck & Onyango, 2010)

Wastewater treatment plant in Naivasha

The Captivator TM System

Anaerobic Digestion

VLR® Systems

Folded Flow® DAF

Surface Aerators

Circular Clarifier for Wastewater treatment

Source: (Evoqua, 2012b).

Wastewater treatment plant for the River Malewa

OMNIFLO® Sequencing Batch Reactor System, OMNIFLO® SBR with Fine Bubble Diffusers (down).

Source: (Evoqua, 2012c)

Rehabilitation of Northern Swamp the River Gilgil

Source: (Cornelissen, 2014).