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VicInAqua

Integrated aquaculture based on sustainable water recirculating system for the Victoria Lake Basin

Deliverable 7.1

Literature review: MBR and RSA technologies, other related technologies and their adoption

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i. Acronyms and abbreviations

ABT	Aquabiotech Limited
AMTA	American Membrane Technology Association.
ASDSP	Agricultural Sector Development Support Program
BMUs	Beach management units
BOD	Biological Oxygen Demand
BPE	BPE International Dr. Hornig GMBH
BUWASA	Bukoba Water Supply and Sanitation Authority
BUWASCO	Busia Water and Sewerage Company
CAS	Conventional Activated Sludge
CBTS	Conventional Biological Treatment Systems
CDI	City Development Index
CSTW	Conventional Sewage Treatment Works
DALFD	Department of Agriculture Livestock and Fisheries Development
DFR	Departments of Fisheries Resources
EAC	East African Community
EC	European Commission
EGZ	Economic Growth Zone
EMS	Environmental Management System
EPA	Environmental Protection Agency

EPRC	European Personnel Recovery Centre
EU	European Union
FAO	Food and Agricultural Organization
FMP	Fisheries Management Plan
FQARs	Fish Quality Assurance Rules
GDI	Gender Development Index
GDP	Gross domestic product
GIZ	Gesellschaft fur Internationale Zusammenarbeit
GMPs	Good Manufacturing Practices
GNI	Gross National Income
HACCP	Hazard Analysis and Critical Control Points
HDI	Human Development Index
HIV/AIDS	Human Immunodeficiency Virus / Acquired Immune Deficiency Syndrome
HOWASCO	Homabay Water and Sewerage Company
HSKA	Hochschule Karlsruhe-Technik Und Wirtschaft
ICRAF	International Center for research in Agroforestry
ITM-CNR	Institute on Membrane Technologies
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KEMFRI	Kenya Marine and Fisheries Research Institute
KEMRI	Kenya Medical Research Institute

KI	Key Informant
KIWASCO	Kisumu Water and Sewerage Company
KMWI	Kenya Ministry of Water and Irrigation
KNBS	Kenya National Bureau of Statistics
LECB	Low Emissions Capacity Building
LVB	Lake Victoria Basin
LVBC	Lake Victoria Basin Commission
LVEMP II	Lake Victoria Environmental Management Project Phase Two
LVFO	Lake Victoria Fisheries Organization
LVSWSB	Lake Victoria South Water and Sewerage Board
MAAIF	Ministry of Agriculture Animal Industry and Fisheries
MBR	Membrane Biological Reactors
MIWASCO	Migori Water and Sewerage Company
MLSS	Mixed Liquid Suspended Solids
MST	Membrane Sewage System
MUWASA	Musoma Urban Water and Sewerage Authority
MWAUWASA	Mwanza Urban Water and Sewerage Authority
MWE	Ministry of Water and Environment
NaFIRRI	National Fisheries Resources Research Institute
NAMA	Naturally Appropriate Mitigation Action
NARO	National Agricultural Research Organization

NEMA	National Environment Management Authorities
NEMC	National Environment Management Council
NFP	National Fisheries Policy
NGO	Non-Governmental Organization
NTNU	Norwegian University of Science and Technology
NWSC	National Water and Sewerage Corporation
OXY	Oxyguard International
PAF	Partnership for African Fisheries
PAI	Population Action International
PPP	Purchasing Power Parity
PV	Photovoltaic
QAU	Quality Assurance Unit
QMP	Quality Management Program
RAS	Recirculating Aquaculture Systems
SAP	Strategic Action Plan
SARNISSA	Sustainable Aquaculture Research Networks In Sub-Saharan Africa
SEZ	Steinbeis-Europa-Zentrum
SIWASCO	Siaya Water and Sewerage Company
SRT	Solid Retention Time
SSP	Sewage Stabilization Ponds

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STPs	Sewage Treatment Plants
TMP	Trans Membrane Pressure
TMWI	Tanzania Ministry of Water and Irrigation
UMWE	Uganda Ministry of Water and Environment
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNICAL	University of Calabria
UNICEF	United Nations Children's Emergency Fund
UNIDO	United Nations Industrial Development Organization
VicInAqua	"Integrated aquaculture based on sustainable water recirculating system for the Victoria Lake Basin".
WHO	World Health Organization

ii. Acknowledgement

This report has been prepared by the "Integrated aquaculture based on sustainable water recirculating system for the Victoria Lake Basin (VicInAqua)" project funded by the European Commission (EC). This report is as a result of concerted efforts from all the VicInAqua Consortium members. Its preparation was spearheaded by the project partners from Uganda (The National Agricultural Research Organization, NARO) together with the Kenya partners; Department of Agriculture Livestock and Fisheries Development (DALFD) and Jomo Kenyatta University of Agriculture and Technology (JKUAT). The project Coordinator and contact for MBR technology, Hochschule Karlsruhe-Technik Und Wirtschaft (HSKA) - Germany and the RAS project contact, Aquabiotech Limited (ABT) - Malta are commended for their technical input on MBR and RAS technologies.

Other Consortium members; Steinbeis-Europa-Zentrum (SEZ) – Germany; Institute on Membrane Technology (ITM-CNR) – Italy; University of Calabria (UNICAL) – Italy; Oxyguard International (OXY) – Denmark; and BPE International Dr. Hornig GMBH (BPE) – Germany, are applauded for tirelessly reviewing and critiquing the entire report.

We are heavily indebted to all the Lake Victoria Basin (LVB) key informants used in Kenya and Uganda for their corporation and information given unreservedly to facilitate capture of current LVB facts perhaps even not published. Their valuable contribution of recommendations to the VicInAqua team are highly valued.

iii. Executive summary

This report entails literature on the socio-economic aspects of fisheries and aquaculture, fish processing and domestic waste water management in the context of Recirculating Aquaculture Systems (RAS) and Membrane Biological Reactors (MBR) technologies in the Lake Victoria basin (LVB). It is prepared as part of the **"Integrated aquaculture based on sustainable water recirculating system for the Victoria Lake Basin (VicInAqua)"** project funded by the European Commission (EC). The study focused majorly on the three shoreline countries in the basin, viz. Kenya, Tanzania and Uganda seeking to inform the RAS and MBR modification to suit the lake basin.

Lake Victoria is the second largest freshwater Lake in the world with a total surface area of 68,800 km^2 and a transboundary water resource covering an area of about 194,200 km^2, the LVB. A side from those bordering the lake, the basin hosts Rwanda and Burundi where the five countries form the East African Community (EAC). It is traversed by the equator providing an all year round solar insolation monthly temperature ranging between 14 and 29 degrees Celsius and two rain seasons. Hosting over 35 million people, the basin is one of the most densely populated areas in the world with over 90% of the population being rural.

Agriculture and fisheries are the most dominant livelihoods with 70% of the populace engaging in agriculture, 75% of which are women. Due to the economic importance of the Lake fisheries, the basin hosts 31 active fish processing plants, weighing heavily on the lake fish stocks. In solution, is the fast growing aquaculture sector with Uganda ranking among the five most aquaculture producing countries in Africa (FAO, 2016). However, earthen pond systems dominate the sector with no wastewater treatment or re-use. Therefore, RAS incorporated with MBR can help in sustainably intensifying aquaculture with little or no negative effect on the lake water quality due to wastewater recycling.

Waste management is the final component of the City Development Index (CDI) - the component that advances most slowly and is most difficult to improve with increasing development (UN – Habitat, 2007). In the LVB, wastewaters originate from domestic Sewage Treatment Plants (STPs); processing industries; groundwater seepage from on-site sources; and from catchment runoff especially after a rain shower. The runoff usually creates smelly stagnant water pools health problems especially among children who play in them. Globally, 2,000 children under the age of five die every day from diarrheal diseases and of these 1,800 deaths are linked to water, sanitation and hygiene (UNICEF and WHO, 2012).

Due to the Lake's critical importance to the society and economy, the governing body, EAC, designated it as an area of common economic interest for the five member countries. EAC, appointed the Lake Victoria Basin Commission (LVBC) to oversee the lake's management. It is helped by the individual responsible ministries in the respective countries responsible for the policies and legal issues.

Deviation from the workplan:

This deliverable was supposed to be submitted to the EC by M03 (end of August 2016). However, we had to postpone this deliverable to M05 due to the difficulty to get inputs about Tanzania since the proposal partner located in Tanzania is no longer part of the consortium.

1.0. Background

1.1. Study area

The Lake Victoria Basin (LVB), (Figure 1) located in the upper reaches of the Nile River Basin (UNEP, 2005)[1] is one of Africa’s largest transboundary water resources covering an area of about 194,200 km^2, and surrounding the second largest freshwater Lake in the world and the first in the tropics (68,800 km^2) (LVBC, 2007[1]). The lake is a global center of aquatic biodiversity featuring the world’s largest freshwater fishery with significant local consumption; and regional; and global exports, in particular the European Union (EU). It is relatively shallow, with a maximum and average depth of 84 m and 40 m, respectively. Situated at an altitude of 1,134 m above sea level, the lake stretches 412km from north to South, between latitudes $0^0$30’ N and $3^0$12” S, and 355km from west to east between longitudes $31^0$37’ and $34^0$53’E (Kayombo *et al*, 2006). The LVB is comprised of five states; Tanzania, Kenya, Uganda, Rwanda and Burundi with only three (Tanzania, Kenya and Uganda) bordering the lake itself. The LVB coverage by country is specified in table 1.

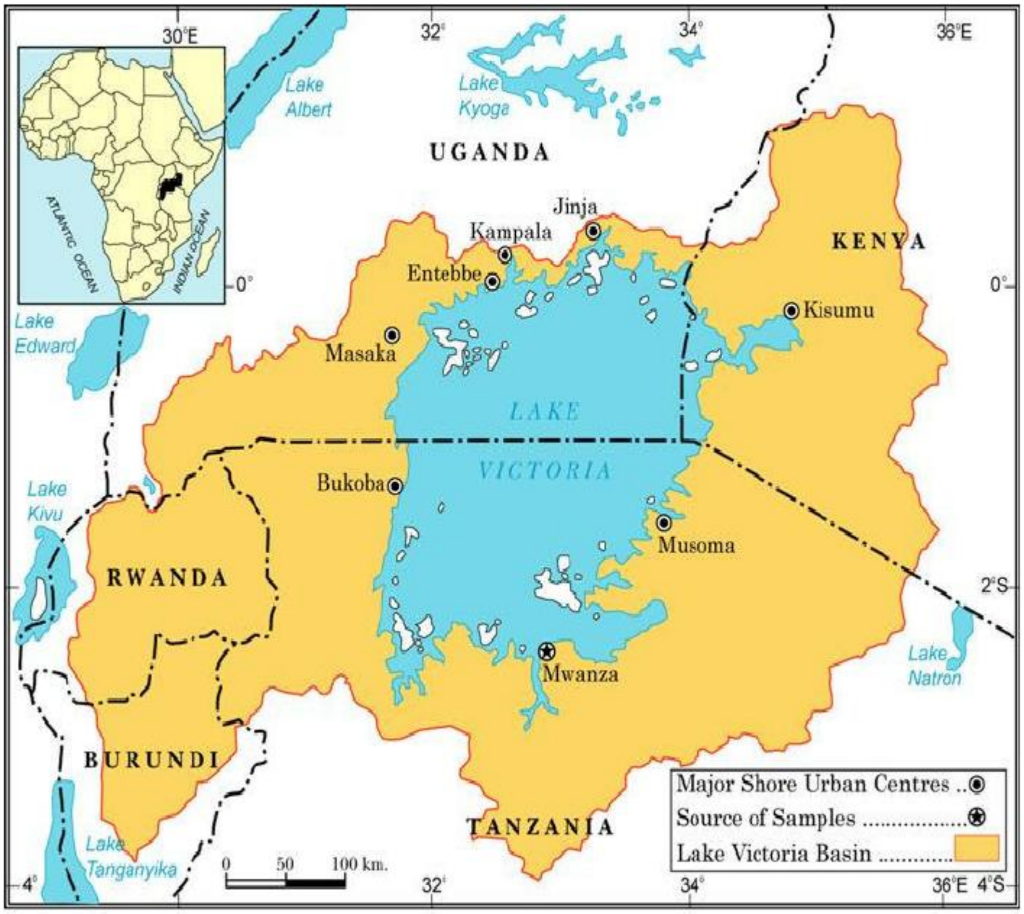
The terrain is majorly hilly with some of the world’s greatest complex wetlands and rivers. These resources offer freshwater, fish, wildlife and other biological resources, providing unique opportunities for socio-economic development.

Table 1: Lake Victoria basin morphometric data

Country	**Lake surface area**		**Catchment area**		**Lake shoreline length**	
	Km^2	**%**	**Km2**	**%**	**Km2**	**%**
Kenya	4,128	6	42,724	22	550	16

Uganda	29,584	43	31,072	16	1,750	51
Tanzania	35,088	51	85,448	44	1,150	33
Burundi	0	0	13,594	07	0	0
Rwanda	0	0	21,362	11	0	0
Total	**68,800**	**100**	**194,200**	**100**	**3,450**	**100**

Source: NTDAs Reports (2005), LVEMP I (1996 - 2005); LVBC (2007[1])



Source: Gumisiriza et al. (2009)

*Figure 1: **Map showing Lake Victoria Basin, Riparian countries and major shore urban centers.***

1.1.1. Climate

LVB falls under the equatorial hot and humid climate with a bi-modal rainfall pattern of long rains from March to May and short rains from October to December due to convergence of winds over the lake, twice a year. Annual rainfall ranges from a maximum of 2,400 mm in Uganda to 1,350 mm in the Kenyan part of the catchment. (Gef *et al*, 2015). The large size of the Lake makes it vital for weather and climate modulation in the region (LVBC, 2007[2]). With an estimated volume of 2,760 km^3, L.Victoria's residence time is 21 years while the flushing time (volume/average outflow) is 138 years, majorly from evaporation (80 %) and the River Nile. Precipitation accounts for 82 % of the water entering the Lake with the rest coming from stream flow and basin runoff (Bootsma, Hecky 1993; COWI 2002; LVBC, 2007[2]).

The LVB monthly temperature ranges between 14 and 29 degrees Celsius throughout the year. It reaches maximum (28.6˚ C - 28.7˚ C) in February, just before the March equinox and reaches its lowest records (14.7˚ C to 18.2˚ C) in July after the June equinox. Comparison of temperature records for the period 1950 - 2000 to 2001 - 2005 show that maximum temperatures have increased by an average of 1˚ C (LVBC, 2007[1]).

Lake Victoria is traversed by the equator providing an all year round solar insolation explicating the moderate to high temperatures in the basin. Though the use of solar thermal energy is not widespread in the basin, globally solar energy has become competitive under varying conditions for water heating and crop drying. In most of these areas, it is viable for refrigeration and as a substitute for diesel powered water pumping. More widespread use of solar water heaters in the basin would, therefore, make a significant impact on water heating costs, especially in urban areas where such heating is mostly by hydro-electricity (Arungu, 1996).

Currently, the patterns of production, conversion, distribution and use of energy in the Basin are wasteful, environmentally unsound and unsustainable. All the rural population and a bigger percentage of the urban population use wood (firewood and charcoal) energy causing massive deforestation in the Basin. According to Arungu, 1996, adequate and reliable availability of energy and access to energy services are a prerequisite to sustainable development. This, therefore, calls for the adoption of renewable energies like solar, wind and biogas whose potential is vast in the region. However, wind energy has not picked due to lack of adequate wind resource data and information to assist investors in decision-making while biogas is challenged by high capital costs for not only the plant, but also the modified burners and lighting units; lack of adequate supplies of water; and poor system design; and inadequate maintenance and management and technical support services - the plants are prone to cracking and leaking yet their operations require that they be air and water-tight.

With the concept of developing and using locally tailored solar and biogas energy systems to run the RAS and MBR systems for waste water treatment, the VicInAqua project will go a long way in tackling the energy challenges in the basin.

1.1.2. Socio-economic status

With a population of about 35 million people, the LVB is one of the more densely populated in the world, with an average of more than 500 persons/km^2, exceeding 1,200 persons/km^2 in parts of Kenya (Gef, *et al*. 2015). It is the most populated area in Africa, with an estimated growth rate ranging between 2.7% per annum in Kenya and Rwanda to 3.3% per annum in Uganda. Burundi and Tanzania are 3.2% and 3.0% respectively (UNDP, 2015). The rural population is about 60% of the total; with the exclusion of Kampala (the capital city of Uganda), the rural population is as high as 90%. On average, 65% of the population is less than 25 years old, which implies a high dependency level (Gef, *et al*. 2015). Table 2 shows a summary of the demographic situation in the basin.

Table 2: Demographic status in the LVB.

Country	Population			Average annual growth	Urban
	Current	Projected 2030	Under 5s		
	(millions)			(%)	
Kenya	45.5	66.3	7.1	2.7	25.2
Tanzania	50.8	79.4	8.8	3	28.1
Rwanda	12.1	17.8	1.9	2.7	20
Uganda	38.8	63.4	7.3	3.3	16.8
Burundi	10.5	16.4	2	3.2	11.8

Source: UNDP. Human Development Report, 2015.

The lake and its resources is of critical importance to the region's society and economy as a source of food, potable/domestic water, transportation, agricultural water and power production. Because of this, EAC has designated L. Victoria and its Basin as an "area of common economic interest" and a "regional economic growth zone" to be developed jointly by the partner states. https://www.lvbcom.org/index.php/who-we-are/overview-of-lvbc. Agriculture and fisheries are the two most important livelihoods. Other economic activities include; tourism (Mara River shared between Kenya and Tanzania, hosts the annual "Great Wildebeest Migration" between July and October); bee keeping; trading activities especially at border towns; quarrying and sand mining; and mining of gold, fossil oil and other minerals. Agrochemicals production and food processing are also among the important economic activities (Gef, *et al*. 2015). Over 70% of the Basin population is engaged in agricultural production mostly as small-scale farmers

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growing sugar cane, tea, coffee, maize, cotton, horticultural products and livestock keeping (Kayombo *et al*, 2006). Of these, 75 % are women yet they do not often own the land (Freidenberg, 2013).

All the five countries in the LVB remain ranked as low human development nations with the national GDP for 2014 ranging from US$ 7.6 billion in Burundi to US$ 120 billion in Kenya. The GDP per capita is lowest in Burundi (US$ 210) and highest in Kenya (US$ 507) (UNDP, 2015). Further human development trends are given in table 3.

Table 3: Major 2014 Human Development Trends of the LVB.

Country	Gross domestic product (GDP)	GDP	Gross National Income (GNI)	Human Development Index (HDI)	Gender Development Index (GDI)
	PPP $ billion	per capita (PPP $)			
Kenya	120.0	2,705	2,762	0.548	0.913
Tanzania	82.2	1,718	2,411	0.521	0.938
Rwanda	51.4	1,368	1,613	0.483	0.886
Uganda	16.8	1,426	1,458	0.483	0.957
Burundi	7.6	747	758	0.400	0.911

Source: UNDP. Human Development Report, 2015.

With about 28 million of the poorest rural inhabitants in the world. Poverty rates in the basin are 50% or more, and are especially high in the lakeshore areas of Kenya, where the situation is further compounded by a high incidence of HIV/AIDS and water-associated diseases along waterways (WAC, 2006). Kwena *et al*, 2012, attributes the HIV/AIDS prevalence to a transactional sex practice known as “Jaboya” in Nyanza where women fishmongers (approximately 27,000 by IRIN) secure the rights to purchase the fish caught by the fishermen by having sex with them. Due to the nature and context of the sexual intercourse, sex typically occurs in a hurried manner, often without preparation or protection.

1.1.3. Management

With all these complex environmental, socio-economic, geo-political, and technological innovations challenges (See table 4), the riparian countries and other development partners (UN, EU, World Bank, etc.) devised various interventions through bilateral and multilateral arrangements (LVBC, 2007[1]).

The East African Community (EAC) is the regional forum for discussing management issues in the five basin countries. Recognizing the vast potential for economic development in the LVB, the EAC declared the area an Economic Growth Zone (EGZ). The functional structure of the basin is given in Figure 2.

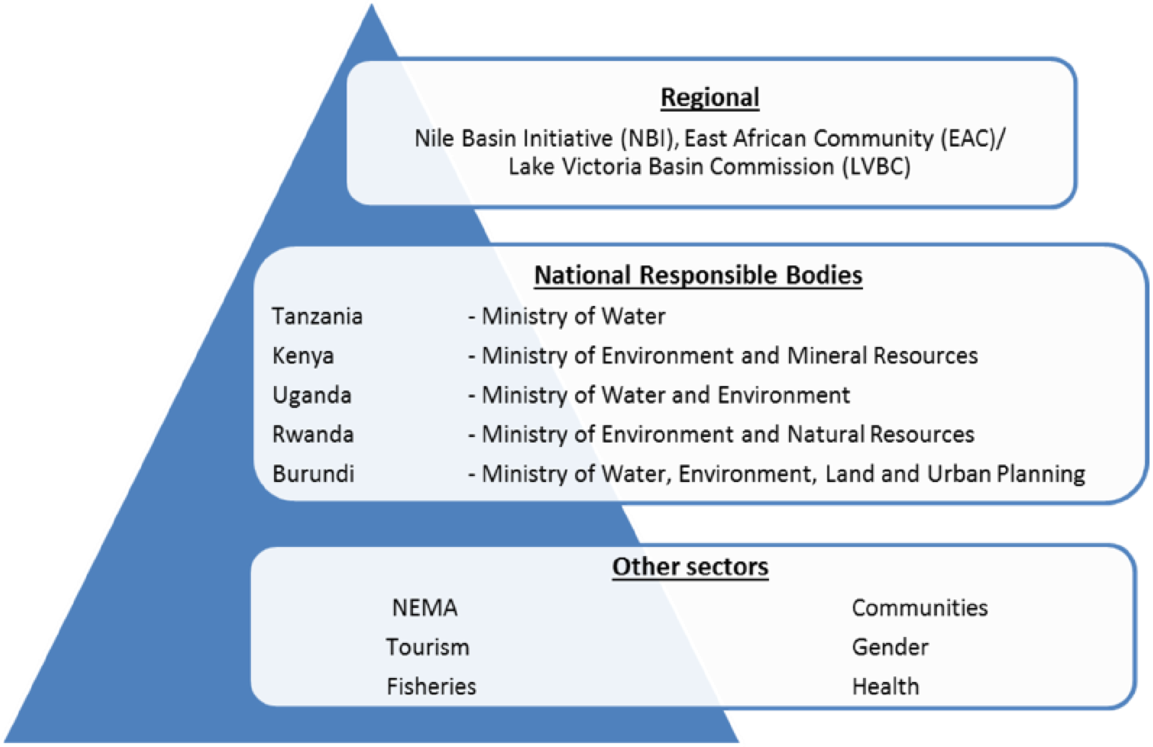

Figure 2: Functional Structure of the Lake Victoria Basin

Table 4: Summary of environmental threats in the LVB.

Location and root causes Basin-wide	
Basin-wide causes	Lack/ineffective/uncoordinated policies, poor governance, institutional and capacity constraints, inadequate awareness, limited access to relevant information, lack of involvement of stakeholders
Priority environmental threats by country	
Burundi	Deforestation, soil erosion, degradation of rivers banks, mining and wildlife hunting
Kenya	Water pollution, deforestation, soil erosion, sedimentation, loss of wetlands, eutrophication and water hyacinth
Rwanda	Deforestation, soil erosion, degradation of river banks, overgrazing, wildlife hunting and desertification
Uganda	Water pollution, deforestation, Wetland draining, encroachment of shorelines, declining water level
Tanzania	Deforestation, soil degradation, water pollution, desertification, declining water level, poaching and shortage of potable water

Source: LVBC. Strategic Action Plan, 2007[2].

1.2. Project focus

VicInAqua will follow an integrated approach in order to develop a sustainable combined sanitation and recirculating aquaculture system (RAS) for wastewater treatment using MBR and reuse in agriculture in the Lake Victoria Basin area. RAS will be operated fully autonomous powered by renewable energies (PV, biogas). The RAS will particularly produce high quality fingerlings of the local farmed fish species to supply the pond aquaculture of the area with stocking material.

2.0. Goal and objectives

2.1. Project goal

The core of the project concept is to develop and test novel self-cleaning water filters which consist of a highly efficient particle filter as well as a membrane bioreactor (MBR) as the principal treatment unit within a combined treatment system where the nutrient rich effluent water will be used for agricultural irrigation**.**

2.2. Project objectives

1. Develop a self-cleaning filter system
2. Design a novel high efficient energy supply system based on renewable energy production
3. Design a robust and low costs water management control system in real-time
4. Conduct awareness raising, capacity building and knowledge transfer
5. Develop an economic support instrument and regulatory framework
6. Ensure gender equality during project implementation

2.3. Report objectives

For the socio-economic factors affecting waste water management in the LVB, the following specific objectives guided the formation of this report.

1. To assess the socio-economic issues of RAS and MBR technologies related to aquaculture, fish processing and domestic waste water.
2. Determine the role of gender and youth in sustainable aquaculture, fish processing and domestic waste water management towards improvement of society wellbeing.

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3. Determine the existing legal and work policy on aquaculture, fish processing and domestic waste water management.
4. Establish availability and accessibility of waste water re-use by the community in the LVB.
5. To determine sustainable business cases which are comparable with MBR technologies in waste water management.

3.0. Approach/ Methodology

The methods used to collect data were mainly literature searching and key informants' round tables and interviews. Literature searching was mainly from online journals, published research reports and relevant organization websites (e.g. EAC, LVBC, FAO, Fish processing associations, SARNISSA among others). Most current factual data was collected by visiting the relevant management bodies and use of e-mails during follow-up.

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4.0. Literature Sectors

4.1. Membrane bioreactor (MBR) technology

“MBR technology was first introduced in the late 1960s. With the current focus on wastewater re-use, the search for cost effective advanced wastewater treatment technologies has never before been so important. The MBR is a suspended growth-activated sludge system that utilizes microporous membranes for solid/liquid separation instead of secondary clarifiers. It represents a decisive step forward concerning effluent quality by delivering a hygienically pure effluent and by exhibiting a very high operational reliability (Radjenovi´c *et al.*, 2007). The first MBR installation (Membrane Sewage System-MST) was made in U.S.A by Dorr-Oliver, Inc., with flat sheet ultrafiltration plate and frame membrane. However, it did not gain much interest in North America due to low membrane flux, permeability, limited membrane life, high costs of the membrane (Visvanathan, 2005) and the potential rapid loss of performance due to membrane fouling (Çağlar, 2013). It however had considerable success in Japan in the 1970s and 1980s (Radjenovi´c *et al.*, 2007). In the mid-90s, the developments gained a significant momentum with more reasonable operating parameters being determined depending on the wastewater characterization. While early MBR systems were operated at SRT (solid retention time) as high as 100 days with MLSS (mixed liquid suspended solids) up to 30 g/L, the recent trend is to apply lower SRT around 10–20 days, resulting in more manageable MLSS levels around 10-15 g/L (Çağlar 2013).

The major breakthrough, which allowed the MBR to grow much faster, was the development in Japan in 1989 (as a result of a Japanese government initiative to find better ways of wastewater treatment) of the submerged membrane. To ensure a homogeneous mixing of the activated sludge and control the clogging of the membrane surface, Yamamoto *et al.*, 1989 developed submerged membranes, dependent on the high Trans Membrane Pressure (TMP). This system became most preferred at the time (Visvanathan 2005, Leiknes, 2013). The resultant submerged (or immersed) MBR used two orders of magnitude less energy than the side stream version. It was this version that then entered the European market in the mid-1990s. Since 1990 the numbers of installed MBR have grown almost exponentially. MBR process has become very efficient and economically feasible for many industrial, commercial, municipal and even residential customers because of the infinitesimally small entities dealt with in this technology (Leiknes and Degaard, 2006). Currently, there are approximately 3000 plants in use worldwide although a lot of these are quite small. (Visvanathan, 2005, Radjenovi´c *et al.*, 2007 and Çağlar, 2013). Over the last 5 years, the MBR market has experienced accelerated growth reaching a market value of $217 million in 2005. It is evidenced by the constantly rising numbers of facilities and their capacities worldwide (Yang et al. 2006).

4.1.1. The Process

The Membrane Bioreactor System (MBR) consists of an activated sludge tank and a solid-liquid separation unit including membrane module. The process of the conventional activated sludge (CAS) system and the membrane bioreactor (MBR) is shown in Figure 3. Unlike the conventional activated sludge system, the activated sludge is separated via membrane filtration in membrane bioreactor systems (Çağlar, 2013).

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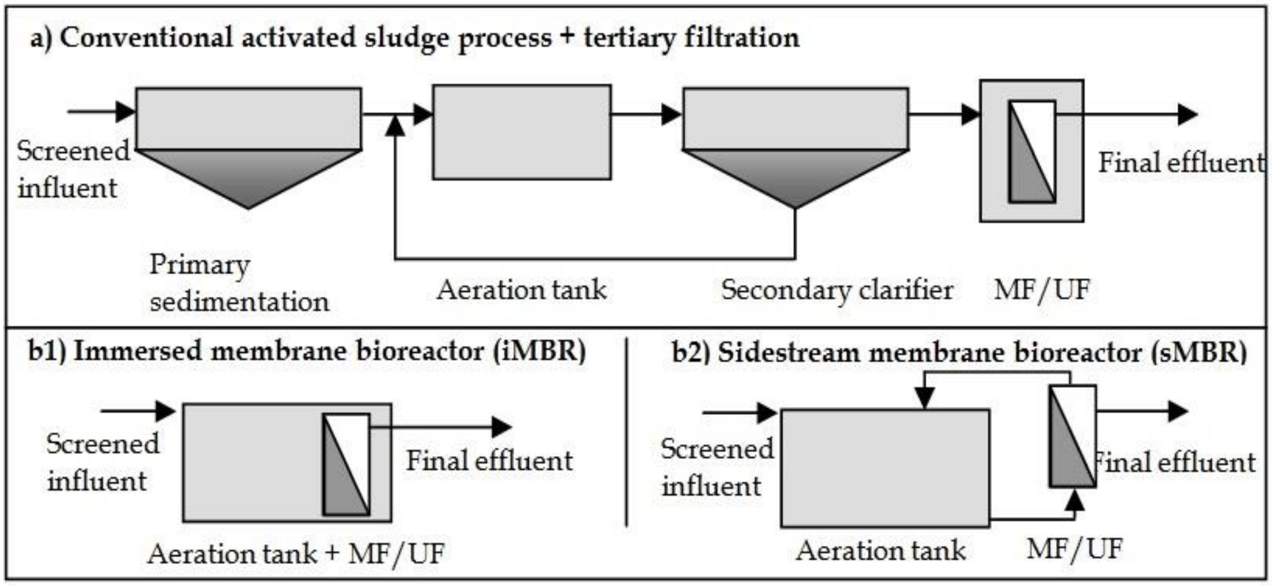

Figure 3: Conventional activated sludge process (a) compare to an immersed (b1) and sidestream (b2) MBR process.

The final products of the process are treated water and excess sludge. Treated water is usually discharged into water bodies such as lakes and rivers, while excess sludge ends up mostly as a fertilizer in agriculture; or converted into biogas production; or it is disposed of on land (Radjenovi´c et al 2007). The organic sludge undergoes considerable changes in its physical, chemical and biological properties during the anaerobic digestion (Appels *et al.*, 2008; Novak *et al.*, 2003; Mirzoyan *et al.*, 2010). Under ideal conditions, the ultimate products of this process are biogas composed of methane and carbon dioxide with small levels of hydrogen sulfide and ammonia (Ahring, 2003; Appels *et al.*, 2008; Mirzoyan *et al.*, 2010).

4.1.2. Benefits

MBR systems have several advantages, such as; excellent effluent quality (such as discharge to bathing waters or water reuse) (Churchouse, 1997; Takht Ravanchia 2009; Wiszniowski *et al.*, 2011; Hoinkis *et al.*, 2012); less footprint requirement (more compact installation), usually 30-50% smaller than an equivalent conventional active sludge facility with secondary clarifiers and media tertiary filtration (AMTA,

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2016); disinfection capacity; higher volumetric loading; less sludge production, lower operator involvement; modular expansion characteristics and combine a suspended growth biological biomass with solids removal via filtration as compared to conventional biological treatment systems (CBTS) (Judd, 2006; EPA, 2007; Till & Malia, 2001; Leiknes, 2013, Deowan *et al.*, 2016). In addition to this, scientific researchers are improving quickly around the world on the membrane surface and energy consumption because these are the most important factors restricting the development of the MBR systems (Chang, Fane & Vigneswaran, 2002, Çağlar 2013, Galiano *et al., 2015; Figoli et al., 2015*).

4.1.3. Challenges or barriers to MBR use

The most significant barrier to the more widespread installation of MBRs still remains the cost, since filtration performance can be limited by membrane cleaning, fouling control and eventual membrane replacement which are some of the basic operational costs (Fred, 2013).

Energy costs are also higher due to the air scouring to provide cross flow velocities for filtration. The amount of air needed for the scouring has been stated to be twice that needed to maintain aeration in a conventional activated sludge system (Fred, 2013).

Another principal limitation is membrane fouling which occurs as a consequence of interactions between the membrane and the mixed liquor. Fouling of membranes in MBRs is a very complex phenomenon with diverse relationships among its causes, and it is very difficult to localize and define membrane fouling clearly (Iorhemen *et al.*, 2016, Radjenovìc *et al.*, 2007). The main causes of membrane fouling are: Adsorption of macromolecular and colloidal matter, Growth of biofilms on the membrane surface, Precipitation of inorganic matter and Aging of the membrane (Iorhemen *et al.*, 2016, Radjenovìc *et al.*, 2007, Hoinkis *et al.*, 2012). However, the addition of coagulants and adsorbents shows a significant membrane fouling reduction, but further research is needed to establish optimum dosages of the various

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coagulants/adsorbents. Similarly, the integration of aerobic granulation with MBRs, which targets biofoulants and organic foulants, shows outstanding filtration performance and a significant reduction in fouling rate, as well as excellent nutrients removal (Iorhemen *et al.*, 2016).

Most current studies about MBR process are to inhibit or limit fouling in order to upgrade the membrane. One of the issues researchers are studying in recent years is modeling and simulation of MBR systems, especially for fouling membrane (Aileen & Albert 2007; Liang, Song & Tao, 2006; Çağlar, 2013). VicInAqua is one of such projects.

4.2. Fisheries and aquaculture

Globally, fish and fishery products represent one of the most-traded products of the world food sector, with its current annual production rate (average annual rate of 3.2 percent) outpacing that of population growth in the past five decades (FAO, 2016). Estimated at 1,000,000 metric tons per annum, Lake Victoria commercial fishery is dominated by three species; Nile perch (*Lates niloticus*), Nile tilapia (*Oreochromis niloticus)* and silver fish (*Rastrineobola argentea*) constituting over 95 % of total fish catch (LVFO, 2011). Supporting more than three million people, the Lake fishery contributes to the GDP of the riparian Partner States as follows– Kenya 2 %, Tanzania 2.8 % and Uganda 3 % (World Bank, 2009). In 2014, Uganda ranked sixth in inland water capture production accounting for 419,249 tonnes in the world (FAO, 2016). However, the fishery has long been dwindling and is increasingly dominated by young fish due to poor fishing gear, high number of fishing fleet and the rapid population growth. According to FAO 2016, the share of basin fish production utilized for direct human consumption has increased significantly in recent decades, up from 67 percent in the 1960s to 87 percent, or more than 146 million tonnes, in 2014. In solution, aquaculture has been adopted and is rapidly growing in the basin.

The basin practices freshwater aquaculture and has significantly recorded progress over the last decade. Currently, Uganda dominates the sector with an estimated production of 100,000 tonnes followed by Kenya at 48,790 tonnes while Tanzania produces 13,530 tonnes. The sector mainly involves small holder farmers with, earthen ponds dominating the culture systems in the basin. These are low labour easily managed systems but sustain fairly low stocking densities (Boyd and Tucker, 1998; Mirzoyan *et al.*, 2010). Fish hatcheries in the basin practice low level flow-through culture systems due to the high oxygen demand of young fish. However, gradually other intensive culture systems; cages in the lake and tanks for backyard fish farming are picking up due to increased fish demand despite the lake's dwindling catches. Cage culture, which started in early 2006 (Blow *et al.*, 2007), has been on Lake Victoria on pilot/experimental basis with 1,323 cages in Uganda, 20 in Kenya and 60 in Tanzania for 2013.

In most developed countries, super intensive systems like raceways and tanks incorporating RAS dominate due to a reliable energy supply coupled with limited land and water resources. Recirculating aquaculture systems (RAS) has seen aquaculture production to an increase throughout the world (FAO, 2012; Holan *et al.*, 2013). In East Africa, RAS technology is relatively new with eleven known farmers in Uganda 4 (one closed) of which are in the LVB. In Kenya ten are known country wide, three in the basin while none are known for Tanzania.

Though aquaculture can complement capture fisheries, e.g. through stocking programmes, by providing alternative livelihoods for fishers leaving the capture fisheries sector, and by providing alternative food resources. It can also negatively affect capture fisheries, e.g. introduction of invasive species and diseases, through competition for water resources, pollution, and access restrictions to traditional fishing grounds (FAO, 2016). The RAS technology promoted by VicInAqua is a modern technology that can help solve some of these problems (introduction of invasive species and diseases and pollution).

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Table 5: Summary of current fish farming status in the basin

Country	Fish farmers	Species	Culture Systems	Hatcheries
Kenya	>5,000	Nile Tilapia African Catfish	• Ponds (> 5,000) • Cages (>1000) • Tanks (> 100)	
Uganda	> 2100	Nile Tilapia African Catfish Chinese carps (under adoptive research)	• Ponds (> 5,000) • Cages (1,323) • Tanks (> 100) • RAS (4)	> 15 (> 20 million fingerlings)
Tanzania		Nile tilapia African catfish Milk fish	• Ponds (>21,300) • Cages (60)	50 (8.09 million fingerlings)

Source: DFR report, 2010/11 (Uganda); DFR report, 2015 (Tanzania); KI interview at DFR and NaFIRRI-Kajjansi in Uganda (2016).

4.2.1. Recirculating Aquaculture Systems

Recirculating Aquaculture System is an aquaculture systems that incorporates the treatment and reuse of water with less than 10% of total water volume replaced per day" (Hutchinson *et al.*, 2004; Pulefou *et al.*, 2007). In most establishments RAS technologies are either indoors, nearly closed, semi-closed or out-door production systems (Martins *et al.*, 2010; Holan *et al.*, 2013). They consists of mechanical and biological filtration components, pumps and holding tanks and a number of additional water treatment elements that improve water quality and provide disease control within the system (Chen *et al.*, 2006; Pulefou *et al.*, 2007). This has offered a number of advantages for aquaculture practices including:

- Full control of all parameters that influence growth so that the fish farmer can better manage economic and production performance,

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- Production in locations where limited water is available,
- Ability to manage waste production for greater environmental sustainability than traditional aquaculture systems,
- Ability to locate the operation close to markets to reduce product transport time and costs,
- Reduction in land area required when compared to pond-based systems, and
- Ability to integrate with agricultural activities (e.g. use of water effluent for hydroponics, horticulture or pre-use of irrigation water) (Pulefou *et al.*, 2007)
- Bio-security since the culture species are enclosed limiting genetic pollution due to escape and disease spread (Yanong, 2012).

The solids originating in the RAS are composed mainly of fish excretions and a small percentage of uneaten feed; and its volatile (organic) fraction ranges from 50 to 92%. Waste characteristics may also vary widely, depending on the fish species (Mirzoyan *et al.*, 2010).

Recirculating aquaculture is still considered a risky business by most people as it requires high animal densities to be feasible, diseases once introduced tend to spread rapidly, often resulting in catastrophic losses. Accidental reduction in oxygen levels increases carbon dioxide levels, system component failure, loss of electricity and related problems increase risks (Wheaton, 2010). In addition, intensive recirculating aquaculture systems (RAS) produce high volumes of bio-solid waste which is a potential source of pollution if not properly treated. A reduction in sludge-mass would, therefore, minimize the potential environmental hazard and economic burden stemming from its disposal. Recently, anaerobic digestion was suggested as an alternative to aquaculture sludge digestion and stabilization in RAS. This practice results not only in sludge-mass reduction, but also in water and energy savings, as well as in biogas production in certain practices, which can serve as an alternative energy source and partially cover the RAS's energy demands (Mirzoyan *et al.*, 2010). This concept is one of the key objectives of the VicInAqua project.

4.2.2. Integrating MBR into RAS for waste water treatment

The RAS system produces considerable accumulation of fine suspended solids and colloids or sludge that must be treated before it can be disposed of. These can, however, be avoided by integrating a membrane filtration unit into the system, where the inclusion of a membrane bioreactor (MBR) may be an alternative that facilitates the incorporation of membrane separation in already existing water treatment systems. (Holan *et al.*, 2013). The MBR combines the activated sludge process of a conventional activated sludge system (CAS) with a membrane (mainly hollow fibre or flat sheet membranes) submerged in the process water capable of filtering particulate waste components from the mixed liquor solution (Sharrer *et al.*, 2007). The role of the membrane is to separate the solids from the treated liquor, ensuring reliable and stable water quality. Despite the increasing commercial use of MBR systems throughout the world, the use of this technology in RAS has been very limited (Holan *et al.*, 2013). There is no experience at all with MBR for RAS in Africa. Some pilot trials have been conducted in Europe (Holan *et al.*, 2014) and Australia (Jegatheesan *et al.*, 2008) which show promising results. However, membrane fouling is posing a problem and frequent cleaning is needed. Jegatheesan *et al*., (2008) managed to reduce fouling by adding powdered activated carbon to the MBR system.

4.2.3. Socio-economic issues

Millions of people around the world find a source of income and livelihood in the fisheries and aquaculture. This increased the employment within the sector from 17 to 33% in 2010 (FAO, 2016). The sector engages several people due to its multiple sub-sectoral nature employing a wide range of the rural population hence contributing to food and nutrition security and alleviating poverty (GIZ, 2013; FAO, 2016). In the LVB, fisheries and aquaculture contributes positively to the GDP of the riparian

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countries through the increase of exports of fish and fish products processed earning foreign exchange revenues to the governments (Cocker, 2014).

In aquaculture, allocation of resources is determined by the farmer's house hold income influencing the choices of species farmed and desired productivity in a certain production period which affects investments and diversification of aquaculture activities (Isyagi, 2007).

However, at a macro-level, weaknesses in Government policy are the reasons for the poor performance and growth of aquaculture in the LVB (Harrison, 1984; Pedini, 1997; Hecht, 2000; Brummett and Williams, 2000; Machena and Moehl, 2001; Phillips., 2001, Isyagi, 2007). This is because government institutions determine farmers' access to resources for production and to markets but does not support the farmers as production and marketing relies on external support and directions leading to unsustainable production of the farming systems (Odongara *et al.*, 2005). VicInAqua will, therefore, adopt a multi-stakeholder participatory approach right from project inception.

4.2.4. Gender issues

Gender mainstreaming is a strategy for making women's as well as men's concerns and experiences an integral dimension to design, implement, monitor and evaluate their performances. (GIZ, 2013). This is because some groups of the society are often marginalized in development processes (NFP, 2015). Since aquaculture is still an emerging activity in East Africa, employment is still very low (Blow *et al.*, 2007). Women are increasingly involved in technical light-weight production jobs such as net mending and are also very active as processing hands in many processing plants, in land-based hatchery operations and low input systems that are an extension of their domestic tasks, allowing them to integrate fisheries and aquaculture activities with household and childcare chores. However, offshore duties are still dominated by men (Blow et al, 2007; GIZ, 2013). Entry into aquaculture appears to have fewer gender barriers as compared to capture fisheries, as this sector develops outside the cultural traditions/ beliefs (FAO, 2012). However, gender analysis in fishing and aquaculture communities is still at its initial stage, and is limited to the different occupational roles according to gender due to social, cultural, political and economic perceptions (GIZ, 2013). An important gender issue in the basin is the transactional sex practice known as “Jaboya” in Nyanza, Tanzania where women fishmongers secure the rights to purchase the fish caught by the fishermen by having sex with them. This has left prevalence of HIV/AIDS in the basin highest in women (WAC, 2006; Kwena *et al.*, 2012).

4.2.5. Governance and Policies

The Lake Victoria Fisheries Organization (LVFO) has overall responsibility for managing the fisheries and aquaculture sector in the LVB. At national level, policy formation and regulation is by ministries helped by the national fisheries departments and research bodies. At the grass roots are the Beach management units (BMUs) for capture fisheries and fish farmers’ associations for aquaculture.

To coordinate the fishery, facilitate the harmonization of policies, regulations, standards and guidelines among the member states and to provide technical support to stakeholders, LVFO uses a regional Fisheries Management Plan (FMP). First developed in 2001 (LVFRP/TECH/01/16), FMP I was implemented between 2005 and 2008. The second plan (FMP II) came into play in 2009 for the period 2009 - 2014. Early this August (2016), LVFO issued FMP III, to serve from 2016 to 2020 and draft guidelines for cage farming on the Lake (Key informant interview).

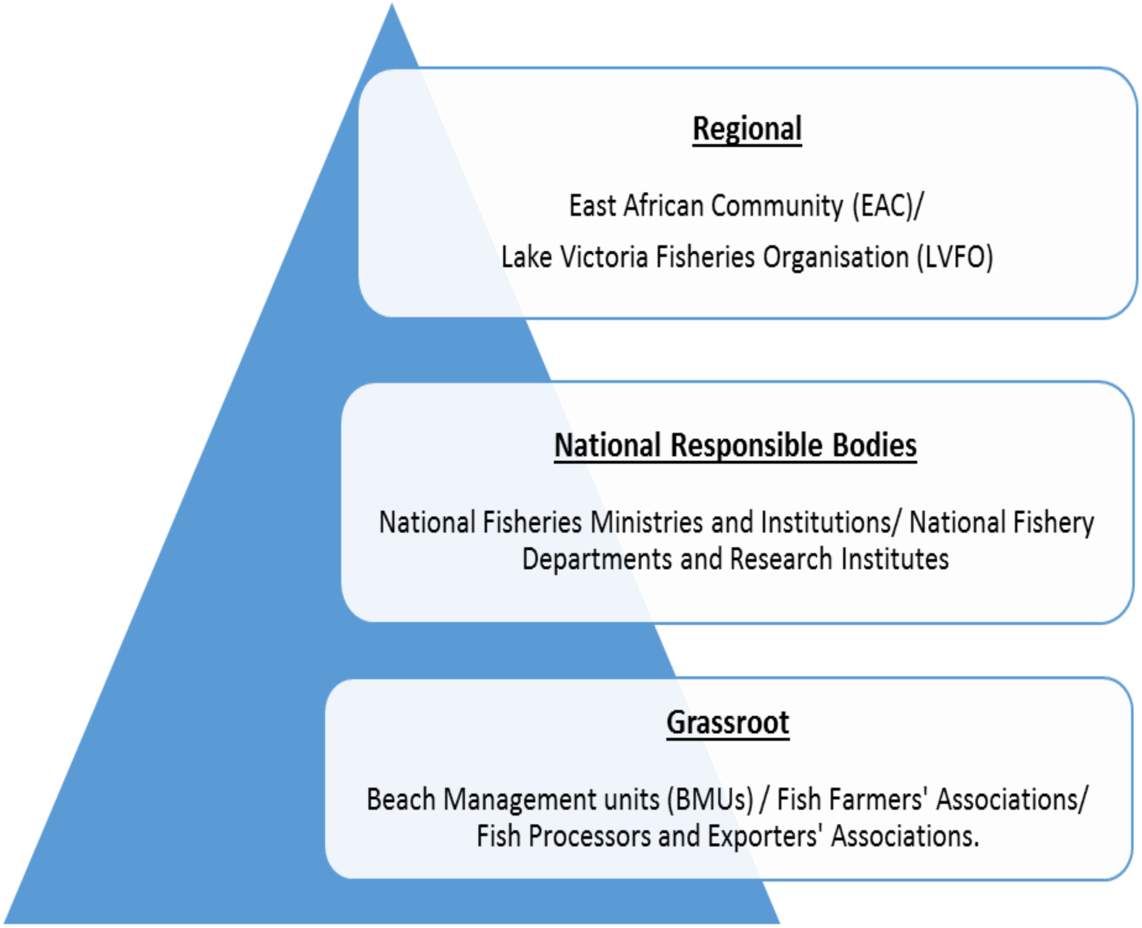

Figure 4: The Fisheries and Aquaculture management bodies in the LVB.

Table 6: Fisheries regulatory frameworks in the LVB.

Country	Policy/Law	Aim
Kenya	Fisheries Act (Cap 378), 1991	Overall legislation of fisheries
	The Fisheries (General) Regulations (1991)	
	The Fisheries (Fish Quality Assurance) Regulations (2000)	Control of quality and hygiene of fish and fish products.
	The Fisheries (Safety of Fish, Fishery Products and Fish Feed) Regulations (2006)	

	Fisheries management Act (2016) (The bill was assented to by the president this month)	Management of fisheries resources
Uganda	The Fish Act (Cap.197), April 1951 (under amendment)	Overall legislation of fisheries
	The Fish (Aquaculture) Rules, 2003	Legislation regulating the aquaculture sector, issue permits.
	The Fish (Beach Management) Rules, 2003	Controls the fishing operations in the fisher folk communities
	The National Fisheries Policy, 2004	Provide strategies to ensure sustainable exploitation of the fisheries resources
	Fish (Quality Assurance) Rules, 2008	Control of quality and hygiene of fish and fish products.
	National Investment Policy for Aquaculture Parks	Sets out concentrated aquaculture production areas (Aquaculture Parks).
Tanzania	National Fisheries Sector Policy and Strategy Statements (1997)	Transformation of the Fisheries Sector into sustainable commercial fishing, aquaculture, and processing.
	The Fisheries Act (2003)	Sustainable development of the sector.
	National Fisheries Policy (2010)	
	National Water Policy (1993)	
	National Aquaculture Development Strategy	Provides a framework in which the aquaculture industry in Tanzania can be developed.

4.3. Fish processing

Although industrial processing started as early as the 1950s (Ponte, 2007), its development in the basin is closely linked to the rapid growth of the Nile perch

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fishery in the LVB (FAO, 2016). In the 1990s, there were 15 processing plants along the shoreline of Lake Victoria (Reynolds and Greboval 1988, Abila 2000; FAO, 2003). However, the impeding collapse of the sector was first reported by Nile perch plants in the 1990s due to the EU ban on fish imports from the basin during the period 1997-2000 through its directive 97/296/EC. This was after the discovery of *Salmonellae* bacteria in samples of Uganda's fish exports coupled with an outbreak of cholera in the same place, which became a huge setback to the basin fish exports to the EU (Mkumbo and Marshal, 2015).

By the end of the crisis period in 2000, fish processors and exporters of the three riparian countries had upgraded their standards and processing systems to meet EU's health, sanitary and food safety requirements raising the number of plants to 35 by 2005. In 2007 for example, Uganda alone had 18 plants (Kiggundu, 2006; Bagumire, 2009; Turyaheebwa, 2014). This saw a rapid decline in the fish landings and together with the global crisis (regulation to control immature fish capture by enforcing a slot size restriction of 40 – 85 cm for the Nile perch fishery from the former 40 cm slot of 2008) caused some plants to close down leaving the basin with 26 plants only in 2008 (Bagumire, 2009). This decreased production of most companies by 30% of their total production. For instance in Tanzania one plant had its production of 25-30 tonnes per day reduced to 15 – 17 tonnes; and exports of 600-700 tonnes per month to 450-500 tonnes. Between 2007 and 2008, a plant in Uganda reported a 65% decline in production exports to international and regional markets. By 2009 most companies had complied with the slot size requirements increasing the number of plants in the LVB to 30 by 2011 (LVFO 2011 and Turyaheebwa, 2014). This saw a tremendous increase in sectoral employment with over 5000 individuals in Uganda alone (Kiggundu, 2005; 2006; SEATINI 2008 Fulgencio, 2009, Maurice, 2011). Today the basin hosts 31 active plants (See table 7); 11 in Tanzania, 14 in Uganda and 5 in Kenya (UFPEA: AFIPEK: TIFPA websites, 2016). The adaptability trend of the fish processors and exporters in the basin offers great opportunities for the VicInAqua MBR and water reuse technologies uptake.

Filleted and frozen Nile perch (*Lates niloticus*) products still dominate the export market to countries like European Union, the Middle East, South Korea, Singapore, Israel, Japan, Australia and within the regional markets (UFPEA: AFIPEK: TIFPA websites, 2016).

Nile tilapia (*Oreochromis niloticus*) is another important fishery that has transformed the fish processing sub-sector from subsistence to largely commercial. However, most of these plants have installed capacity which is twice the permitted quota due to lack of strict supervision on how much fish a plant buys per day, some plants process more fish than the permitted quota. (Abila *et al.*, 2003).

During processing fish by-products constitute 30 - 70 % of the plant produce. These are further processed into fishmeal and fish oil contributing to the GDP per capita supply of the riparian countries. Between 2011 and 2013, Kenya stood at 2−5 kg/year, Tanzania 5−10 kg/year and Uganda 10−20 kg/year. Fishmeal and fish oil are very important feed ingredients for the aquaculture sector which is the world’s fastest growing food production sector (FAO, 2016).

However, the increase in the growth of industrial processing has caused a decline in the artisanal processing (smoking, salting) in the basin. Furthermore, processing of aquaculture products is still negligible though growing since most processing plants deal in specialized fish products and are geared to serve primarily overseas markets (Odongkara *et al.*, 2006).

Table 7: Distribution of fish processing plants in the riparian countries.

Tanzania (TIFPA) Started in 2006	**Kenya (AFIPEK) 2000**	**Uganda (UFPEA) 1993**
Kagera Fish Company Ltd. Bukoba	Fish Processors (2000) Ltd. Kisumu	Byansi Fisheries Co. Ltd. Rakai

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Musoma Fish Processors Ltd.Musoma	Peche Foods Ltd. Kisumu	Fishways (U) Ltd. Entebbe
Mwanza Fishing Industries Ltd. Mwanza	W.E. Tilley (M) Ltd.	Fresh Water Fish Exporters Ltd.Masaka
Nile Perch Fisheries Ltd. Mwanza	J Fish Ltd. Kisumu	Gomba Fishing Industries Ltd. Kampala
Omega Fish Ltd. Mwanza	Victoria Delight Ltd. Kisumu	Greenfields (u) ltd. Entebbe
Primecatch Export Ltd. Musoma	East African Sea Food. Kisumu	Lake Bounty ltd. Kampala
Tanperch Ltd. Mwanza		Igloo Food Industries Ltd. Kampala.
Tanzania Fish Processors Ltd. Mwanza		Marine & Agro Export Processing. Kampala
Vicfish Mwanza Ltd. Mwanza		Ngege Ltd. Kampala
Vicfish Bukoba Ltd. Bukoba		Oakwood investments Ltd. Rakai
Tanzania Fisheries Development Cp. Ltd. Mwanza		Tampa fisheries Ltd. Kampala
		Uganda fish packers Ltd. Kampala
		Iftra (U) Ltd. Kampala

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		Unifoods (U) Ltd. Kampala

Source: UFPEA: AFIPEK: TIFPA websites, 2016.

NB: - In Kisumu all factories have closed down except East African Sea Food and Food Processors 2000, East African Sea Food is currently importing fish from China.

4.3.1. Socio-economic issues

The rapid expansion of the fish processing plants in the LVB has immensely impacted on the development of the riparian countries creating employment opportunities mostly for the rural based sector of the population, reducing rural-urban migration in the region.

The fish demand by the processing plants has raised the price of fish to a level which cannot be easily afforded by the majority of the local people. There is, therefore, need for a nutritional policy to ensure, adequate fish consumption for locals (EPRC1999, LVFO, 2005). One such policy is the illegal export of unprocessed fish in Uganda (Dhatemwa 2009; Maurice, 2011).

Since these fish processing plants comprise an important segment of the economy (Gumisiriza *et al.*, 2009), it contributes to GDP and continues to be an important source of foreign exchange earned from exports and revenues to the local and national governments through levying of various taxes, levies and license fees which enables proper management of the resources in the basin (LVFO, 2007).

Recently, the fish processing sub-sector is important for poverty reduction as it provides a direct source of income to households in semi and artisanal processing (FAO, 2012). However, the distribution of these benefits varies regionally, nationally and individually creating a sense of social injustice among the beneficiaries. This limits individual growth and poverty alleviation, leading to low compliance to fisheries regulations and hinders attaining sustainable fisheries exploitation in the basin (Abilla *et al.*, 2000; LVFO, 2005).

4.3.2. Gender issues

Fish processing around the LVB is characterized by a high participation level of single, divorced, widowed women and separated mothers (Ogutu 1992; Medard and Wilson 1996; Geheb 1997; Lwenya *et al*. 2006). Women are usually involved in semi-processing due to the huge capital investment required in full processing (Medard *et al*, 2003). The processing is mainly done around the beach, not inland markets, due to the highly perishable nature of fish.

The employment and credit arrangement between men and women in processing plants also vary considerably (Medard *et al*, 2003). Women are being marginalized in the fish plants with their involvement limited to small scale, lower remuneration tasks of processing native species and their roles ignored to discount their potential to strengthen the sector (Sumudra, 1995; Medard *et al*, 2003). Women's income from fish processing and other post-harvest work leads to their active involvement in financing fish catching operations, providing up to 60% of the cash flow needed for their families (DFR, 2012). Despite their importance and contribution to artisanal fish processing, women have received little attention from both the government and non-governmental organization (NGOs). If the fisheries sector is to maintain its current level of contribution towards household and national economy, then the role of women in the sector has to be a matter of priority (Medard *et al*, 2003). Therefore, due to an increasing number of women in the fish processing sector, policy and management must address the gender dimension to include the interests and needs as well as environmental impacts of both men and women in fish processing plants (*Gumisiriza et al., et al.*, 2009).

4.3.3. Waste water management

Industrial fish processing generates large amounts of waste waters or residues of high nutrient content which, if not properly utilized or treated, creates pollution and health problems since they are always deposited in waterbodies like Lake Victoria (Hwang

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and Hansen, 1998; Kotzamanis *et al.*, 2001; Gumisiriza *et al.*, 2009). These fish processing industries generate approximately 36,000 tonnes of solid waste which constitutes about 30 - 40% of the total production depending on the processing efficiency. In the basin, Tanzania generates more than 75% of the total solid waste emitted because of the high processing capacity of the industries along the Tanzanian side of the lake particularly in Mwanza. The LVB fish processing wastewater annual production is 1,838,000 cubic meters. (Gumisiriza *et al.*, 2009; Masiga, 2013). The major wastes generated along the fish processing line are shown in table 8 shown. The current physio-chemical composition of waste waters from a few plants in the basin is given in table 9.

Table 8: Major fish processing waste streams and their predominant waste fractions

WASTE STREAM	WASTE FRACTION EMITTED
Receiving section	Caucus/Fish rejects, Wash-off water
Filleting section	Skin, Flame/Bony skeleton, Bloody water, caucus
Trimming	Chips, Fats, Fillet rejects pieces of bones
By-product	Viscera, Fats Roes/eggs, Head, Breast, Bloody water
Headed & Gutted	Scales, Viscera, Bloody water, Fins
Grading & Packaging	Fillet rejects, deteriorated fillets

Source: Gumisiriza *et al.*, 2009

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Table 9: Waste water analysis of two Fish Processing Plants in Uganda in relation to the National Standards for effluents Discharge.

Plant	Effluent	pH	EC (µS/cm)	CA (PtCo)	Turbidity NTU	Temp. (°C)	TA (mg/L as CaCO3)	TSS (mg/L)	TDS (mg/L)	BOD5 (mg/L)	COD (mg/L)	Ammonia -N (mg/L)	Nitrate (mg/L)	Phosphate (ortho) (mg/L)	TP (mg/L)	O+G (mg/L)	FC (CFU/100 mL)
Recommended Discharge		**6.0 - 8.0**	**1500**	**500**	**300**	**500**	**800**	**100**	**1200**	**50**	**100**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10000**
A	**Raw**	6.95	640	*	*	27.0	90	72.0	*	320	700	142.35	*	5.50	8.50	*	15000
	Intermediate	6.83	621	*	*	25.6	100	52	*	98	230	105.00	*	2.73	5.30	*	6300
	Final	6.70	633	*	*	25.0	100	22	*	52	180	98.40	*	2.62	4.03	*	2700
B	**Raw**	6.72	1152	291	152	*	318	96	630	482	591	122.4	0.22	49.2	49.2	392.1	44208
	Intermediate	6.81	844	171	68	*	266	55	500	122	235	28.5	0.38	17.7	17.7	19.2	1420
	Final	6.69	720	144	62	*	260	52	401	45	98	10.1	0.41	9.9	9.1	7.7	940

Where: TSS (Total Suspended Solids), TA (Total Alkalinity), CA (Colour: apparent), TP (Total Phosphate), Temp. (Temperature), FC (Faecal Coliform), EC (Conductivity) and C+G (Oils and grease).

Samples collected on 21st April, 2015 for Plant-A and 3rd August, 201 6 for Plant-B.

* Not collected

Source: DFR, Uganda (Key Informant interview)

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Table 10: Raw waste water analysis of two Fish Processing Plants in Kenya in relation to the National Standards for effluents Discharge.

Plant	Sample Date	pH	EC (µS/cm)	CA (PtCo)	Turbidity NTU	Temp. (^{o}C)	SS (mg/L)	TSS (mg/L)	TDS (mg/L)	BOD5 (mg/L)	COD (mg/L)	Ammonia -N (mg/L)	Nitrate (mg/L)	Phosphate (ortho) (mg/L)	TP (mg/L)	O+G (mg/L)
A	14th July, 2016 for	6.8	572	*	*	23.5	4.3	217	*	219	*	*	0.2	6.2	*	*
	25th July, 201 6	6.8	960	*	*	23.0	3.1	311	*	274	*	*	1.23	10.2	*	*
B	14th July, 2016 for	7.1	480	*	*	21.4	2.1	202	*	211	*	*	0.11	3.0	*	*
	25th July, 201 6	7.0	466	*	*	24.3	1.8	219	*	233	*	*	0.81	5.3	*	*

Where: TSS (Total Suspended Solids), TA (Total Alkalinity), CA (Colour: apparent), TP (Total Phosphate), Temp. (Temperature), FC (Faecal Coliform), EC (Conductivity) and C+G (Oils and grease).

* Not collected

Source: DFR, Kenya (Key Informant interview)

According to LVEMP (2002), most fish processing plants in the LVB do not have effluent treatment plants although there has been an increased focus on water minimization in recent years due to the introduction of the EU Waste Water Treatment Directive. The specificity of fish processing operations leads most authors to recommend a waste audit for each company as a starting point that may lead to an overall Environmental Management System (EMS) (Pfeiffer, 2003). As a result, most large fish processors in the basin have now undertaken wastewater audits and minimization strategies (Pfeiffer, 2003). The nature of fish processing wastewater suggests that industries must have high biological oxygen demand (BOD) together with inorganic compounds from detergents and disinfectants which if not sufficiently treated leads to eutrophication of the lake, which may result into changes in species composition, and even loss. (Muyodi *et al.*, 2004; *Gumisiriza et al.*, 2009 and Masiga, 2013). Despite the attempt by most fish processing plants to treat their waste water, the methods employed are compromised mainly due to the nature of the fish waste itself and limited land. For those which attempt to treat the wastewater, small sized conventional stabilization ponds are used despite the high strength nature of the fish processing wastewater (Muwanga and Barifaijo, 2006; Muyodi *et al.*, 2004 ; *Gumisiriza et al.*, 2009; Wang *et al.*, 2013). However, the high lipid content of fish processing wastewater leads to the formation of a thick layer of fats that covers the pond surface. This compromises pond aeration consequently lowering their efficiency; although these fats can be removed for use in biodiesel production.

With the implementation of guidelines for discharge of effluent into water or on land, most treatment plants in the basin have devised on-site treatment methods before release into the adjacent municipal sewers or lake or wetland. A point-in-case is the Uganda "National Environment (Standards for discharge of effluent into water or on land) Regulations, 1999" which sets out the effluent discharge water quality standards (see table 9). A fish processing plant (Plant-A, table 9) in Uganda requires an annual average general water usage (production, ice production, cleaning, sanitaries, and domestic/canteen) of 21,600 m^3 (cubic) costing 63,129.6 Euros. Of this, about 20% is used for production with the fresh Perch line using 20,000 liters per hour. Due to this

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high water requirement, the plant management expressed interest of wastewater reuse for general cleaning and sanitaries. As a requirement by the government fish processing inspection unit (monthly effluent quality), the plant spends 947 Euros on average annual waste water analysis. Situated in the heart of the city, the plant discharges its effluents in the nearby municipal sewers at an average annual silage emptying cost of 4,735 Euros. Another expense incurred is maintenance of the waste water treatment unit at an annual cost of 263 Euros. This brings the plant total water related expenses to 69,074.6 Euros (Key informant interview). The VicInAqua MBR concept if adopted, will help such plants improve their effluent quality and reduce the cost of silage emptying since the effluent will be fit for reuse in agriculture.

4.3.4. Policies, Quality Assurance and Safety

Due to the generous contribution of the fish processing industries to the GDP in the basin, the sub-sector has taken policies aimed at providing and enabling investment environments, privatization and export promotion (Odongkara and Okarono 1999; LVBC, 2007[2]) to ensure that there is adequate fish processed for both local and export markets; and to improve food security, societal wellbeing and the economic position of the LVB (Nyeko 2004, 2007).

The legislative authority of fish processing in the basin (LVFO) is guided by the Fish Acts of the three riparian countries and is supported by the subsidiary legislation of the respective responsible ministries. All processors in the basin must document and implement a Quality Management Program (QMP), which considers all HACCP (Hazard Analysis and Critical Control Points) principles and other regulatory requirements in order to maintain their certificate of registration annually (Omoding, 2001). To qualify for registration, the establishment must meet certain requirements for construction, equipment and operation. HACCP regulations are harmonized with the EU regulations thus fish plants meeting the basin regulations also meet the EU regulations (Atyang, 1999). The Quality Assurance Unit (QAU) of LVFO is responsible for statutory inspections, certifications, monitoring and control of fish and fishery products in fish processing establishments and upstream operations in the basin. It is guided by the Fish Quality Assurance Rules (FQARs) of the respective countries which mandate all plants to adhere to the GMPs (Good Manufacturing Practices). Under the QAU, Fisheries Laboratories were established in each of the three riparian countries. At national level, the Departments of Fisheries Resources (DFR) act as the competent authority for the EU where it carries out regular test on the fish and water sediments to check for heavy metal, microbial tests and pesticides residues (LVBC, 2007[2]).

After the illegalities that hit the fish industry in mid-2000 leading to the reduction in the fish stocks, the Fish Processors and Exporters Associations in the three riparian countries have committed themselves to take self-policing and devised control programmes. These involve individual inspection of fish processing plants and measures all fish processed (Key informant interview).

4.4. Domestic waste water management

Sustainable access to safe drinking water and basic sanitation through proper domestic wastewater treatment is an important part of the millennium development goals (MDGs) (Wang *et al.*, 2013). Domestic wastewater is the water that has been used by a community and contains all the materials added to the water during its use (Mara, 2004). These wastes are generated by household activities like flushing toilets, bathing, laundry, food preparation and the cleaning of kitchen utensils. The two major components of domestic waste water are human feaces and sullage. These wastes are largely organic, and are together equivalent to the raw sewage (Emmerton *et al.*, 1998). The human fecal matter are composed of varying percentages of moisture, organic matter, nitrogen, phosphorus, potassium, carbon and calcium while Sullage contributes a wide variety of detergents, soaps, lubricants, pesticides, fats and greases of various kinds, acids, xenobiotics, nitrates and heavy metals e.g. mercury (Mara, 2004, Christopher, 2004, Wang *et al.*, 2013, Shire, 2014).

In the LVB, domestic wastes contribute by far the greatest quantity of wastewater and highest proportion of the total nutrient load entering the wetland and lake (COWI/VKI 1998; Emmerton *et al.*, 1998). They originate from the Sewage Treatment Plants (STPs); groundwater seepage from on-site sources; and from catchment runoff especially after a rain shower. The runoff generally ends up in open and vacant lands resulting in the creation of smelling stagnant water pools which in many cases affect those in contact with them especially children who play in them. As a result health risks have increased by the fact that households and surface water drainage systems are always combined, resulting in the contamination of floodwater with excreta (Christopher, 2013). The greatest impacts have been felt by poor communities and slums, who often inhabit low-lying and marginal lands where such waters stagnate.

Also the rapid population growth, growing commercial activities and industrialization in Kampala, Uganda coupled with inadequate provision of proper domestic wastewater management services have led to increased volume of wastewaters entering the environment (Eric *et al.*, 2004). Therefore, domestic wastewater management can be one of the many basic strategies for keeping the environment clean and safe for human habitation (Christopher, 2013). Treatment combined with productive re-use contributes even more directly to socio-economic development (Mara, 2004).

4.4.1. Waste water management

The principal aim of domestic wastewater treatment is to reduce effects felt when the domestic wastewaters are untreated and disposed into the community, this may be environmental transmission of the (excreta-related) diseases caused by a substantially high concentration of pathogens in the domestic wastewaters (Christopher, 2013).

Fecal treatment methods in the LVB are mainly on-site pit latrines and septic tanks widely used in rural and semi-urban areas (Ong'ang'a & Makonge, Wang *et al.*, 2013). However, the maintenance and management of these pit latrines is very poor which deteriorates the ground water quality (UNEP, 2010; Wang *et al.*, 2013). Many of them are full and flowing especially those in and around the wetlands posing a threat of waterborne diseases around the basin. Due to lack of proper maintenance of septic tanks, many are ageing and breaking causing the seepage of highly contaminated waste waters (with components such as chemicals, bacteria, protozoa and viruses) into the drinking water supply systems.

Wastewater (sullage) treatment or disposal in the basin is mainly done in the natural wetlands; however, due to the rapidly growing population, there are increased pollutant loads causing functional deterioration of these wetlands. In addition, the rate of wetland degradation for settlement purposes is on the upsurge in the basin. Municipalities in the basin are practicing off-site wastewater treatment technologies like; conventional treatment processes (activated sludge treatment; biofilms ditches; and aerated lagoons) and stabilization ponds (Wang *et al.*, 2013).

Off-site waste water treatment in the LVB started with Sewage Stabilization Ponds (SSP), the wastewater is treated through two processes: physical treatment and biological treatment (Wang *et al.*, 2013 and Mara 2004). They are low cost technologies used for wastewater treatment by most of the water treatment authorities in the urban settlement in the basin. These WSPs are easy to operate; require little energy supply; yet effectively remove solids, coliform, and ammonia and reduce BOD. However, managing these ponds can be a challenge due to wastewater loss through seepage; weed growth; embankment damage due to erosion; periodic settled sludge and inert material removal; difficulty in controlling or predicting ammonia levels in effluent; excessive sludge accumulation during cold weather due to reduced microbial activity; and require relatively large areas of land. They also act as disease incubation grounds as they host vectors like mosquitoes and similar insect vectors. (Wang *et al.*, 2013; UNEP/WIOMSA, 2009).

The increasing population and urbanization triggered the on-set of Conventional Sewage Treatment Works (CSTW) also known as fixed film technologies. CSTWs treat high volumes of waste water yet occupy smaller space as compared to SSPs.

They use trickling filters and aerated lagoons to remove organic matter from wastewater (Wang *et al.,* 2013; Key Informant interview).

With the high establishment and maintenance costs involved in CSTWs, many private investments requiring waste water treatment have adopted the relatively new low-cost technology of constructed wetlands. Constructed wetlands are the engineer-made equivalent of natural wetlands, designed to reproduce and intensify the wastewater treatment processes that occur in natural wetlands (Mara, 2004). It physically, chemically and biologically removes pollutants and sediments from the wastewater passing through it. For example the wetland at Nakivubo Kampala plays an extremely important role in maintaining the quality of the city's water supply (Emerton *et al.,* 1998). However, these technologies and systems widely used in the LVB today for wastewater treatment are extremely challenged. They have a low coverage; with limited technical manpower/skills for proper operation and maintenance of existing sewerage system; many lack regular monitoring of treatment performance; some plants and technologies used are very old; and unreliable power supply system. Another challenge is the growth of algae that consumes more chemicals and clogs filters resulting in bad odour and may cause microcystin, which is toxic and hazardous to human health [Okello *et al.*, 2010; Wang *et al.*, 2013]. To date in LVB no treated wastewater is being reused for irrigation in agriculture. Due to its high water quality MBR effluent offers a great opportunity to reuse treated wastewater for irrigation what will significantly contribute to water saving.

Though the development and application of a membrane bioreactor (MBR) for full scale municipal wastewater treatment is the most important recent technological advance in terms of biological wastewater treatment (Radjenovi´c *et al.,* 2007), No MBR use is registered in the basin. The VicInAqua project therefore finds a MBR niche in the LVB.

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Table 11: Waste water analysis for the Kampala City treatment plants sampled in July, 2016.

STATION	EFFLUENT	**pH**	**EC (μS/cm)**	**TA (mg/L as CaCO3)**	**TSS (mg/L)**	**BOD5 (mg/L)**	**COD (mg/L)**	**Phosphate (ortho) (mg/L)**	**TP (mg/L)**	**Ammonia -N (mg/L)**	**% Reduction**	
											BOD	TSS
CSTW-A	**Raw**	7.56	2011	955	1100	332	525	20.87	33.72	nd		
	Final	7.79	1117	295	**146**	**55**	**175**	**11.95**	**16.46**	nd	**94**	**93**
CSTW-B	**Raw**	7.50	34708	5850	3953	385	1418	50.74	66.42	nd		
	Final	7.93	**4053**	**1700**	**298**	**74**	**285**	**13.47**	**22.06**	nd	**99**	**99**
SSP-A	**Raw**	7.42	839	318	351	293	590	5.70	13.01	nd		
	Final	**8.86**	803	340	**170**	38	**108**	3.03	6.41	nd	**88**	**80**
SSP-B	**Raw**	7.18	835	230	423	297	548	7.37	13.20	nd		
	Final	**8.39**	491	180	72	21	61	4.10	5.48	nd	**91**	**91**
SSP-C	**Raw**	6.86	789	278	257	258	556	6.76	8.29	nd		
	Final	7.90	623	365	81	25	68	5.09	5.90	nd	**91**	**90**

Where: TSS (Total Suspended Solids), TA (Total Alkalinity), TP (Total Phosphate), EC (Conductivity), BOD (Biological Oxygen demand) and COD (Chemical Oxygen Demand)

nd - not determined

The Red Bold - Failed to meet standard.

Source: NWSC Uganda (Key Informant interview)

STATION	EFFLUENT	**pH**	**EC (µS/cm)**	**Temp. (^{0}C)**	**SS (mg/L)**	**TSS (mg/L)**	**TDS (mg/L)**	**BOD5 (mg/L)**	**COD (mg/L)**	**Ammonia -N (mg/L)**	**Nitrate (mg/L)**	**Phosphate (ortho) (mg/L)**	**Inflow Rate (m^3/day)**	**Discharge Rate (m^3/day)**
CSTW	**Influent**	6.98	148.7	25.2	0.48	625.5	*	525.6	*	*	1.12	13.68	5886	5766.6
	Pri-sed	7.09	639.4	25.0	0.1	203	*	101.4	*	*	0.8	9.30		
	Filters	7.19	225.5	24.7	0.72	76.2	*	57.1	*	*	0.64	7.23		

Table 12: Raw waste water analysis for KIWASCO, Kenya sampled in July, 2016.

	Sec-sed	7.23	77.1	24.8	*	39.7	*	44.2	*	*	0.59	7.17		
	Effluent	7.27	563.8	24.8	0.1	19.16	*	21.8	*	*	0.55	6.98		
SSP	**Raw**	7.1	808	25.2	7.3	307	*	311	*	*	0.73	10.6	5776.4	*
	Final	7.6	39.8	25.09	0.1	14.3	*	19.3	*	*	0.14	2.13		

Where: TSS (Total Suspended Solids), TA (Total Alkalinity), CA (Colour: apparent), TP (Total Phosphate), Temp. (Temperature), FC (Faecal Coliform), EC (Conductivity) and C+G (Oils and grease).

* Not collected

Source: DFR, Kenya (Key Informant interview)

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4.4.2. Socio-economic issues

Waste management is the final component of the City Development Index (CDI) - the component that advances most slowly and is most difficult to improve with increasing development (UN – Habitat, 2007). The greatest development challenges facing Lake Victoria basin are its socio-economic and ecological problems, with a close correlation between poverty, environmental degradation from wastes, ignorance and diseases while the human population continues to grow with expanded human settlements and urbanization without proper planning and improved infrastructure facilities (Odada *et al.,* 2006). This consequently leads to low propensity for healthy and nutritious population due to poor water supply and sanitation and other water borne diseases (Colophon, 2015).

Domestic and industrial wastewater, solid waste, sediments from soil erosion, agricultural waste and atmospheric deposition are the major nutrient sources of Lake Victoria (Odada *et al.,* 2006). Deeper areas of Lake Victoria are now considered dead zones because they are unable to sustain life due to oxygen deficiency in the water and have caused considerable hardship for the population depending on it for their livelihoods. (Kayombo *et al.,* 2005). The discharge of partially treated or untreated raw sewage from the above sources have resulted in to waterborne diseases such as diarrhea, cholera and typhoid fever, dysentery, and certain intestinal parasites because of the combination of unsafe drinking water and inadequate sanitation facilities causing a number of deaths in the LVB (Odada *et al.,* 2004, Byamukama *et al.,* 2005, Muyodi *et al.,* 2006).

Poverty reduction is a major aim of most governments; urban poverty is often manifested most severely in cities where the poor are compelled to live together in informal settlements with poor sanitation and disposal of waste and limited food and clean water (UN – Habitat, 2007). Poverty is widespread in the Lake Victoria basin particularly among the rural communities and is greatly linked to cash-income generating source caused by numerous diseases, conflicts, lack of education and skills, and lack of infrastructure (Odada *et al.,* 2006; Colophon, 2015) increasing infant mortality rates from as high as 176/1000 to 259/1000 in the basin (McElroy and others 2001). In 2002 infant mortality rate estimates for Tanzania stood at 104/1000 (UNCD 2005). This has prompted governments to design measures; and provide water and sanitation at the local level by developing Community Owned Water Supply Organizations to ensure proper

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management and maintenance of the installed local schemes thus improving water quality and sanitation that greatly contribute to a reduction in child mortality (Colophon, 2015; UNICEP and WHO 2012).

4.4.3. Gender issues

The importance of involving both women and men in the management of water, sanitation and access-related questions has been recognized at the global level (Colophon, 2015).This demonstrates that, at the community level, solutions to clean water and appropriate sanitation problems must address prevailing gender systems, gender division of labour that determines women`s primary responsibility for water in the households and distribution of power between men and women (UN, 2006). Waste water in LVB tends to affect men and women differently (Muyodi *et al.*, 2006). In many local cultures in the LVB, women and girls bear the primary responsibility for water, sanitation and hygiene at the household level. For them, sanitation means more than just latrines: it incorporates safety and dignity. They require sufficient water for personal use to maintain good hygiene, as well as local drainage systems that ensure wastewater is not discharged into the areas around their households. Unhygienic public toilets and latrines without water facilities threaten the health and dignity of women, exposing them to myriad infections, particularly those affecting their reproductive organs (UN-HABITAT, 2008).

Social expectations dictate that women and girls are the primary water carriers for their households. Over 70% of households where water is fetched, women and girls do the water fetching. In rural and Lakes areas, water sources are distant and women walk up to two hours to fetch water for household use. Collection of water from the lakeshore is mostly done by women and children, making them more vulnerable to contract water borne diseases such as malaria, dysentery, diarrhoea, bilharzia, cholera, skin-related infections, influenza, hepatitis A, and typhoid fever (Colophon, 2015). Poor women and men, the elderly, youth, orphans and other vulnerable groups are often excluded from decision-making but are the most affected by the lack of water and sanitation services including pregnant women and children (Karanja, 2006).

Therefore, there is need to provide answers to the different interests of men and women in ensuring access to clean water and sanitation breaking down many barriers based on prevailing traditional gender standards (UN-HABITAT, 2007).

4.4.4. Governance and policies

The lead government agencies of the water sector are the respective ministries in the three riparian countries; the Ministry of Water and Environment (MWE) for Uganda; Ministry of Water and Irrigation (KMWI) in Kenya and the Ministry of Water and Irrigation (TMWI) for Tanzania. These supervise the national utilities (table 8) responsible for sewerage services in urban centres; operation and maintenance; and investment in sewerage infrastructure. To regulate the use and management of Wetlands and environment related issues, the National Environment Management Authorities (NEMA) for Uganda and Kenya and the National Environment Management Council (NEMC) in Tanzania, are employed. For water irrigation and drainage, the mandated Ministries are KMWI for Kenya, TMWI in Tanzania and the Ministry of Agriculture Animal Industry and Fisheries (MAAIF) for Uganda (Gef *et al*, 2015; Key Informant interview).

The major governing policies are the National Water Policies and the National Irrigation Policies in the respective riparian countries. All the EAC countries signed the RAMSAR convention for the conservation and sustainable use of wetlands.

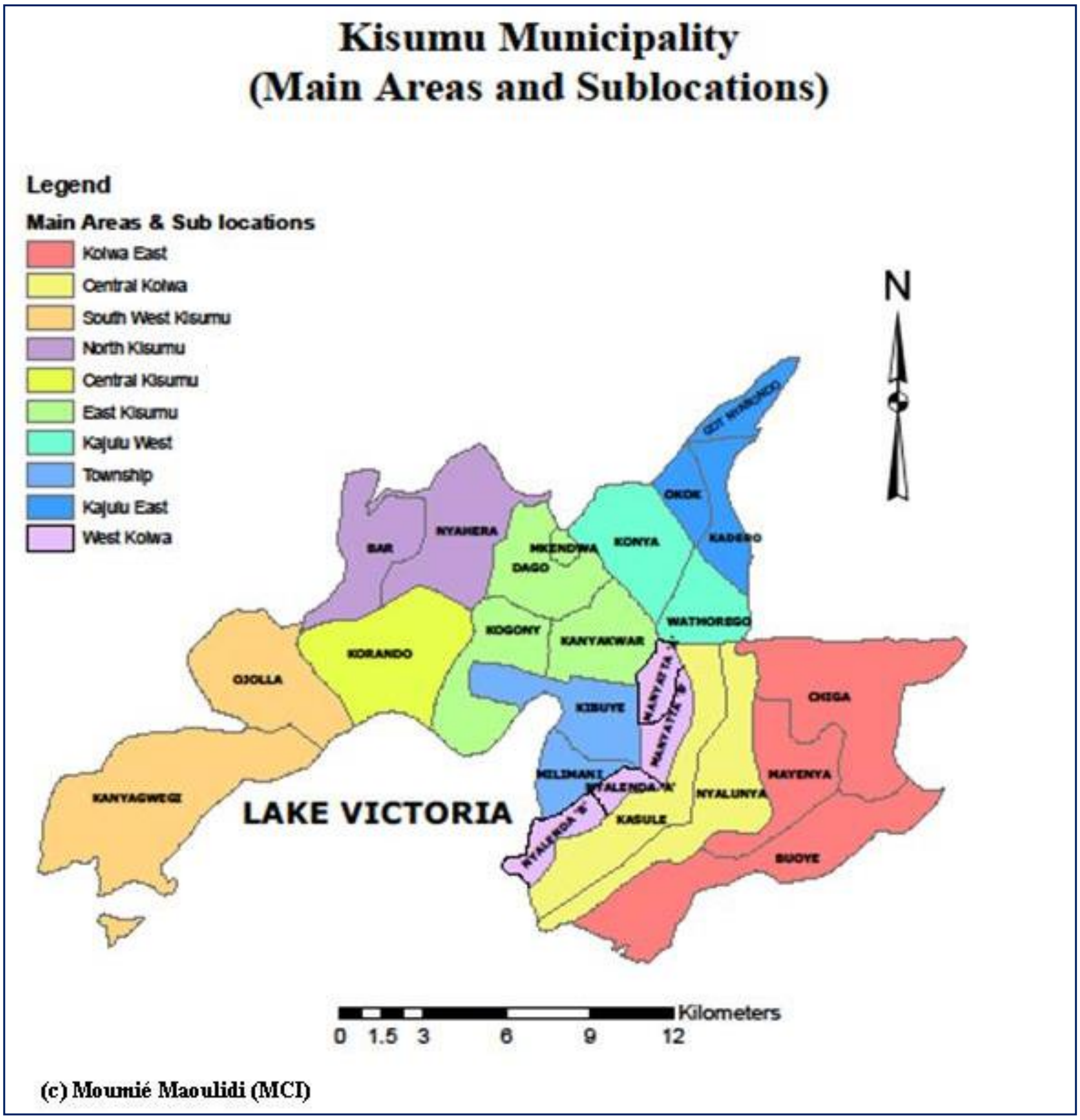
Table 13: Major wastewater utilities in the Lake Victoria region

Country	Utility
Kenya	• Kisumu Water and Sewerage Company (**KIWASCO**) • Siaya water and sewerage company (**SIWASCO**) • Busia water and sewerage company (**BUWASCO**) • Migori water and sewerage company (**MIWASCO**) • Homabay water and sewage company (**HOWASCO**) • Lake Victoria South Water and Sewerage Board (**LVSWSB**)
Uganda	• The National Water and Sewerage Corporation (**NWSC**)
Tanzania	• Mwanza Urban Water and Sewerage Authority (**MWAUWASA**) • Bukoba Water Supply and Sanitation Authority (**BUWASA**) • Musoma Urban Water and Sewerage Authority (**MUWASA**)

Apart from domestic wastewaters, there are other sectors from which the wastewaters are derived including agro-processing industries, fish processing and abattoirs discharge of raw/untreated water into the environment and runoffs.

5.0. KISUMU City, the Pilot Site for VicInAqua Project

Kisumu is one of the largest cities in Kenya and a major urban center on the shores of Lake Victoria located in the western part of the country. It is the second most important city after Kampala, Uganda in the greater LVB. The city covers a total area of 417 km^2, of which 297 km^2 is land, and 120 km^2 is water mass (Maoulidi, 2010). It consists of 25 sub-locations that are grouped into 10 main locations with the residents broadly divided into; urban, informal settlements, and peri-urban areas located on the outskirts of the Township (Awange *et al.*, 2007) as shown in the Figure 5.



Source: ***Maoulidi, 2010***

Figure 5: Main areas and Sub-locations in Kisumu.

It receives 1,500 mm rainfall p.a. mostly between March and May, and around December. The mean annual minimum temperature is 17 ^{o}C while the maximum stands at 30 ^{o}C. The humidity is 60 to 70% at 0600 Hrs and 36 to 55% at 1200 Hrs (Obera *et al*., 2002). The city is characterized by chronic water shortages and a poor sanitation framework. Many residents living in its low-income areas (informal settlements and peri-urban areas) lack access to clean water, safe and environmentally sound sanitation facilities.

5.1. Demographic characteristics

Kisumu is characterized by a rapidly growing population; high population density, water scarcity, falling food production, low resilience to climate change and poor sanitation. The population is composed of locals mainly; Luo, Kisii, Luhya, Nubian and Asian descents. By 2014, it stood at 968,909 persons with an annual growth rate estimated at 2.8% and densities of 828 persons per km^2 (ASDSP and PAI, 2014). Three quarters of the population is under 30 years old while 43.5% is under 15 years. According to the 2013/2014 poverty survey by the Kenya National Bureau of Statistics (KNBS), about 60% of the population is living in extreme poverty against the national poverty level of 46% (KNBS, 2014), with 61% of the population food-poor (ASDSP and PAI, 2014).

The main economic activities are farming, livestock keeping, fishing and trading. This brings the associated complexes in urban planning that have resulted in the rapid expansion of informal settlements and mounting pressure on the inadequate waste management system.

5.2. Water Supply and Waste Discharge

The Municipal Council of Kisumu owns all water and sewerage facilities in the city. However, since the enactment of the Kenya Water Act in 2002, which separated the functions of policy formulation and regulation from service provision, the task of efficient and economical provision of water and sewerage services has been devolved to Water Service Boards. Many residents in the municipality depend on underground well water for their domestic use. Currently, water supply and sewage systems command 40% and 10% coverage respectively leaving most parts not covered. This shortage of water supply and poor sanitation framework lead to semi-treated or untreated sewage discharge into water courses, especially in areas surrounding informal settlement (Ong'ang'a and Makonge).

The municipal's designed sewage system serves about 17% of the current population leaving the over 80% of Kisumu residents not served to rely on pit latrines, a few on septic tanks and in some cases, others use fecal disposal in polythene bags a phenomena known as "flying toilets". (Ong'ang'a and Makonge; Obera *et al*., 2002). Periodically, the full sludges from these septic tanks and pit latrines are usually disposed of at the municipals sewage system using cesspool trucks. These overstretched and malfunctioning sewage treatment plants release the sewage into rivers, ground water and the lake either semi or untreated creating a health concern in the basin (UN-HABITAT, 2016; Maoulidi, 2010).

With a relatively high water table; consequently, the shallow wells are easily contaminated by overflowing pit latrines, poor wastewater management and inadequate drainage systems. This is commonest in peri-urban areas where these wells are in close proximity to the pit latrines, thereby increasing the chances of cross-contamination, especially during the rainy season. Dependence on such readily contaminable water sources contributes to dangerous outbreaks of such diseases as diarrhea, cholera, typhoid, dysentery and malaria.

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6.0. Recommendations

As technologies are gendered, gender should be the key entry point for VicInAqua project in the basin. The aim of gender should be to improve the livelihoods of the LVB community, however, most problems are socially structured/created, therefore, VicInAqua should **aim at capturing the practical gender strategic needs for waste water re-use (i.e. Inquire from the different genders what their uses for recycled water would be).** Do not restrict it to agricultural use only.

There is need for MBR and RAS technologies popularization through a multi-stakeholder participatory approach right from project inception (**develop the technologies with the end users**). This will prevent technology rejection by the targeted end users resulting from perceiving it as the “originator’s many minting toy”.

The reality is that Lake Victoria pollution is not only from the targeted fisheries sector in the basin but also other food and water using industries. Therefore, **since this is a safety issue and all are players in polluting the Lake, they need to be brought on board during project buy-in and sensitization (round tables).**

The municipal councils in the respective towns hosting fish processing plants should be brought on board too since the fish processing plants only treat their wastewaters to municipal (domestic waste water) standards then release into the municipal sewers.

Being a relatively new concept in the LVB, VicInAqua project will have to **do a lot of stakeholder buy in for all organizations with stake in waste water management especially the legal and political players.**

RAS needs to clearly show its linkage to pond aquaculture during VicInAqua entry into the basin since pond culture accounts for more than 90 % coverage of the culture systems in the LVB. One major aquaculture challenge in the basin is moving the much available water into the production systems with very low or no cost**.**

An almost already existing market for the RAS and MBR technology are the fish hatcheries in the basin. These should all be involved in the project.

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Given the nature of placement of the point sources of the targeted three waste waters (aquaculture, fish processing and domestic) in the basin, coupled with the economic status of the basin population, **VicInAqua could consider designing low-cost and low-load MBR technology prototypes to suite different interested end-users than designing an expensive one to treat all the three waste waters for cos-effectiveness.**

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