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VicInAqua

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

Deliverable 6.1
Report on literature review

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EXECUTIVE SUMMARY

This Literature Review is made in the Framework of the integrated aquaculture based on sustainable water recirculating system for the Victoria Lake Basin (VicInAqua) project.

VicInAqua seeks to provide a sustainable and environmental-friendly solution for sanitation and more efficient fish production within the Lake Victoria region by responding to the technical and social economic challenges in aquaculture and water recirculation. This will be achieved by developing innovative multipurpose self-cleaning water filtration solutions adapted for sanitation of different waste water streams, which will be reused in Recirculation Aquaculture Systems (RAS) and irrigation agriculture. The technological development and demonstration at pilot scale will be combined with participatory measures aimed at capacity building of local and regional actors. A special focus is set on the robustness, energy efficiency and economic viability of the VicInAqua solutions in order to be adapted to the local challenges and to achieve a high acceptance in peri-urban areas, where the sanitation infrastructures are poor and the demand for water high.

The VicInAqua concept's sustainability is based on the fact that it will run on renewable energy through the combination of high performance photovoltaic panels (solar energy) and a bio-gas facility complemented with the incorporation of thermoelectric generators (TEG's)

This report is made as part of the Work Package (WP) No 6 which is primarily dedicated to the Environmental and Sustainable impact analysis of the VicInAqua solutions for the Lake Victoria region. This report covers literature on the main issues relevant to sustainability such as life cycle assessment, energy, the fishing industry, relevantstandards, the institutional as well as the regulatory framework. The National Agricultural Research Organisation (NARO) of Uganda and the Department of Agriculture, Livestock and Fisheries Development (DALFD) of Kisumu, Kenya have provided invaluable input to this report.

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1 Life Cycle Assessment

1.1 Introduction

The ever-increasing demand for products is putting added pressure on the environment. Exploitation of resources and manufacturing of products are creating potentially devastating stresses on the natural world. Life Cycle Assessment (LCA) is a tool for the systematic evaluation of the environmental aspects of a product or service system through all stages of its life cycle. LCA provides an adequate instrument for environmental decision support. Reliable LCA performance is crucial to achieve a life-cycle economy. The goal of LCA is to compare the environmental performance of products in order to be able to choose the least burdensome. The term 'life cycle' refers to the notion that for a fair, holistic assessment the raw material production, manufacture, distribution, use and disposal (including all intervening transportation steps) need to be assessed. This is the 'life cycle' of the product. The concept can also be used to optimize the environmental performance of a single product (eco-design) or that of a company.

The International Organization for Standardization (ISO) has standardized this framework within the series ISO 14040 on LCA.ISO has published new, improved editions of its life cycle assessment standards designed to highlight environmental problems and areas for improvement in the production and use of products. The new standards will facilitate the process of evaluating the impacts that a product has on the environment over its entire life, thereby encouraging the efficient use of resources and decreasing liabilities. The two standards are(UNEP, 2016):

- ISO 14040:2006, Environmental management – Life cycle assessment – Principles and framework. This standard provides a clear overview of the practice, applications and limitations of LCA to a broad range of potential users and stakeholders, including those with a limited knowledge of life cycle assessment. It describes the principles and framework for life cycle assessment (LCA) including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, the relationship between the LCA phases, and conditions for use of value choices and optional elements.However, it does not describe the LCA technique in detail, nor does it specify methodologies for the individual phases of the LCA. The intended application of LCA or LCI results is considered during definition of the goal and scope, but the application itself is outside the scope of this International Standard.
- ISO 14044:2006, Environmental management – Life cycle assessment – Requirements and guidelines. This is designed for the preparation of, conduct of, and critical review of, life cycle inventory analysis. It also provides guidance on the impact assessment phase of LCA and on the interpretation of LCA results, as well as the nature and quality of the data collected.

ISO 14040:2006 and ISO 14044:2006 replace the previous standards (ISO 14040:1997, ISO 14041:1999, ISO 14042:2000 and ISO 14043:2000). The new editions have been updated to improve the readability, while leaving the requirements and technical content unaffected, except for errors and inconsistencies.

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1.2 The Phases of Life Cycle Assessment

Goal and Scope Definition, the product(s) or service(s) to be assessed are defined, a functional basis for comparison is chosen and the required level of detail is defined.

Inventory Analysis of extractions and emissions, the energy and raw materials used, and emissions to the atmosphere, water and land, are quantified for each process, then combined in the process flow chart and related to the functional basis;

Impact Assessment, the effects of the resource use and emissions generated are grouped and quantified into a limited number of impact categories which may then be weighted for importance;

Interpretation, the results are reported in the most informative way possible and the need and opportunities to reduce the impact of the product(s) or service(s) on the environment are systematically evaluated.

1.3 LCA Methodology

The following steps shall be taken.

1. Defining the system boundaries and characteristics of the MBR and RAS systems as well as the collection of appropriate data for the study.The system boundary will be from 'cradle to grave'; comprising the extraction and processing of materials, transport of the materials to the RAS and electricity generation from the power plants; building of the infrastructure is also included.
2. Development of appropriate environmental and economic (sustainability) indicators to be used in the modelling stage; Life Cycle environmental impacts and economic costs will be used as the sustainability indicators. Theeconomiccosts represent the'totalcapitalinvestment'andthe'total cost' comprising the annual fixedcost, annual variablecostandannual feedstock costs.
3. Modelling of the scenarios from preliminary (scoping) to the full environmental impact analysis usingSimaPro 64 Softwares and databases;
4. Analysis, interpretation and discussion of the environmental and economic results obtained in the modelling stage.

1.4 Computer Softwares

Three computer Softwares commonly used in LCA are reviewed below for their suitability in the current situation. These are GaBi, SimaPro and Umberto NXT LCA Softwares.

1.4.1 GaBi

GaBi is the next generation product sustainability solution with a powerful Life Cycle Assessment engine to support the following business applications:

(i) Life Cycle Assessment

Life Cycle Assessment (LCA): Analyses and comparisons of product, process and services according to the ISO standard covering the whole life cycle from the production of raw materials to end of life.

- **Design for Environment:** developing products that meet environmental regulations
- **Eco-efficiency:** reducing material, energy and resource use in the most cost-effective way

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- **Eco-design:** developing products with smaller environmental footprints such as fewer GHG emissions, reduced water consumption and waste
- **Efficient value chains:** enhancing efficiency of value chains e.g. R&D, design, production, suppliers, distribution

(ii) Life Cycle Costing

- **Cost reduction:** designing and optimizing products and processes for cost reduction

(iii) Life Cycle Reporting

- **Sustainable Product Marketing:** product sustainability labels & claims, Environmental Product Declarations (EPDs)
- **Sustainability Reporting:** environmental communication & product sustainability reporting
- **LCA knowledge sharing:** reporting and analysis for internal departments, management and supply chain

(iv) Life Cycle Working Environment

- **Responsible manufacturing:** developing manufacturing process that address social responsibilities

Its reported advantages include helping the user in sustainable product design & innovation, identifying and mitigating risks in the products' life cycle, optimizing energy and resource efficiency to reduce costs, determining the environmental and social impacts within the products' life cycle and communicating the product's sustainability performance to internal and external stakeholders.

GaBi maps a product's impacts including carbon, water, energy, emissions, waste, materials and natural resources, social impact, costs, health and safety, across your supply chain and its life cycle. It appears that GaBi is rich in the number and variety of sustainability indicators and is therefore selected for the current work.

1.4.2 Umberto NXT LCA software

The software combines many life cycle indicators includingReCiPe, Impact 2002+, Eco-Indicator 99, CML, TRACI, IPCC and many other indicator systems which are integrated with the software. Individual Key Performance Indices (KPIs) of different indicator systems can be freely combined

The user chooses which impact indicators will be used to display the results. The Reports generated include:

- Mass and energy inventories for the entire life cycle model as well as for custom-defined sub-systems
- Break down results by phases, by material groups, by processes, ...
- Export of all life cycle inventories (LCI) and LCIA results to Microsoft Excel
- Sankey diagrams and all result graphics can be exported quickly and easily

1.4.3 SimaPro

This software does not have an inbuilt economic costing module and one would have to use specialized economic analysis software such as GEMIS (Guinée *et al.*, 2001).

Life cycle environmental impacts can be used as the sustainability indicators for the purposes of the analysis. The life cycle environmental impacts in SimaPro include (1) global warming (GWP), (2) abiotic depletion(ADP),(3) Ozone depletion(ODP), (4) human toxicity(HTP), (5) freshwater toxicity(FTP), (6) marine toxicity (MTP), (7)

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terrestrial toxicity(TTP), (8) photochemical oxidation(POCP), (9) acidification (AP)and (10) eutrophication (EP) (Guinée *et al*., 2001).

1.5 Environmental risk assessment

1.5.1 Introduction

As pressures on the environment increase, there is a need for understanding the resulting environmental risks from developmental actions as well as innovations. Forecasts of risk to the environment could provide basic information needed for sustainable resource development decisions — however, such information is often lacking. In response to this need the project team will undertake an Environmental Risk Assessment (ERA).

1.5.2 What is Risk impact assessment?

Risk impact assessment is the process of assessing the probabilities and consequences of risk events if they are realized. The results of this assessment are then used to prioritize risks to establish a most-to-least-critical importance ranking(MITRE, 2007). Ranking risks in terms of their criticality or importance provides insights to the project's management on where resources may be needed to manage or mitigate the realization of high probability/high consequence risk events.

In this report, risk is taken to mean the probability times the consequence of an adverse or hazardous event. A broad meaning of risk is retained here because the report is concerned with the incorporation of risk assessment into environmental management. For the purposes of management, environmental risks have other relevant characteristics in common as well as their probabilistic nature. These characteristics justify an approach which treats environmental risks as a set of related phenomena(Habitat, 2000). They include:

1. The risks that involve a complex series of cause and effect relationships. They are connected from source to impact by pathways involving environmental, technological and social variables which need to be modelled and understood in concert. There are thus common elements in the systematic approaches required for the study of risk.
2. The risks are connected to each other. Usually several or many risks occur simultaneously within the same country, region, or city and this requires an ability to compare them and make trade-offs or balancing decisions about how much of one risk to accept in relation to another.
3. The risks are connected to social benefits so that a reduction in one risk usually means a decline in the social benefits to be derived from accepting the risk. The social benefits of different risks are related to each other or may be very similar.
4. The risks are widespread over the globe and concern many countries, both developed and developing. They occur in both industrial and agricultural sectors of the economy. There are advantages to nations therefore in comparing approaches to risks in the context of environmental management.
5. The risks are not always easy to identify and sometimes identification occurs long after serious adverse consequences have been felt. There is merit in comparing the ways in which different risks arise and are recognized.
6. The risks can never be measured precisely. Because of their probabilistic nature it is always a question of estimation. The methods for risk estimation have underlying similarities that can be described and improved.

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7. The risks are evaluated differently in social terms. Thus a risk considered serious in one place may be considered unimportant in another. It is important to understand why similar processes of risk evaluation can give rise to such dissimilar conclusions.

When used in this report 'risk' therefore means a hazard or danger with adverse, probabilistic consequences for man or his environment. When only the probability component of risk is meant, expressions such as 'risk probability' or 'probability of risk' are used. When used in 'risk assessment', the concept of risk includes not only probability and consequences but also how societies evaluate them (Everest et al., 1997).

Environmental Risks

The risks with which this report is concerned are all in some way 'environmental'. They arise in, or are transmitted through, the air, water, soil or biological food chains, to man. Their causes and characteristics are, however, very diverse. Some are created by man through the introduction of a new technology, product or chemical, while others, such as natural hazards, result from natural processes which happen to interact with human activities and settlements (Garvey, 2008). Environmental risks, as defined here, share a second common feature in addition to being transmitted through environmental media. They cause harm to people who have not voluntarily or specifically chosen to suffer their consequences, and thus they require regulation on the part of some authority above that of an individual citizen that is, they require managing.

1.5.3 Environmental Risk Assessment process

Occupational Safety and Health (OSHA) 2007, Sec 6 (3), it's a requirement for all workplaces to conduct RA. It is therefore important to conduct an ERA for this project in adherence to the Act. ERA uses similar techniques to the health and safety risk assessment. The main steps would therefore involve;

Step 1: Establish the context for ERA

Step 2: Identify and characterize key environmental pressures

Step 3: Specify environmental values and indicators for the ERA

Step 4: Characterize environmental trends, indicator relationships and establish risk classes

Step 5: Evaluate changes to indicators and risks

Step 6: Report results and develop risk reduction strategies

Below is a summarised flow chart for all the above steps undertaken while conducting the ERA.

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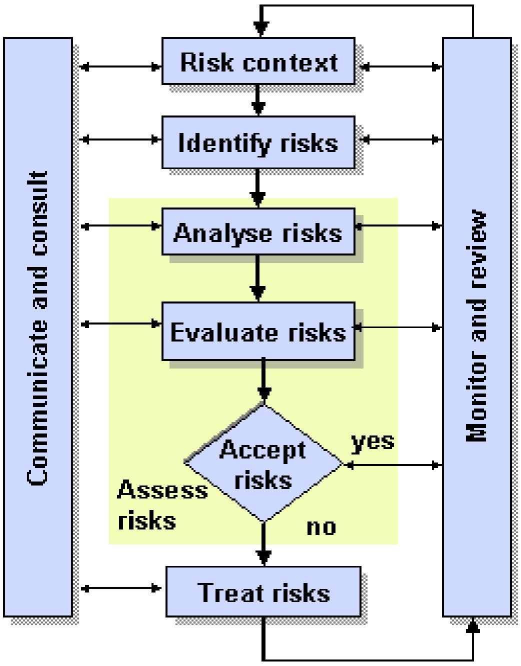

Figure 1.1:Steps in conducting ERA.
Source: (AS/NZS 4360:2004)

The entire can be grouped into three main stages namely risk identification, risk estimation and risk evaluation.

1.5.4 Risk Identification

Risk identification is the process of finding, recognizing and describing risks. It is a screening exercise and serves as a preliminary step for the subsequent risk analysis stage. Risk analysis is the process to comprehend the nature of risk and to determine the level of risk. Identification stage is based as much as possible on quantitative (historical, statistical)data. However, as the purpose of the risk identification stage is to find and recognize all likely hazards and significant consequences, it is appropriate to extensively use also qualitative methods, such as expert opinions, checklists, intelligent information etc.

The outcome of the risk identification stage is a listing of the different identified risks and risk scenarios that will be analysed in more detail in risk analysis.

1.5.4.1 Risk analysis

The analysis stage assigns each risk a significance rating taking into account any existing factors which will operate to control the risk. For simple risk statements, where the risk can be expressed as an uncertain event, this can be accomplished with qualitative impact and likelihood scales and a matrix defining the significance of various combinations of these. This process can involve modelling, monitoring, screening and diagnosis (Kates, 1978).

The findings of risk analysis and evaluation can be presented in a risk matrix. There are two types of risk matrix i.e. a 3x3 and a 5x5 risk matrices. This project will utilize the 5X5 matrix in order to be able to adequately identify all the possible risks.

The probability of harm occurring might be categorized as 'certain', 'likely', 'moderate', 'low' and 'very low'. However it must be considered that very low probabilities may not be very

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reliable. The severity of the risk event occurring can be categorized as ‘insignificant’, ‘minor’, ‘significant’, ‘major’ and ‘severe’.

1.5.4.2 Risk matrix

		Consequence				
		How severe could the outcomes be if the risk event occurred? →				
		1 Insignificant	2 Minor	3 Significant	4 Major	5 Severe
Likelihood (What's the chance the of the risk occurring? ↑)	5 Almost Certain	5 Medium	10 High	15 Very high	20 Extreme	25 Extreme
	4 Likely	4 Medium	8 Medium	12 High	16 Very high	20 Extreme
	3 Moderate	3 Low	6 Medium	9 Medium	12 High	15 Very high
	2 Unlikely	2 Very low	4 Low	6 Medium	8 Medium	10 High
	1 Rare	1 Very low	2 Very low	3 Low	4 Medium	5 Medium

Figure 1.1: Risk matrix with the likelihood and consequences

Source:(AS/NZS 4360:2004)

1.5.4.3 Risk Evaluation

The third component of risk assessment is risk evaluation in which judgements are made about the significance and acceptability of risk probabilities and consequences. Evaluation techniques seek to compare risks against one another, and against benefits, as well as providing ways in which the social acceptability of risks can be judged. After a risk has been identified, estimated or evaluated (or any combination of the three) there comes a point where some kind of intervention (or deliberate decision not to intervene or to delay action) takes place.

1.5.4.4 Monitoring and Review

There are two levels to the underlying monitoring and review component of the process. The outputs of the other five stages must be kept under review as time moves on. Changes in the environment or simply the discovery of better information might make the original assessment out of date. It is not generally necessary to begin the whole process over again when this happens, unless the change is particularly profound, but those parts which are directly affected by changing circumstances must be brought up to date.

The second component of this part of the process is the monitoring of the operation of the other five stages. The execution of the risk management process absorbs resources and must be managed to ensure that it is conducted cost-effectively.

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1.5.4.5 Communication and Consultation

Consultation and communication is both a key component of the risk management process and a major beneficial side effect. Successful risk management relies on achieving a high level of creative input and involving all parties with a role to play in achieving a successful outcome for the project or business process being addressed. In both the planning and execution of the risk management process, it is important to ensure that all those who need to be involved are given adequate opportunity to do so and are kept informed of developments in the understanding of risks and themeasures taken to deal with them.

The operation of the risk management process offers many opportunities for cost-effective communication between people working on a project or business. The context statement is a concise summary of the most important features of the task; its objectives and scope, who is involved, costs and mitigation measures. Four questions are mainly answered in the register. These are

What are the risks?

Who is involved?

When was the risk identified and/or reviewed?

How much the risks would cost?

Whereby are risks mitigated? What are the treatments?

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2 The Energy sector in Kenya

Kenya is an energy scarce country with the cost of electricity rising up to 20US cents per kWh due to the inclusion of thermal generation in the energy supply mix. According to the Energy regulatory commission (ERC, 2016), Kenya had an installed capacity of 2,298MW as of November, 2014.

Table 2.1: Sources of Electric power generation in Kenya

Source	*Category*	Capacity (MW)	Share (%)	Dispatch (GWh)
Hydropower		820	35.70	229,496.7
Fossil	Thermal (diesel)	746.8	32.50	121,018.6
	Emergency	30	1.31	10,308.5
	Gas	60	2.62	1.783
Geothermal		588	25.59	352,119.7
Wind		26.16	1.14	6,520.1
Bagasse		26	1.13	-
Solar		0.55	0.00	86.907
Imports				4,354.1
		2,298	**100**	**723,906.6**

Source: ERC, 2016

Furthermore, the grid system is unstable and unreliable with substantial interruptions of supply. Kenya's grid system is interconnected in various voltage levels through transformers, transmission lines, distribution and eventually service lines. The lowest distribution line is the 11kv line which connects small industries and homes through a stepdown transformer to 415/240V at 50Hz. The further a load is from a transformer/substation, the lower the voltage and frequency. This causes frequent outages which cannot be attended by the distribution company promptly either due to economic issues or lack of adequate manpower. According to the last housing and population census carried out in Kenya, the population of Kenya was about 40 million by the year 2009 (KNBS, 2010) and continues to grow by about 1 million people per year. The increased demand has put a great strain on the energy supply and only about 30% of the population have access to electricity. The situation is expected to improve as the government implements the various energy access improvement actions identified in the Vision 2030 economic blue print by the Government of Kenya.

2.1 Renewable energy

Renewable energy technologies are said to be clean and green because they produce few or no pollutants. They offer a sustainable way of accessing energy and include solar energy, biomass energy, hydro energy, geothermal energy, wind energy, Tidal and wave energy. Using more renewables in the electricity mix in Nigeria was shown to have the potential to reduce the life cycle environmental impacts considerably (Gujba et al., 2011).However, the authors warn that appropriate measures must be taken for the introduction of biomass since the source should be sustainable.

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2.1.1 Biogas production from Biomass

There are many potential advantages of using biomass instead of fossil fuels to meet energy needs. Some of these are; reduction of greenhouse gases and air pollutants, energy cost savings, local economic development, waste reduction, security of a local fuel supply and reliability (non-intermittence) of the source compared to other renewables.

In order to produce biogas, the organic material in biomass is broken down by bacteria (digested) in the absence of air (anaerobically). The principle components of biogas are methane (CH_4) and carbon dioxide (CO_2). Some level of gas cleaning is required before the gas can be used in many applications.

The invasive water hyacinth (*EichhorniaCrassipes*) started appearing on Lake Victoria in 1989 and has been associated with oxygen depletion in the lake (threatening fisheries and biodiversity), choking of important waterways and fish landings (Twongo& Balirwa, 1995) It is thought that nutrient inputs from the Lake Victoria catchment have caused eutrophication which has created favourable conditions for the proliferation of Water hyacinth. There have been efforts to remove the weed by hand, by machine, by biological methods and even by use of chemical pesticides. These efforts have only achieved minimal success. As a solution, Bhattacharya& Kumar (2010) suggested the possibility of using this noxious weed as a biofuel. In a study by Kamau*et al.*, (2015) the authors sought to assess the social economic and environmental impacts of utilizing water hyacinth as a feedstock for biogas production while another study by Njogu *et al.,*(2015) sought to establish the potential for electricity production using the produced biogas. The studies found that co –digestion of the water hyacinth with cow dung has a good prospect for biogas production and offers a potential solution in the management of the weed

In a LCA study by Gujba *et al.*, (2011) using SimaPro, Biomass burning was shown to increase the photochemical oxidation and eutrophication. However, using anaerobic digestion to produce biogas is a more sustainable way to produce energy since waste biomass can be utilized as the feedstock. Horecky & Saska (2004)showed that it is possible to use sugar press mud as the feedstock in anaerobic biogesters to produce biogas. It was shown that sugar press mud, even when used as compost, has adverse effects on the soil – including increasing the wax content in the soil and therefore reducing its porosity (Rouf et *al.,* 2010). Biogas is a non-polluting renewable energy resource and is now replacing liquefied petroleum gas in many applications (Karan *et al.*, 2012).

2.1.2 Solar Energy

Kenya straddles the equator and therefore has over 10 hours of sunshine per day. This means that solar radiation is in abundance throughout the year. On average, Kenya receives solar insolation of between 4 – 6 kWh/m^2 per day. This translates to the average number of hours when solar irradiance averages $1kW/m^2$ per day (MEP, 2014). However some areas of Kenya receive extraordinarily higher values of irradiance. Nakuru town situated on the rift valley has recorded daily average insolation of between $4.8kWh/m^2$ and $7.8kWh/m^2$ within a period of one year (Omwando *et al*., 2014). Solar energy technologies available include the solar photovoltaic (PV) technology and solar thermal technologies. In the VicInAqua energy concept, solar PV technology will be used in combination with thermoelectric generators (TEG).

The Solar PV business and practice in Kenya is regulated under the Energy Act (Solar PV regulations). Under these regulations, practitioners are required to be licenced by the Energy

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Regulatory Commission before commencing any business or practice involving Solar Photovoltaic Technology.

The efficiency of photovoltaic modules is measured under standard conditions of irradiance ($1kW/m^2$), temperature (25^0C) and air mass (1.5).However the nominal operating temperature in many areas of Kenya is higher than 25^0C and is a major cause of reduced efficiency and electrical power output. We have estimated that voltage drop with temperature is about $0.05V/^0C$ in Kisumu.

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3 Food security situation in Kenya

3.1 Introduction

Kenya has experienced high population growth the last fifty years. Over these fifty years, the production of most basic food crops did not keep pace with population growth. The basic crops which did (potatoes, sweet potatoes, rice and beans) did so through area increase than through yield increase. In the 1960s, basic food crop production improved both in terms of area harvested and in terms of yield and its population was food sufficient based on WHO requirements at the time. After 1970, the situation began to deteriorate as a result of diminishing government support for agriculture and rural development (Fernando, 2013) and deepening socio-economic divides (Nyanjom, 2013). Crop production areas expanded somewhat in the 1970s but yields dropped, partly due to severe droughts. During the 1980s the harvested area of cereals, roots and tubers stabilized and that of pulses more than doubled, and yields recovered, for roots and tubers to their highest levels ever. In the 1990s yield levels deteriorated for all basic food crops and the harvested area of pulses declined again. In the last decade improvements were seen, until 2006. Kenya produced 3.9 million tons of cereals, 0.7 million tons of pulses and 3.8 million tons of roots and tubers in 2006. Its total basic food production could have potentially fed 96% of its population that year, up from 68% in 2000 (assuming that staple foods cover 65% of energy requirements).

At the end of 2007, the political situation alerted the trend as many farmers had to seek refuge in camps or with relatives elsewhere and to abandon their fields. The harvested cereal area went down by about 15%. In 2008 there was a further reduction in the area under cultivation but yields fell back to only 1420 kg/ha and in 2009 they even hit average levels. Kenya's basic food production in 2009 reached low levels and the country could only potentially feed 72% of its population of 39 million at WHO food requirement levels. By 2009, total food energy in Kenya had dropped by 19% compared to 2006 and this was partly associated to the 2007/2008 post- election violence. After 2009, the agricultural situation started to normalize and in 2011 Kenya could feed 88% of its population based on its own agricultural production (assuming staple food covers 65% of all dietary requirements).

Recognizing aquaculture as one of the viable options for revamping the country's food sector, the Kenyan government initiated intensive aquaculture through the Economic Stimulus Program in 2009 to stimulate economic development, improve the food security, foster economic recovery, alleviate poverty, and spur regional development. The Kenyan aquaculture industry growth had been slow for decades until the year 2009 when the government-funded Economic Stimulus Program increased fish farming nationwide (ESP, 2009; Munguti *et al*., 2014)

The Ministry of Fisheries Development undertook the economic stimulus program with the intention to improve nutrition, create over 120,000 employment and income generation as it supplemented the low production from the staple foods. The program also aimed to increase production of farmed fish from 4000 MT to over 20,000 MT in the short term and over 100,000 MT in the long term (Charo-Karisa & Gichuri, 2010). To achieve this, 200 fish ponds were constructed in each of the selected constituencies (Western Kenya, Nyanza, parts of Rift Valley, Eastern, Central Kenya and Coast regions) at an estimated cost of Kshs. 8 million per constituency (Munguti *et al.*, 2014). The State Department of fisheries also trained fishers, implementing officers and stakeholders on fish farming practices, conducted a national aquaculture suitability appraisal and developed suitability in the country, developed fish breeding structures with a holding capacity of over 200,000 brood-stock, developed fish

feed specifications for tilapia, catfish and trout and related supply chain (Fisheries annual statistical bulletin, 2013).
The implementation of this program led to an increase in fish production from about 962metric tons (1%) in the year 2002 to over 19,584 metric tons (12%) in the year 2011. Food security improved and poverty levels reduced and there was also an increase in commercialization of Nile tilapia, (*O. niloticus*) and the African catfish (*C. gariepinus*) among fish farmers.

3.2 History of fish farming in Kenya

In Kenya fish farming development started in the 1920s with the arrival of European settlers through introduction of trout in rivers for sport fishing while fish culture (tilapia, common carp, and catfish) as a source of protein for rural indigenous population began in the late 1950s and early 1960s (Maar *et al*., 1966; Ngugi *et al.*, 2007). Fish campaigns were also introduced by the government in the late 1960s to accelerate the interest in rural fish farming. Mariculture was introduced in the late 1970s with the establishment of the Ngomeni Prawn Pilot Project (Nyonje *et al*., 2011) but it is not fully exploited to date. This is mainly due to accessibility problems, conflicts over land ownership, and lack of clear policies.

Fish farming in Kenya picked up in 2009 with the introduction of the Economic Stimulus Program. Despite the enormous potential for fish farming in Kenya, aquaculture has been characterized by low levels of production that have stagnated at less than 1% of the country's protein needs over the past decade (Nyonje*et al.*, 2011).

3.3 Fish production in Kenya

Kenya is well endowed with numerous aquatic resources with aquaculture potential. It has highly varied climatic and geographic regions, covering part of the Indian Ocean coastline, a portion of the largest freshwater lake in Africa (Lake Victoria), and several large rivers, swamps, and other wetlands. These aquatic environments range from marine and brackish waters to cold and warm fresh waters, and many can sustainably contribute to the operation of ponds for fish production.

The primary cultured fish species in Kenya today are Nile tilapia (75%) and African catfish (15%) and are mostly cultivated under intensive earthen pond (closed) systems (Fisheries annual statistical bulletin, 2013), but efforts to introduce other indigenous fish, such as *Labeovictorianus,* in aquaculture have not been widely adopted by farmers. Mariculture remains under-developed, although there are research initiatives to promote seaweed culture, milkfish, and shrimp.

The fisheries and aquaculture sector contributes approximately 0.8 percent to the country's GDP (NES, 2014). Total fishery and aquaculture production in 2014 totaled to 192 300 tonnes, with 83.3 percent coming from inland capture fisheries with Lake Victoria contributing about 90 percent of the total. In the same year, about 220,000 people derived their livelihood from fishing and fish farming and approximately 5.7% protein required was attained (FAO, 2015).

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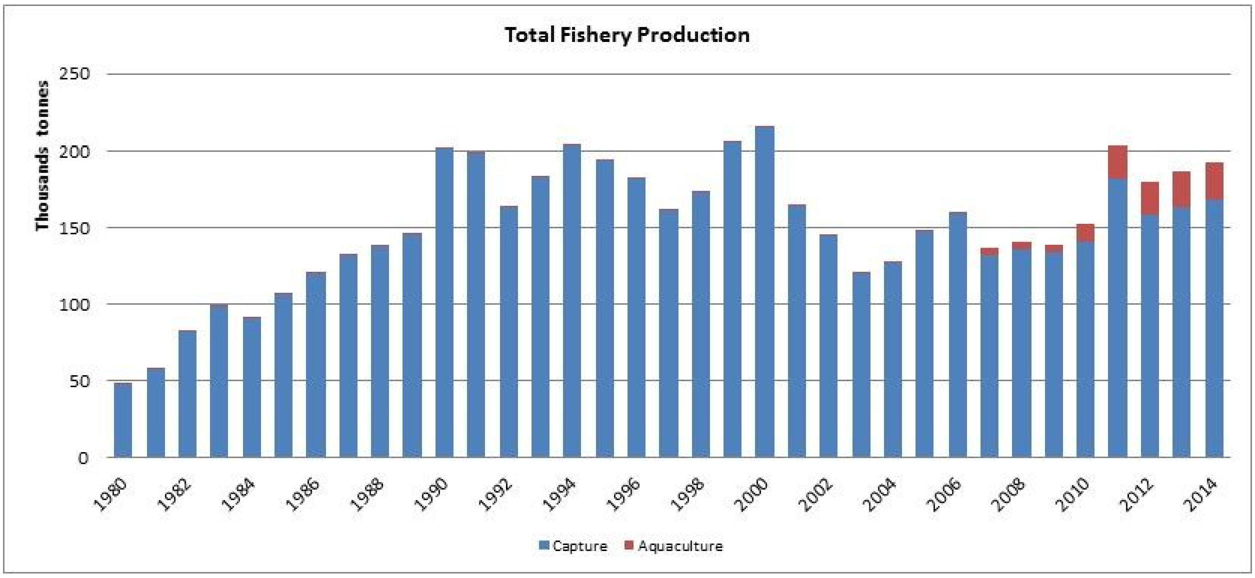

Figure 3.1:Total fishery production in Kenya (1980-2014).
Source: FAO, 2015

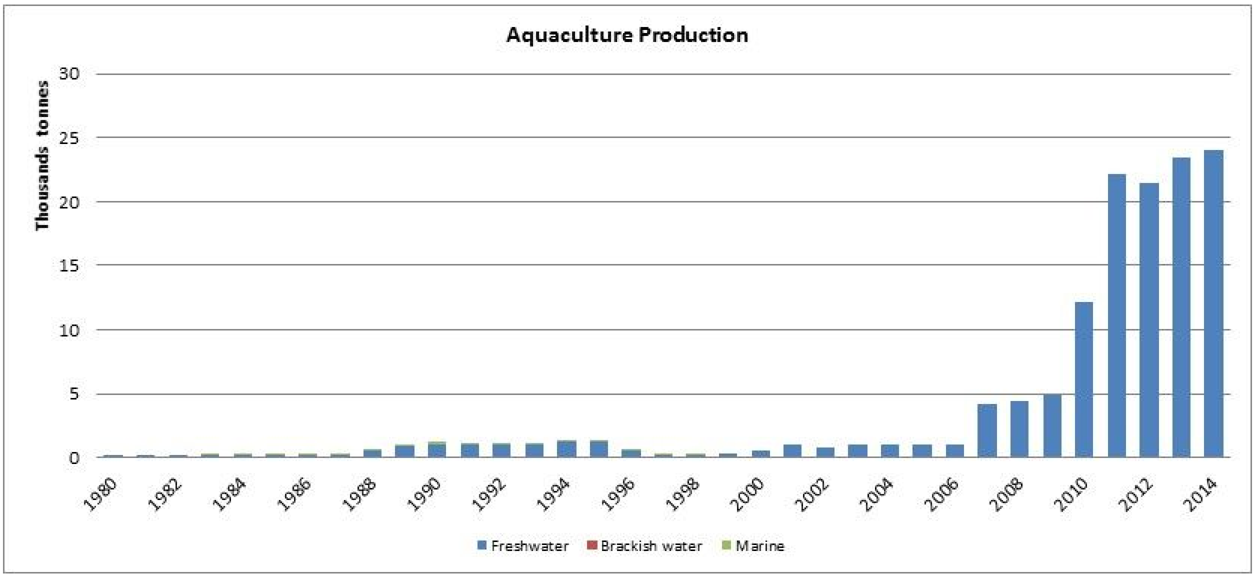

Figure 3.2: Aquacultureproduction in Kenya (1980-2014).
Source: FAO, 2015

With population growth escalating to unsustainable levels and increasing food insecurity, Kenya's dwindling capture fisheries are unable to adequately provide cheap protein for the growing population. Natural water bodies, which are the main sources of fish, have had many challenges that include dwindling catches, pollution and reduction of water levels that compromise fisheries (LVBC, 2014). Therefore, aquaculture is the best opportunity to bridge the escalating gap of supply and demand for fish.

The development of fish farming is one of the core activities in the Ministry of Agriculture Livestock and Fisheries because aquaculture has the potential to reduce fishing pressure on oceans, lakes and rivers and improve food security, create employment and wealth, and promote healthy living.

In a bid to promote and develop aquaculture, the Kenyan government has set up several aquaculture facilities to serve as research centers, training facilities, and sources of

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fingerlings and feed for fish farmers. They include the National Aquaculture Research Development & Training Center (NARDTC) in Sagana, Kisii fish farm training center, Kiganjo trout farm, Ndaragua trout farm, Chwele fish farm, Lake Basin Development Authority (LBDA) in Kisumu, Wakhungu fish farm in Busia, Sangoro research station, Kegati research station, and Kabonyo and Ngomeni fish farms. However, most of these centers lack basic laboratory equipment and human capacities to spur significant aquaculture development in their respective spheres of influence.

3.4 Use of fish ponds in Kenya

Kenya has an enormous potential for fish farming in the agricultural rural zones but only about 0.014% of the 1.4 million ha of potential aquaculture sites are used for aquaculture and about 95% of fish farming is on a small scale (Munguti *et al.*, 2014). Currently, aquaculture is practiced mostly in the central, Nyanza, western, and parts of Rift Valley and coastal regions. The potential for growth and expansion is high due to many favorable physical endowments of the region such as adequate rainfall, well distributed network of rivers, streams, dams, and wetlands. Coordinated promotion of fish farming through institutions like research institution, Universities, NGOs and Regional authorities has the potential to also boost the aquaculture sector.

In the first year of the Economic Stimulus Program, 200 fish ponds were constructed in each of 140 constituencies, totaling more than 27,000 fish ponds nationally (Charo-Karisa& Gichuri, 2010).This growth resulted in increased demand for supplementary feed and seeds of Nile tilapia and African catfish, and growth in hatcheries and financial investment in the sector. The country's aquaculture production almost doubled between 2010 and 2012 from 12 000 metric tonnes to about 22 000 metric tonnes.

However, the growth of the industry is faced with challenges. These challenges include;

- High demand for fingerlings to stock the fast-growing number of fishponds
- Lack of comprehensive policies on fish farming and legislation
- Lack of adequate and affordable fingerlings and commercially produced feeds
- Poor understanding of market dynamics, and risk reduction
- Poor understanding of general pond management for increased production
- Inadequate training programmers' for farmers and slow transfer of information on proven practices through extension
- Lack of access to quality information on aquaculture technologies
- Poor adoption of fish husbandry techniques by some farmers
- Water scarcity due to other competing uses – industry, domestic and agriculture
- Security and safety of fish in ponds posed by thieves and predators
- Poor book keeping and record management

Despite these challenges the Kenya aquaculture is growing rapidly and export markets for the fish and fish products are opening up. Last year the European Union opened up its market for Kenya's farm fish and fish products. Previously the EU only permitted fish from natural sources like Lake Victoria for its market.

3.5 Fishing along Lake Victoria

Lake Victoria contributes greatly to the total national annual fish production (Approx. 80%) even in the face of rapidly declining fish stocks in the lake. Capture fisheries of Lake Victoria

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are a source of livelihood to many people employed directly as boat owners, fishermen, fish traders, fish processors and indirectly as fishing gear manufacturers, boat builders, and ice producers among others. Lake Victoria is a multi-species fishery with hundreds of known species, but only *Rastrienobolaargentea*(Omena), *Latesniloticus* (Nile perch), and *Oreochromisniloticus*(Nile tilapia) are of economic significance. Lake Victoria has 1,433 fish landing beaches, of which 535 are on several islands of the lake and 321 are in Kenya (LVNR, 2014).

Table 3.1:Distribution of landing sites by Sub-counties (Kisumu) 2014

Sub county	**No of landing sites**	**% of landing sites**
Bondo	47	14.6
Bunyala	18	5.6
Homa bay	6	1.9
Kisumu Central	3	0.9
Kisumu East	1	0.3
Kisumu West	10	3.1
Mbita	67	20.9
Nyakach	7	2.2
Nyando	9	2.8
Nyatike	29	9.0
Rachuonyo	37	11.5
Rangwe	3	0.9
Rarienda	31	9.7
Samia	5	1.6
Seme	10	3.1
Suba	38	11.8
Total	**321**	**100**

Source: LVNR, 2014

The landing sites have facilities such as Bandas, cold rooms, pontoon/jetties, potable water, electricity supply, fish stores, all weather roads, boat repair, net repair and toilet facilities. However, there has been a rapid decline of fish stocks in Lake Victoria in the last few years thereby creating a wide gap between supply and demand for fish in the country. The main challenge in fisheries in Lake Victoria is overexploitation and therefore increasing conflict, overfishing, and falling incomes and infestation of the lake by aquatic weeds(Fisheries annual statistical bulletin, 2013). This issue is being addressed in cooperation with neighboring countries through the Lake Victoria Fisheries Organization (LVFO), and through the Regional Plan of Action for the Management of Fishing Capacity in Lake Victoria that was agreed in March 2007.

In addition, use of ponds is being promoted by the Ministry of Agriculture, livestock and Fisheries around Lake Victoria to curb the shortage and meet the demand of fish in the country.With the advent of fish ponds, households in Kisumu are investing in the ponds and there are over 1,330 fish ponds in the county. Overall, there are about 3,275 fishermen and

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189 fish farm families in the county (CIDP, 2014). The decline in tilapia catches from Lake Victoria and increased human population has also resulted in imports of tilapia from china to meet the demand of tilapia fish in Kisumu through East African Sea Food Limited. Hence there is need for increase and promote use of ponds in Kisumu.

3.6 Fish quality

The Fisheries Department in Kenya is mandated as the national food safety control agency for the fish and fishery products. The Fish Inspection and Quality Assurance (FIQA) section under the fisheries department ensures sustainable production, utilization and marketing of safe and high quality fish and fishery products(EA, 2005). The Kenya Bureau of Standards also sets and supervises the attainment of standards for manufactured goods, defines standards for processed fish for both local market and export market.

Food safety and quality are important in international fish trade. Stringent conditions are imposed by major fish-importing nations in the developed world. The quality of Kenya's fish and fish products is highly variable and the Kenyan government has put up measures to effectively compete and access the domestic and international market (Fisheries Act, 1991). The standards and requirements of hygiene, composition and other specifications for export rely mainly on the application of hazard analysis critical control point (HACCP) principles and general requirements ofWorld Trade Organization (WTO) agreements, Food and Agricultural Organization (FAO) technical guidelines, Codex Alimentarius Food Standards, United Nations Convention on the Law of the Sea (UNCLOS), World Health Organization for Animal Health (OIE) and the Aquatic Health Code.

Fish are prone to rapid pathogenic contamination and safety concerns are in handling during and after fish harvest, refrigeration, processing, and packaging. Failure to apply adequate quality and safety measures can lead to losses at various stages of fish handling and marketing. Postharvest fish losses include physical loss from poor handling and preservation; economic loss when spoilage occurs or when higher costs are incurred in reprocessing fish; and nutritional loss when fish is unsafe to eat(Abila, 2003).

Quality characteristics that consumer check when purchasing fish and fish products include physical characteristics such as size, organoleptic characteristics (smell, texture, taste, and flavor), nutritional composition and microbial characteristics (Lokuruka*et al.,* 2012). These characteristics are accessed either by subjective methods (visual and sensory analysis) or by objective methods (instrumental and chemical analysis).

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4 FISHERIES IN THE LAKE VICTORIA BASIN

4.1 Distribution and importance

The 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 the same report, 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.

However, the basin practices freshwater aquaculture 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 (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& Leonard, 2007) has been on Lake Victoria on an experimental basis with 1,323 cages in Uganda, 20 in Kenya and 60 in Tanzania for 2013.

In East Africa, Recirculation Aquaculture (RAS) technology is relatively new with eleven known farmers in Uganda, with 3 ofthem in the Lake Victoria Basin (LVB). In Kenya there are a total of 10 RAS farmers with only three of them being in the basin. None are known to operate in Tanzania.

4.2 Socio-economic and Gender issues

Millions of people around the world find a source of income and livelihood in the fisheries and aquaculture sector. This has 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 (FAO, 2016).

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 (Olago*et a*l., 2006). Domestic and industrial wastewater, solid waste, sediments from soil erosion, agricultural waste and atmospheric deposition are the major sources of pollution for the Lake (Olago *et al*., 2006). Deeper areas of the lake 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& Jorgensen, 2005). The discharge of partially treated or untreated raw

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sewage from the above sources have resulted in to waterborne diseases such as diarrhoea, 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 (Semalulu *et al*., 2005).

In the basin, fisheries and aquaculture contribute positively to the GDP of the riparian countries through the increase of exports of fish and fish products processed and exported, thereby earning foreign exchange revenues to the governments (Cocker, 2014).

In aquaculture, allocation of resources is determined by the farmer's house hold income which influences the choice of species to be farmed and the desired productivity in a certain production period. This affects investments and diversification of aquaculture activities (Isyagi, 2007). However, at the macro-level, weaknesses in Government policy are the reasons for the poor performance and growth of aquaculture in the LVB(Isyagi, 2007). This is because government institutions determine farmers' access to resources for production and to markets.

On the other hand, gender issues need to be considered in all development issues since they could be an impediment to the achievement of the development goals. Gender mainstreaming should be used as a strategy for making women's as well as men's concerns and experiences an integral dimension in the design, implementation and monitoring of every development activity . This is because some groups of the society are often marginalized in development processes if their issues are not considered. Since aquaculture is still an emerging activity in East Africa, employment is still very low (Blow& Leonard, 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& Leonard, 2007). 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. 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 is thought to be responsible for the high prevalence of HIV/AIDS among women in the basin(Kwena *et al*., 2012; WAC, 2006).

Despite their importance and contribution to artisanal fish processing, women have received little attention from both the government and non-governmental organization. If the fisheries sector is to maintain or improve on its current level of contribution towards household and national economy, then the role of women in the sector has to be enhanced through an enabling environment.

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5 Water, air and soil quality standards

These standards in Kenya are specified in theEnvironmental Management and Coordination Act (EMCA, 1999). Under EMCA, the National Environment Management Authority (NEMA) was created for the general supervision and co-ordination over all matters relating to the environment.

5.1 Water quality Standards

The water quality standards according to the World Health Organization(WHO, 2004) for physical and chemical substances (concentration limit levels) in drinking water are as followers:

Table 5.1:Standards of chemical and physical quality in Drinking water

Substance	Maximum allowable concentrations
Lead (as Pb)	0.1 mg/l
Selenium (as Se)	0.05 mg/l
Arsenic (as As)	0.2 mg/l
Chromium (as Cr hexavalent	0.05 mg/l
Cyanide (as CN)	0.01 mg/l
Fluorides	1 .O-1.5 mg
Nitrates	50 to 100 mg/l

Source; *WHO, 2004*

Table 5.2:Physical and chemical requirements

	Permissible	Excessive
Total solids	500 mg/l	1500 mg/l
Color	5 units *	50 units *
Turbidity	5 units* *	25 units * *
Taste	unobjectionable	-----
Odor	unobjectionable	----
Iron (Fe)	0.3 mg/t	1.0 mg/l
Manganese (Mn)	0.1 mg/l	0.5 mg
Copper (Cu)	1.0 mg/l	1.5 mg/l
Zine (Zn)	5.0 mg/l	15 mg/l
Calcium (Ca)	75 mg/l	200 mg/l
Magnesium (Mg)	50 mg/l	150 mg/l
Sulfate (SO_4)	200 mg/l	400 mg/l
Chloride (Cl)	200 mg/l	600 mg/l
pH range	7.0-8.5	Less than 6.5 or greater than 9.2
Magnesium + sodium sulfate	500 mg/l	1000 mg/l
Phenolic substances (as	0.001 mg/l	0.002 mg/l

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phenol)		

Source: WHO, 2004

Some of the water quality standards were formulated in accordance with EMCA and are specified in the EMCA (water quality regulations) of 2006.These Regulations apply to drinking water, water used for industrial purposes, water used for agricultural purposes(Benard& Omondi, 2012), water used for recreational purposes, water used for fisheries and wildlife, and water used for any other purposes(Kinyua, 2012). The regulations are as stipulated in the following sections.

5.1.1 Quality standards for drinking water

These are specified in the first schedule of the regulations as follows(EMCA, 2006).

Table 5.1: Quality standards for drinking water

Parameter	Guide Value (max allowable)
pH	6.5 – 8.5
Suspended solids	30 (mg/L)
Nitrate-NO_3	10 (mg/L)
Ammonia –NH_3	0.5 (mg/L)
Nitrite –NO_2	3 (mg/L)
Total Dissolved Solids	1200 (mg/L)
Scientific name (*E.coli*)	Nil/100 ml
Fluoride	1.5 (mg/L)
Phenols	Nil (mg/L)
Arsenic	0.01 (mg/L)
Cadmium	0.01 (mg/L)
Lead	0.05 (mg/L)
Selenium	0.01 (mg/L)
Copper	0.05 (mg/L)
Zinc	1.5 (mg/L)
Alkyl benzyl sulphonates	0.5 (mg/L)
Permanganate value (PV)	1.0 (mg/L)

5.1.2 Standards for Irrigation Water

These are contained in the ninth schedule and are as follows:

Table 5.1: Quality standards for irrigation water

Parameter	Permissible Level

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pH	6.5-8.5
Aluminum	5 (mg/L)
Arsenic	0.1 (mg/L)
Boron	0.1 (mg/L)
Cadmium	0.5 (mg/L)
Chloride	0.01 (mg/L
Chromium	1.5 (mg/L)
Cobalt	0.1 (mg/L)
Copper	0.05 (mg/L)
E.coli	Nil/100 ml
Fluoride	1.0 (mg/L)
Iron	1 (mg/L)
Lead	5 (mg/L)
Selenium	0.19 (mg/L)
Sodium Absorption Ratio (SAR)	6 (mg/L)
Total Dissolved Solids	1200 (mg/L)
Zinc	2 (mg/L)

Source; Benard & Omondi, 2012; EMCA, 2006

5.1.3 Quality Guidelines for Wastewater Used in Irrigation

The microbiological guidelines for waste water used in irrigation are specified in the eighth schedule as follows:

Table 5.1: Quality standards for waste water used for irrigation

Reuse conditions	Exposed group	Intestinal nematodes (MPN/L)*	Coliforms (MPN/100 ml)
Unrestricted irrigation (crops likely to be eaten uncooked, sports fields, public parks)	Workers, consumers, public	<1	<1000**
Restricted irrigation (cereal crops, industrial crops, fodder crops, pasture and trees***	Workers	<1	No standard recommended

Source:Benard & Omondi, 2012; EMCA, 2006

* Ascarislumbricoides, Trichuristrichiura and human hookworms.

** A more stringent guideline (<200 coliform group of bacteria per 100 ml) is appropriate for public lawns, such as hotel lawns, with which the public may come into direct contact.

*** In the case of fruit trees, irrigation should cease two weeks before fruit is picked and fruit should be picked off the ground. Overhead irrigation should not be used.

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5.1.4 Standards for Effluent Discharge into the Environment

These are covered in the third schedule and are as follows(EMCA, 2006);

Table 5.1: Standards for effluent discharge into the environment

Parameter	Max Allowable(Limits)
1,1,1-trichloroethane (mg/l)	3
1,1,2-trichloethane (mg/l)	0.06
1,1-dichloroethylene	0.2
1,2-dichloroethane	0.04
1,3-dichloropropene (mg/l)	0.02
Alkyl Mercury compounds	Nd
Ammonia, ammonium compounds, NO_3 compounds and NO_2 compounds (Sum total of ammonia-N times 4 plus nitrate-N and Nitrite-N) (mg/l)	100
Arsenic (mg/l)	0.02
Arsenic and its compounds (mg/l)	0.1
Benzene (mg/l)	0.1
Biochemical Oxygen Demand (BOD 5days at 20 ^oC) (mg/l)	30
Boron (mg/l)	1.0
Boron and its compounds – non marine (mg/l)	10
Boron and its compounds –marine (mg/l)	30
Cadmium (mg/l)	0.01
Cadmium and its compounds (mg/l)	0.1
Carbon tetrachloride	0.02
Chemical Oxygen Demand (COD (mg/l)	50
Chromium VI (mg/l)	0.05
Chloride (mg/l)	250
Chlorine free residue	0.10
Chromium total	2
cis –1,2- dichloro ethylene	0.4
Copper (mg/l)	1
Dichloromethane (mg/l)	0.2
Dissolved iron (mg/l)	10
Dissolved Manganese(mg/l)	10
E.coli (Counts / 100 ml)	Nil
Fluoride (mg/l)	1.5
Fluoride and its compounds (marine and non-marine) (mg/l)	8
Lead (mg/l)	0.01
Lead and its compounds (mg/l)	0.1

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n-Hexane extracts (animal and vegetable fats) (mg/l)	30
n-Hexane extracts (mineral oil) (mg/l)	5
Oil and grease	Nil
Organo-Phosphorus compounds (parathion,methylparathion,methyldemeton and Ethyl parantrophenylphosphorothroate, EPN only) (mg/l)	1
Polychlorinated biphenyls, PCBs (mg/l)	0.003
pH (Hydrogen ion activity----marine)	5.0-9.0
pH (Hydrogen ion activity--non marine)	6.5-8.5
Phenols (mg/l)	0.001
Selenium (mg/l)	0.01
Selenium and its compounds (mg/l)	0.1
Hexavalent Chromium VI compounds (mg/l)	0.5
Sulphide (mg/l)	0.1
Simazine (mg/l)	0.03
Total Suspended Solids, (mg/l)	30
Tetrachloroethylene (mg/l)	0.1
Thiobencarb (mg/l)	0.1
Temperature (^{o}C) based on ambient temperature	± 3
Thiram (mg/l)	0.06
Total coliforms (counts /100 ml)	30
Total Cyanogen (mg/l)	nd
Total Nickel (mg/l)	0.3
Total Dissolved solids (mg/l)	1200
Color in Hazen Units (H.U)	15
Detergents (mg/l)	Nil
Total mercury (mg/l)	0.005
Trichloroethylene (mg/l)	0.3
Zinc (mg/l)	0.5
Whole effluent toxicity	
Total Phosphorus (mg/l)	2 Guideline value
Total Nitrogen	2 Guideline value

Independent monitoring of water quality is also undertaken by;

- The ministry of Water and Irrigation (MW&I)
- Kenya Bureau of Standards (KEBS),
- Ministry of Health (MoH)
- National Environment Management Authority (NEMA).

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5.2 Water quality for fish farming

5.2.1 Introduction

Water quality is the most important factor affecting the health and quality of fish. Fish farmers must therefore understand the water quality requirements of the fish they want to grow or are growing. Good water quality refers to what the fish wants and not what we think the fish wants.

Farmers must understand that different fish species have different and specific range of water quality aspects (temperature, pH, oxygen concentration, salinity, hardness, etc.) within which they can survive, grow, reproduce and perform optimally. Within these ranges, each species has its own optimum range within which it performs best. It is therefore very important for fish producers to ensure that the physical and chemical conditions of the water remain, as much as possible, within the optimum range of the fish under culture all the time. Outside these optimum ranges, fish will exhibit poor growth, erratic behaviour, and disease symptoms or parasites infestations. Under extreme cases, or where the poor conditions remain for prolonged periods of time, fish mortality may occur.

Pond water contains two major groups of substances:

• Suspended particles made of non-living particles and very small plants and animals, the plankton.

• Dissolved substances made of gases, minerals and organic compounds;

The composition of pond water changes continuously, depending on climatic and seasonal changes, and on how a pond is used. The goal of good management is to control this composition to yield the best conditions for the fish.

For producers to be able to maintain ideal pond water quality conditions, they must understand the physical and chemical components contributing to good or bad water quality.

5.2.2 Physical Aspects of Water Quality

Temperature

Fish assume the temperature of the water they live in and are referred to as “cold-blooded”. Water temperature is therefore a very important physical factor for fish survival and growth. The water temperature and thus the body temperature of the fish, has an effect on level of activity, behaviour, feeding, growth, and reproduction of the fish. Each species has its tolerance limits and optimum range. When water temperatures are outside the optimum range, fish body temperature will either be too high or too low and fish growth will be affected or even the fish die.

Table 5.1: Tolerance limits and optimum temperature ranges for commonly cultured fish species of Kenya

Fish species	Ova and juveniles	Adults	
		Minimum DO level	Preferred DO level at least equal to
Trout	Close to 100%	5 mg/l (50%)	8 mg/l or 70%
Common carp	At least 70%	3 mg/l (30%)	5 mg/l or 50%

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Tilapia	At least 70%	2 mg/l	4 mg/l or 50%
African catfish	At least 90%	1 mg/l or less (aerial respiration)	3 mg/l or 35%

Turbidity

Fine suspended solid particles lead to water turbidity. Turbid Water can be said to be "cloudy". Turbidity can result from suspended solids (clay) or plankton (living organisms in water).

Clay turbidity in pond water (muddy water) can be harmful to fish and limit pond productivity. Clay turbidity in pond can be controlled by:

• Treating affected ponds with animal manures at rates of 2.4 T/ha every three weeks or applying agricultural lime at the recommended rates to improve soil pH and water alkalinity
• Avoiding stocking species that stir up pond bottom mud e.g. the common carp
• Designing water supply system in a way that allow muddy water to sediment or diverted away from the ponds

Planktons are small often microscopic aquatic plants (phytoplankton) and animals (zooplankton) found suspended in the water column. Phytoplankton forms the base of the food chain while zooplankton forms the second link in the chain in aquatic systems such as ponds.

In addition to their role as food for fish in ponds, phytoplankton provides oxygen through photosynthesis during the day. This oxygen dissolves into the water (DO) and therefore becomes available to the fish in the ponds.

Low phytoplankton density in ponds means less food and DO for the fish. On the other hand, too much (algal boom) lead to minimised sunlight penetration causing algal deaths. Less phytoplankton and decomposing plankton also lead to less food and DO for the fish. Good water quality, in relation to plankton therefore means water with just the right bloom. Visibility in a pond with the right plankton density should be about 30 cm.

A simple method of measuring turbidity it to stretch one arm, and immerse it vertically into the water until the hand disappears from sight.

Note the water level along your arm:

- If it Is well below your elbow, plankton turbidity is very high;
- If it reaches to about your elbow, plankton turbidity is right;
- If it reaches well above your elbow, plankton turbidity is low.

Suspended fish wastes are generally not a problem in semi-intensive aquaculture but in intensive systems, especially recirculation systems, they may be a major cause of poor water quality:

5.2.3 Chemical Aspects of Water Quality

This is in reference to the following parameters:

- pH
- Alkalinity
- Hardness
- Dissolved gases: oxygen, carbon dioxide, nitrogen, ammonia
- Salinity
- Essential nutrients—Nitrogen (N), Phosphorous (P) and Potassium (K)

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- Soil pH and Acidity

Pond water may be acid, alkaline or neutral. Depending on this, water will react in different ways with substances dissolved in it. It will also affect in different ways the plants and animals living in the water. The measure of the alkalinity or acidity of water is expressed by its pH value. The pH value ranges from 0 to 14, with pH 7 indicating that the water is neutral. Values smaller than 7 indicate acidity while those greater than 7 indicate alkalinity.
Fish production can be greatly affected by excessively low or high pH. Extreme pH values can even kill your fish. The growth of natural food organisms may also be greatly reduced. The critical pH values vary according to the fish species, the size of individual fish and other environmental conditions. For example, fish are more susceptible to extreme pH during their reproductive seasons, and eggs and juveniles are more sensitive than adults.
Waters ranging in pH from 6.5 to 8.5 (at sunrise) are generally the most suitable for pond fish production. Most cultured fish will die in waters with pH below 4.5 and 11 and above.
Fish reproduction and general performance can be greatly affected at pH below 6.5 and above 8.5, while a pH below 4.5 and above 10 will cause fish death.

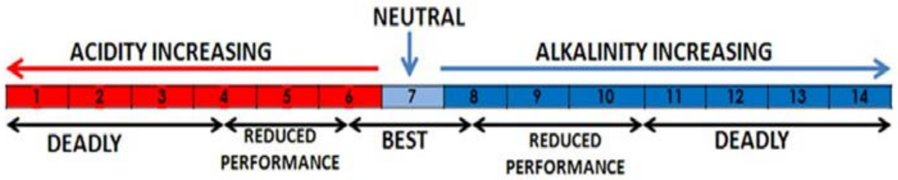

Figure 5.1:pH ranges showing tolerance limits and optimum range for fish

Pond water with pH unfavourable for fish production can be corrected as follows:

- pH is below 6.5 at sunrise: use lime and alkaline fertilizers
- pH is above 8.5 at sunrise: you can use acid fertilizers

Ensuring that soil pH and acidity are within acceptable limits is a necessary part of managing the alkalinity, hardness, and pH of the water, which were discussed above. The key is to keep soil pH at 6.5 or above, which will usually maintain water pH, hardness, and alkalinity at desirable levels. Soil pH can be kept at the right level by:

- Drying the pond for at least two weeks after each harvest before refilling and restocking.
- Applying lime (preferably agricultural limestone) to the pond after each harvest.

Normally lime should be applied to the pond bottom before it is refilled, but if necessary, it can be applied to the water surface after filling the pond. Only recommended liming materials and application rates should be used (see pond farming of tilapia)
Pond water pH varies over the course of a 24-hour day. This variation is related to the light intensity which is important in photosynthetic activity of phytoplankton.

- pH is lowest at sunrise and as the light intensity increases, photosynthesis increases causing more and more carbon dioxide to be removed from the water by the plants leading to rise in pH.
- A peak pH value is reached in late afternoon.
- As the light intensity starts decreasing toward the evening there will be less photosynthesis and less carbon dioxide is removed from the water. Respiration adds more carbon dioxide to the water and the water pH starts to decrease.

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- At sunset, photosynthesis stops, but respiration continues for the rest of the night. More and more carbon dioxide is produced, and pH keeps decreasing until sunrise, when it reaches its minimum.

Dissolved oxygen in fish ponds

The most important gas dissolved in water is oxygen (O2). Dissolved oxygen (DO) is essential for respiration and decomposition.

Dissolved Oxygen in water comes from atmospheric oxygen and photosynthesis.

The atmospheric oxygen diffuses and dissolves into the water. But the diffusion and its subsequent dissolving into water is a slow process. The major source of dissolved oxygen in ponds is photosynthesis. However this process depends on the amount of light available to the aquatic plants in water (Phytoplankton).

Therefore;

• Oxygen production decreases during cloudy days

• It stops at night

• It decreases in increase in water depth the rate of the decrease depends on the water turbidity

Measuring DO

DO can be measured by,chemical or electrical methods. Chemical methods rely on the use of kits which can be bought from shops dealing with laboratory equipment. They contain chemicals and equipment necessary to determine the DO content with sufficient accuracy for pond management purposes.

Electrical methods use an oxygen meter, this too can be bought from laboratory equipment shops but it is expensive. Using this equipment DO can be measured directly from the pond at any depth.

DO and water temperature should be measured at the same time so as to be able to relate the DO to the temperature.

DO is expressed as mg of oxygen/litre of water (mg/l).

Table 5.1: DO requirements commonly farmed fishes in Kenya (in mg/l or percent saturation values)

Fish species	Ova and juveniles	Adults	
		Minimum DO level	**Preferred DO level at least equal to**
Trout	Close to 100%	5 mg/l (50%)	8 mg/l or 70%
Common carp	At least 70%	3 mg/l (30%)	5 mg/l or 50%
Tilapia	At least 70%	2 mg/l	4 mg/l or 50%
African catfish	At least 90%	1 mg/l or less (aerial respiration)	3 mg/l or 35%

Fluctuating oxygen levels

From sunrise to sunset

• Photosynthesis increases the DO level

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• DO production is higher in clear sky days than on cloudy days
• The higher the phytoplankton population, the higher the DO production.
At night,
• Photosynthesis does not take place
• Respiration and decomposition which are the main activities taking place, reduces the DO content until sunrise
• The higher the plankton population and dead matter, the faster the DO will fall

There may be very little oxygen left by morning and fish may suffocate if corrective measures are not taken.

In over fertilised ponds, where there is very high plankton density and high turbidity, the bottom water may become anoxic (without oxygen) even during the day. The fish will concentrate at the surface of the pond to survive. This will be much worse at night.

Where DO test equipments are not available, signs indicating reduced DO in pond water include:

• Fish not feeding well or even stopping feeding;
• Fish coming to the water surface to breathe from the better oxygenated surface water (this is called piping).

The DO content of pond water can be increased in several ways:
• Through design and management
• Through structures that cause water to splash e.g. by use of cascades along the inlet canal and raised inlet pipes before the water gets into the ponds
• By use of mechanical aerators for the emergency aeration of pond water

A simple way to ensure a good supply of atmospheric oxygen to fish ponds is in the design of the pond. The ponds should be designed such that they take maximum advantage of the winds. The ponds should be design such that the lengths are parallel to the direction of the important winds.

Proper pond management can also improve the DO content of the water. The following measures can be taken before any emergency happens:

- Flashing the pond by removing the less oxygenated bottom water and replacing it with better oxygenated water
  • Use of water aerators e.g. mushroom blowers or paddle wheels

Alkalinity and Hardness

It is desirable to maintain both alkalinity and hardness at 40-70 mg $CaCO3/L$. This can be done by:

• Where water is "soft" or acidic and soils are acid, apply lime (agricultural limestone) to the pond soil at recommended rates before to filling the pond
• Lime may also be added after filling by spreading it uniformly over the water surface.
• In areas where soils are alkaline and hardness and alkalinity are high, application of lime is not required.
• Note that proper management of hardness and alkalinity will usually eliminate the need to worry about pH.

Ammonia

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Un-ionized ammonia (NH3) concentrations in pond water should be kept below 0.5 mg/L. Concentrations of this form of ammonia, which is toxic to fish, are influenced by DO, pH, and alkalinity, therefore it is important to manage this by:
• Maintain water alkalinity at 40 mg CaCO3/L or above
• Keeping pH near neutral, and at least below 9.0
• Keeping DO concentrations high

Toxic Materials
Substances toxic to fish and other organisms (herbicides, insecticides, and other chemicals) should be kept out of the ponds. Ponds should be protected by:
• Not using insecticides, herbicides, or other chemicals (except for recommended inorganic fertilizers) in or near your pond
• Keeping agricultural runoff from the ponds
• Avoiding spraying agricultural crops or animals near ponds on windy days

5.3 Air Quality Standards

These were formulated in accordance with EMCA, (1999) and are known as EMCA (Air Quality) Regulations, 2014(EMCA, 2014).

Table 5.1: Ambient Air Quality Tolerance Limits

Pollutant	Time weighted Average				
			Industrial area	Residential, Rural & Other area	Controlled areas***
1	Sulphur oxides (SO_X);	Annual Average*	80 µg/m^3	60 µg/m^3	15µg/m^3
		24 hours**	125µg/m^3	80µg/m^3	30 µg/m^3
		Annual Average		0.019 ppm/50 µg/m^3	
		Month Average			
		24 Hours		0.048ppm /125 µg/m^3	
		One Hour			
		Instant Peak		500 µg/m^3	
		Instant Peak (10 min)		0.191 ppm	
2	Oxides of Nitrogen (NO_X)	Annual Average*	80 µg/m^3	60 µg/m^3	15µg/m^3
		24 hours**	150µg/m^3	80µg/m^3	30 µg/m^3
		8 hours			

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		Annual Average		0.2 ppm	
		monthly Average		0.3 ppm	
		24 hours		0.4 ppm	
		One hours		0.8 ppm	
		Instant Peak		01.4 ppm	
3	Nitrogen Dioxide	Annual Average	150µg/m^3	0.05 ppm	
		monthly Average		0.08 ppm	
		24 hours	100µg/m^3	0.4 ppm	
		One Hour		0.2 ppm	
		Instant Peak		0.5 ppm	
4	Suspended particulate	Annual Average*	360 µg/m^3	140µg/m^3	70µg/m^3
	Pollutant	Time weighted Average			
		24 hours	500 µg/m^3	200 µg/m^3	100 µg/m^3
			Industrial area	area Residential, Rural & Other area	Controlled areas***
	mg/Kg				
	Annual Average****			100 µg/m^3	
				180 µg/m^3	
5	Respirable particulate matter (<10 m) (RPM)	Annual Average*	70 µg/m^3	50 µg/m^3	50 µg/m^3
		24 hours**	150 µg/Nm^3	100 µg/Nm^3	75µg/Nm^3
6	$PM_{2.5}$	Annual Average	35 µg/m^3		
			70µg/m^3		
7	Lead (Pb)	Annual	1µg/Nm^3	0.75µg/Nm^3	0.50

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		Average*			µg/Nm^3
		24 hours**	1.5µg/Nm^3	1.00µg/Nm^3	0.75µg/Nm^3
		Month Average		2.5	
8	Carbon monoxide (CO)/ carbon dioxide (CO_2)	8 hours**	5.0mg/m^3	2.0mg/m^3	1.0mg/m^3
		1 hour	10.0 mg/m^3	4.0 mg/m3	2.0 mg/m3
		mg/Kg			
		24 hours**			
9	Hydrogen Sulphide	24 hours**	150 µg/m^3		
10	Non-methane hydrocarbons				
		instant Peak	700ppb		
11	Total VOC	24 hours**	600 µg/m^3		
12	Ozone	1-Hour	200 µg/m^3	0.12 ppm	
			120 µg/m^3	0.25 ppm	

Any other parameter as may be prescribed by the Authority from time to time. The following abbreviations have the indicated meaning;
a) µg- microgram
b) M^3 – cubic metre
c) Ppm – parts per million
d) Ppb – parts per billion
e) Values at Standard Temperature and Pressure (STP)
f) * Annual Arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hourly at uniform interval.
g) ** 24 hourly/8 hourly values should be met 98% of the time in a year. However, 2% of the time, it may exceed but not on two consecutive days.
h) The 24-hour limit may not be exceeded more than three times in one year;
i) ** 24-hour limit may not be exceeded more than three times in one year micrograms/m^3
j) *** Not to be exceeded more than once per year average concentration
k)***In conversion of units from ppm to mg/m3 and vice versa shall use guidelines set out under Part II of the Fifth Schedule.
The following guidelines on Conversion factors may be used:

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ppm to mg/m^3 - air The conversion between ppm and mg/m^3 is dependent on both the molecular weight of the substance and the temperature at which the conversion is made. The assumption is that the pollutant behaves as an ideal gas and as such, 1 mole of the substance occupies 22.4 litres at standard temperature (273K) and pressure (101.3 kPa). This is consistent with normalized concentrations, and it is therefore not normally necessary to take account of the temperature or pressure difference in the conversion. However, when converting ppm to mg/m^3 at actual discharge conditions, it is important to take account of the necessary factors.

To convert from ppm to mg/m^3, the following formula should be used: mg/m^3 = ppm x (MW/22.4) x (273/T) x (P/101.3)

Where:

MW is the molecular weight of the substance (in grams)

T is the temperature at which the conversion is to be made (degrees Kelvin)

P is the pressure at which the conversion is to be made (kPa)

To convert from mg/m^3 to ppm, the following formulae should be used: ppm = mg/m^3 x (22.4/MW) x (T/273) x (101.3/P)

Table 5.2: Emission parameters to be monitored in specified plants

Industry air pollutant	Opacity	Particulate (Dust)	Sulphur oxide	Nitrogen oxides	Carbon monoxide	Carbon dioxide	Hydrocarbons	Hydrogen Sulphide(H_2S)	Hydrogen Chloride	Dioxins/Furans
Thermal Power Plants		*	*	*	*	*				*
Geothermal Power Plants			*	*			*	*		
Waste water Treatment Plants				*			*	*		

And any other parameter as may be prescribed by the Authority from time to time

Legend

a) * - parameters to be monitored

b) Frequency – dependent on parameter and reported on a quarterly basis

5.4 Soil Quality Standards

5.4.1 Contaminant limits for Heavy metals

These are given as per the Environmental Management (Soil quality standards) Regulations of 2007 (Tanzania)(EMA, 2007).

Table 5.1: Test methods and limits for heavy metals in soil

S/N	Parameter	Upper Limit (mg/kg)	Test method
1.	Arsenic	1	***

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2	Cadmium	1	ISO 11047:1998 (E) TZS 974
3	Hexavalent Chromium	100	ISO 11047:1998 (E) TZS 974
4	Lead	200	ISO 11047:1998 (E) TZS 974
5	Manganese	1,800	ISO 11047: 1998 (E) TZS 974
6	Mercury	2	ISO 16772:2004 (E) TZS 975
7	Nickel	100	ISO 11047:1998 (E) TZS 974
8	Selenium	20	***
9	Copper	200	ISO 11047:1998 (E) EMDC 3 (1850) P3
10	Zinc	150	ISO 11047:1998 (E) TZS 974
11	Molybdenum	5	***

******* = No reference method has been specified, hence currently no restriction on test methods as long as they give reliable results.

5.4.2 Soil Quality Standards for Habitat and Agriculture

The standards used in this case are adopted from the United States Environmental Protection Agency (EPA)(Jennings, 2013).

Table 5.1:Contaminant limits for Heavy metals

Parameter	Unit	Standard value	Analytical method
Arsenic	mg/kg	Not exceed 3.9	Inductively Coupled Plasma-Atomic Emission Spectrometry or Inductively Coupled Plasma-Mass Spectrometry or Atomic Absorption, Furnace Technique or Atomic Absorption, Gaseous Hydride or Atomic Absorption, Borohydride Reduction or other Methods Approved by Pollution Control Department
2) Cadmium and compounds	“	Not exceed 37	Inductively Coupled Plasma-Atomic Emission Spectrometry or Inductively Coupled Plasma-Mass Spectrometry or Atomic Absorption, Direct Aspiration or Atomic Absorption, Furnace Technique or other Methods Approved by Pollution Control Department
Hexavalent Chromium	“	Not exceed 300	Co-precipitation or Colorimetric or Chelation/Extraction or other Methods Approved by Pollution Control Department
Lead	“	Not exceed	Inductively Coupled Plasma-Atomic Emission Spectrometry or Inductively Coupled Plasma-Mass

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		400	Spectrometry or Atomic Absorption, Direct Aspiration or Atomic Absorption, Furnace Technique or other Methods Approved by Pollution Control Department
Manganese and compounds	"	Not exceed 1,800	"
Mercury and compounds	"	Not exceed 23	Cold-Vapor Technique or other Methods Approved by Pollution Control Department
Nickel, soluble salts	"	Not exceed 1,600	Inductively Coupled Plasma-Atomic Emission Spectrometry or Inductively Coupled Plasma-Mass Spectrometry or Atomic Absorption, Direct Aspiration or Atomic Absorption, Furnace Technique or other Methods Approved by Pollution Control Department
Selenium	"	Not exceed 390	Inductively Coupled Plasma-Atomic Emission Spectrometry or Atomic Absorption, Furnace Technique or Atomic Absorption, Gaseous Hydride or Atomic Absorption, Borohydride Reduction or other Methods Approved by Pollution Control Department

Table 5.2: Pesticides limits

1) Atrazine	mg/kg	Not exceed 22	Gas Chromatography or other Methods Approved by Pollution Control Department
2) Chlordane	"	Not exceed 16	Gas Chromatography/Mass Spectrometry (GC/MS) or other Methods Approved by Pollution Control Department
3) 2,4-D	"	Not exceed 690	Gas Chromatography or High Performance Liquid Chromatography/Thermal Extraction/Gas Chromatography/Mass Spectrometry (TE/GC/MS) or other Methods Approved by Pollution Control Department
4) DDT	"	Not exceed 17	Gas Chromatography or Gas Chromatography/Mass Spectrometry (GC/MS) or other Methods Approved by Pollution Control Department
5) Dieldrin	"	Not exceed 0.3	"

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6) Heptachlor	"	Not exceed 1.1	"
7) Heptachlor Epoxide	"	Not exceed 0.5	"
8) Lindane	"	Not exceed 4.4	"
9) Pentachlorophenol	"	Not exceed 30	Gas Chromatography or Gas Chromatography/Mass Spectrometry (GC/MS) or Gas Chromatography/Fourier Transform Infrared (GC/FT-IR) Spectrometry or other Methods Approved by Pollution Control Department

Table 5.3: Other chemicals limits

1)Benzo (a) pyrene	mg/Kg	Not exceed 0.6	Gas Chromatography/Mass Spectrometry (GC/MS), or Thermal Extraction/Gas Chromatography/Mass Spectrometry (TE/GC/MS), or Gas Chromatography/Fourier Transform Infrared (GC/FT-IR) Spectrometry, or other Methods Approved by Pollution Control Department
2) Cyanide and compounds	"	Not exceed 11	Total and Amenable Cyanide: Distillation, or Total Amenable Cyanide (Automated Colorimetric, with off-line Distillation), or Cyanide Extraction Procedure for Solids and Oils or other Methods Approved by Pollution Control Department
3) PCBs	"	Not exceed 2.2	Gas Chromatography or other methods approved by PCD
4) Vinyl Chloride	"	Not exceed 1.5	Gas Chromatography or Gas Chromatography/Mass Spectrometry (GC/MS) or other methods approved by PCD

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6 FISHERIES LEGAL FRAMEWORKS AND INSTITUTIONAL ARRANGEMENTS

6.1 Legal instruments

The following are the key legal instruments underpinning governance of fisheries in Kenya:

- Fisheries development and management Act, 2016
- The Wildlife (Conservation and Management) Act of 2002 (revised)
- Fisheries (Beach management unit) regulations, 2007
- Physical Planning Act,1999
- Fish quality assurance regulations, 2000
- Fisheries (safety of fish, fish products and fish feed) Regulations, 2007
- Environmental Management and coordination Act, 1999
- Environmental Management and coordination (Water quality), Regulations, 2006
- National, Oceanic and Fisheries Policy, 2008

6.1.1 Fisheries development and management Act, 2016

The Fisheries Development and Management Act 2016 provides for the conservation, management and development of fisheries and other aquatic resources to enhance the livelihood of communities that depend on fishing.The new law also gives guidance on the import and export trade of fish and fish products, fish quality and safety among other provisions.It also establishes the Kenya Fisheries Services and the Kenya Fisheries Advisory Council.

Functions of the Kenya Fisheries Services include ensuring the appropriate conservation, development of standards on management, sustainable use and protection of the country's fisheries resources.The enactment of the law comes in handy because for decades, communities around fishing areas have remained poor because of lack ofconducive legal framework to guide the sector.

The fisheries sector has been faced with several challenges including a weak policy framework, limited access to markets, low productivity (yields) and outputs (quantities), weak institutional capacity, weak monitoring and evaluation and lack of use of informational technology, which have limited the sector's contribution to food security and wealth creation.This has seen regions with vast natural fish production such as Western and Nyanza, Turkana and Coast regions recorded as some of the least developed areas.

Under the Act, The Tuna Management Strategy is expected to transform fisheries from artisanal to commercial industry by engaging in Private Public Partnerships (PPP).The Act provides that existing infrastructure, including the ports in Mombasa and Lamu and the proposed fishing ports of Shimoni, Kilifi, Malindi and Kiunga, be upgraded and made efficient. Devolved units along the coast lines are expected to invest more resources mainly through the construction of jetties at strategic locations to encourage commerce and tourism.The country strategy is to focus on coastal tourism, offshore oil and gas exploration, deep and short-sea shipping, yachting and marinas, passenger ferry services and cruise tourism as a starting point.

The focus will gradually shift to fisheries and aquaculture, inland water way transport, coastal

protection, offshore wind, blue biotechnology, desalination, aggregates and marine mineral mining, marine aquatic products and ocean renewable energy.The Fisheries Management and Development Act 2016 will establish a Fisheries Service Advisory Council to negotiate partnership and fishing access agreements, fisheries monitoring and patrol mechanisms and improve aquaculture to commercial levels.
Further, Kenya Fish Marketing Authority will be established to spearhead the implementation and co-ordination of a fish marketing strategy.

6.1.2 The Wildlife (Conservation and Management) Act of 2002

This Act provides for protection, conservation and management of wildlife in Kenya and related matters. The Act shall apply to all wildlife resources on public, community and private land, and Kenya territorial waters. The 119 sections of this Act are divided into 15 Parts: Preliminary (I); Establishment of the Service (II); Financial provisions (III); The wildlife regulation mechanisms (IV); Establishment of Wildlife Endowment Fund (V); Conservation, protection and management (VI); Establishment of the Wildlife Research And Training Institute (VII); Conservation Orders, easements and incentives (VIII); Human wildlife conflict (IX); Licensing and regulation (XI); Offences and penalties (XI); International treaties, conventions and agreements (XII); Enforcement and compliance (XIII); Miscellaneous (XIV). (Completed by 11 Schedules)Wildlife resources shall be protected, conserved, managed and regulated in accordance with a national wildlife conservation and management strategy to be drafted every five years by the Cabinet Secretary. The Act establishes the Kenya Wildlife Service as a body corporate for management of wildlife resources and protected areas and a Wildlife Research and Training Institute. The Service shall be managed by a Board of Trustees. The Wildlife Regulation Mechanism shall consist of a County Wildlife Conservation and Compensation Committee for each county. The Service shall establish a Wildlife Endowment Fund for purposes of developing wildlife conservation initiatives, managing and restoring protected areas and conservancies, protecting endangered species, habitats and ecosystems, etc. A Wildlife Compensation Scheme shall be used for compensation of damage caused by wildlife. Protected areas such as national parks, marine protected area and wetlands may be established by the Cabinet Secretary. Exchange part of a national park with private land with the consent of the owner may be effected at certain conditions. Any person or community who owns land on which wildlife inhabits may individually or collectively establish a wildlife conservancy or sanctuary in accordance with the provisions of this Act and associations, communities and landowners may be registered as a recognized wildlife manager. The Cabinet Secretary shall publish a national list of wildlife ecosystems and habitats that are endangered and threatened and are in need of protection. The species of wildlife set out in the Sixth Schedule are declared to be critically endangered, vulnerable, nearly threatened and protected species. Wildlife conservation easements may be created by voluntary private arrangement or upon appropriate application to the Environment and Land Court. The provisions of this Act with respect to conservation, protection and management of the environment shall be in conformity with the provisions of the Environmental Management and Coordination Act. The provisions of that Act regarding reference to the Tribunal established under that Act shall apply to hearing of appeals arising from the decisions made under this Act. No provision of this Act and no rights or entitlements conferred and granted under this Act shall, wherever appropriate operate to exempt a person

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from compliance with the provisions of the Water Act, 2002 concerning the right to the use of water from any water resource, reservoir or point.

6.1.3 Fisheries (Beach management unit) regulations, 2007

In Kenya BMUs have exclusive management rights over fish landing sites and consist of an assembly, an executive committee, and may have sub-committees. They are required to provide data on catches and develop co-management plans to ensure sustainable fisheries in that area. These management plans must be approved by the Director of Fisheries and may include measures such as closing areas for fishing, and restricting fishing gear and the number of fishing vessels. BMUs are expressly required to protect the aquatic environment and cooperate with authorities to that effect. BMUs possess certain law-enforcement powers with regard to gear regulations, registration of vessels, and protection of fishing grounds. Monitoring the performance of BMUs is conducted both by the Unit itself as well as by external, authorized fisheries officers in six month intervals. BMUs can receive funding from the Ministry of Fisheries Development, or generate their own income through membership fees, taxing migrant fishers, or vessel registration fees. The roles of the BMUs are;

- Create Beach Management Units at local level with exclusive management rights over fish landing sites and obligations to develop sustainable co-management plans
- Designate government body (e.g. Ministry of Fisheries) to approve co-management plans and monitor and supervise their implementation and offer funding
- Delegate authority for enforcement of co-management plans to Beach Management Units

6.1.4 Physical Planning Act, 1999

This Act makes provision for development control. The Local Authorities are empowered under section 29 of the Act to reserve and maintain all land planned for open spaces, parks, urban forests and green belts. The same section, therefore allows for the prohibition or control of the use and development of land and buildings in the interest of proper and orderly development of an area.

In the development of any land, approval must be obtained from the relevant local authority. Section 30 states that any person who carries out development without development permission will be required to restore the land to its original condition. It also states that no other licensing authority shall grant license for commercial or industrial use or occupation of any building without a development permission granted by the respective local authority.

Finally, section 36 states that if in connection with a development application, local authority is of the opinion that the proposed development activity will have injurious impact on the environment, the application shall be required to submit together with the application an environment impact assessment EIA report. EMCA echoes the same by requiring that such an EIA is approved by the NEMA and should be followed by annual environmental audits.

6.1.5 Fish quality assurance regulations, 2000

The Division was created as a unit in the office of Director of Fisheries in the late 1980s. The Division is responsible for the overall technical supervision of fish quality assurance in the country and in particular implementation and coordination of fish safety activities to ensure

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compliance with national and international market requirements.
Through the creation of the Division and formal recognition of the Ministry responsible for fisheries as the Competent Authority on matters of food safety in respect to fish and fishery products and enactment of the Fish Quality Assurance Regulations 2000, Kenya was listed as a member of third countries to export fish and fisheries products from the capture fisheries to the European Union. To align with global developments on food safety, a review on the 2000 legislation was conducted and a subsequent Fisheries (Safety of fish, fish products and fish feed) Regulations, 2007 adopted. In 2015, the European Union approved imports of farmed fish and fishery products from Kenya following a successful submission of the Implementation of Residue Monitoring Plan.

6.1.6 Fisheries (safety of fish, fish products and fish feed) Regulations, 2007

These Regulations make provision with respect to the official control of the safety of fish, fishery products and fish feed and specify health requirements for the production and placing on the market of (particular) fish products. The Ministry responsible for fisheries shall be the Competent Authority for purposes of these Regulations. A standing committee and a technical committee are established for management purposes. The Competent Authority shall, among other things: monitor fish production, fish, fishery products and fish feed with a view to assessing risks to human health; control fish handling, landing, transportation, processing and marketing; assess and approve plans and structures of intended fishery enterprises; maintain a register of fishery enterprises approved under these Regulations; and issue health certification for fish, fishery products and fish feed. No person shall establish or use a fishery enterprise for the purpose of production, culture, keeping, processing, storage, packaging, transporting or placing on the market of fish or fishery products intended for human or animal consumption unless the enterprise is approved by the Competent Authority. The rules that apply to fish products and feed concern, among other things, the following matters: harvesting of bivalve molluscs; prohibition on placing on the market of certain fish species; health conditions on vessels; environmental impact assessment for aquaculture facilities; contamination of fish culture; use of feed and drugs in fish culture; control of fish diseases and pest control systems; storage and transport of fish; HACCP and other internal control; packing and identification of fish products; inspection; and traceability of products.

6.1.7 Environmental Management and coordination Act, 1999

The Environmental Management and Coordination Act of 1999 (EMCA) was enacted to provide an appropriate legal and institutional framework for the management of the environmental and for matters connected therewith and incidental thereto. EMCA does not repeal the sectoral legislation but seeks to coordinate the activities of the various institutions tasked to regulate the various sectors. These institutions are referred to as Lead Agencies in EMCA. Lead Agencies are defined in Section 2 as any Government ministry, department, parastatal, and State Corporation or local authority in which any law vests functions of control or management of any element of the environment or natural resource.

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6.1.8 Environmental Management and coordination (Water quality), Regulations, 2006

Water Quality Regulations apply to water used for domestic, industrial, agricultural, and recreational purposes; water used for fisheries and wildlife purposes, and water used for any other purposes. Different standards apply to different modes of usage. These regulations provide for the protection of lakes, rivers, streams, springs, wells and other water sources.

The objective of the regulations is to prohibit discharge of effluent into the environment contrary to the established standards. The regulations further provides guidelines and standards for the discharge of poisons, toxins, noxious, radioactive waste or other pollutants into the environment in line with the Third Schedule of the regulations.

The regulations have standards for discharge of effluent into the sewer and aquatic environment. While it is the responsibility of the sewerage service providers to regulate discharges into sewer lines based on the given specifications, NEMA regulates discharge of all effluent into the environment.

No person shall discharge any effluent from sewage treatment works, industry or other point sources into the environment without a valid effluent discharge license issued by NEMA.

Every person shall refrain from any actions, which directly or indirectly cause water pollution, whether or not the water resource was polluted before the enactment of the Environmental Management and Coordination Act (EMCA), 1999

6.1.9 National, Oceanic and Fisheries Policy, 2008

Acknowledging the need for the fisheries sector in Kenya to operate within a specific policy framework, the Government took a key decision to develop a comprehensive policy for the sector in 2008. It is a sectorial policy which aims to ensure increased and sustainable fish production and utilization by properly managing the ocean and other Kenya Fishery waters.

The overall objective of this Policy is:"to enhance the fisheries sector's contribution to wealth creation, increased employment for youth and women, food security, and revenue generation through effective private, public and community partnerships". Specifically, the policy aims: (i) to promote conservation and management of fisheries resources, (ii) to generate the maximum amount of employment, (iii) to maximize revenue from fisheries and other related activities, (iv) to promote an integrated economy, (v) to enhance food supply and food security, (vi) to promote safety at sea, (vii) to develop Aquaculture, recreational and ornamental fisheries, and (viii) development of the ocean fisheries.

In order to eliminate hunger, food insecurity and malnutrition, the policy plans to take every effort to achieve self-sufficiency in fish and that the domestic market is at all times adequately supplied. The government will further emphasize the nutritional importance of fish consumption while adhering to local and international food safety standards. In order to make agriculture, forestry and fisheries more productive and sustainable, the government of Kenya plans to continue to prioritize fisheries resources conservation and management. In doing so, the government will utilize appropriate management tools to ensure long-term sustainability. The precautionary approach to management will be adopted where there is inadequate scientific evidence.

Regarding the reduction of rural poverty, the policy envisages the development of the fisheries sector with a view to generating employment opportunity for the maximum number of Kenyans either directly or indirectly. The policy will also ensure that fishers and those

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involved in supporting fishing activities enjoy improved livelihood. Furthermore, through the policy, the government will ensure that the maximum amount of foreign exchange is earned from the export of fish and fish products while putting emphasis on improving both qualities, health and safety standards. The Government will create conditions that will increase the contribution of the fisheries sector to the national wealth by increasing production and value addition to fisheries products.

To enable inclusive and efficient agricultural and food systems, the policy plans to encourage investment in small medium and large scale commercial aquaculture for domestic and export markets. In doing so, the government will encourage the provision and availability of affordable microfinance. Finally, the policy will promote private sector investment in the development of recreational and ornamental fisheries through the provision of incentives and infrastructure.

To increase the resilience of livelihoods to threats and crises, the policy addresses issues such as the effect of climate change, the impact of deforestation land degradation, introduction of alien species and loss of critical habitats negatively affect fish production. Pollution from agricultural, domestic and industrial activities affects fish production and quality.

Regarding the governance, Kenya has taken bold steps through the creation of a fully-fledged ministry to enhance the profile of oceans and fisheries sector. For a start the Government has reorganized the department of fisheries to create a technical coordination arm in the Ministry, by creating Kenya Oceans and Fisheries Services. The government will put in place and monitoring and evaluation mechanism to ensure efficient and effective implementation of this policy, in particular, a major evaluation will be conducted in five years to review planned policy priorities.

6.2 Institutional framework

The following key institutions relate to fisheries governance structures in Kenya:

- Ministry of Fisheries Development (MoD)
- Department of Fisheries (FiD) – a department under MoD
- Kenya Marine and Fisheries Research Institute (KMFRI)
- Kenya Wildlife Services (KWS)
- National Environment Management Authority (NEMA)
- Lake Victoria Fisheries Organization (LVFO)

With respect to fisheries governance this review focuses on the Ministry of Fisheries Development, the department of fisheries (FiD) and the marine research arm (KMFRI). The role of KWS in fisheries governance is also discussed.

6.2.1 Ministry of fisheries development and the marine and coastal fisheries directorate.

The department of fisheries is a technical department of the ministry whose mandate is to provide for the exploration, exploitation, utilization, management, development and conservation of fisheries resources, and undertake research in marine and fresh water fisheries. Their stated mission is “to facilitate sustainable management and development of fishery resources and products for socio- economic development so as to maximize the contribution of fisheries to the achievement of national development objectives especially poverty reduction, food security, creation of employment and rural incomes”.

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Included in the service charter of MoD are the following core activities:

- Fisheries policy formulation and review;
- Fisheries licensing ;
- Management and development of marine fisheries including the Exclusive Economic Zone;
- Management and development of fresh water fisheries;
- Commercialization including formation of fisheries groups for local fishermen;
- Promotion of fish quality assurance, value addition and marketing;
- Development of aquaculture;
- Marine and Fisheries Research;
- Promotion of recreational fisheries.
- Other non-core functions include:
- Facilitation of ice production and cold storage at landing sites;
- Promotion of credit facilitation to fishery sub-sector in liaison with financial Institution;
- Promotion of affordable and safe fishing boats and appropriate gears;
- Promotion of appropriate fishing technology.

6.2.2 Kenya Marine and Fisheries Research Institute (KMFRI)

The parastatal, KMFRI is a State Corporation that was established by an Act of Parliament (Science and Technology Act, Cap 250 of the Laws of Kenya) in 1979 and run by a Board of Management.

The research mandate of KMFRI is defined by article No. 4 of the Science and Technology Act of 1979, Cap 250.

The Institute is empowered to carry out research in Marine and Freshwater fisheries, Aquatic biology, Aquaculture, Environmental Chemistry, Ecological, Geological and Hydrological studies, as well as Chemical and Physical Oceanography.

KMFRI remains semi-autonomous and is contracted through MoD, MCD or other independent groups (such as NGOs) to undertake fisheries research. KMFRI appears to have no direct responsibility for fisheries other than in a research and advisory capacity;

The shift from a provincial to a county system had a considerable impact on the governance structures, in particular the devolution of authority (and governance) and the need to enhance capacity to undertake the fundamental fisheries management activities;

In the new county structure, offshore fisheries remain a responsibility of MoD (Nairobi) and Counties are responsible for fisheries in territorial waters.

The relationship of the other institutions is relatively minor. However, they do have governance roles in fisheries occasionally such as through management of mangroves (KFS and KEFRI), community development and public private partnerships (CDA) and through NEMA for Environmental Impact Assessments (EIAs) related to fisheries.

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6.2.3 The Beach Management Units (BMUs) and Locally Marine Managed Areas (LMMA)

Co-management in Kenya is a concept that was started with the purpose of shifting management from government institutions to a decentralized style in which stakeholders/resource users are involved in decision making. It is considered an "ecosystem approach to fisheries management" that aims to integrate into the overall fisheries management structures, both the "ecosystem" and "human" aspects – it is believed to "offer a viable option for achieving sustainable fisheries utilization". The BMU regulation is an important governance instrument as it is a bottom-up approach embracing communities and all stakeholders who effectively become the stewards of the resources they exploit and are, therefore, involved in the decision making, implementation, and monitoring processes. BMUs also provide a framework for managing fisheries that often are of a trans-boundary or shared nature (only in the coastal zone though).

BMUs are therefore a critical governance tool – application however has limitations as they can only be implemented on the coast (and inland waters) and conceptually are difficult to apply to fisheries beyond territorial waters.

BMU responsibilities include:

- Law enforcement [registration of boats, enforcement of gear regulations and protection of fishing grounds];
- Beach Development [fish bandas and sanitation];
- Collection of fisheries data;
- Conflict Resolution and welfare matters;
- Handling emergencies.

The BMU concept falls within a broader concept of Locally Marine Managed Areas (LMMAs). This is an aspect highlighted by the ReCoMaP State of Coast Report (2009). Typically, the process of implementing an LMMA involves the participation of non-governmental organizations, as well as FiD. In Kenya, a typical scenario is to have a degree of division of labor, with government performing the overall institutional management role, a local NGO supporting local implementation, with a third NGO providing ecological planning and monitoring.

6.2.4 Lake Victoria Fisheries Organization

The Lake Victoria Fisheries Organization (LVFO) has overall responsibility for managing the fisheries and aquaculture sector in the LVB. It is an initiative of the counties that participate in fishing within 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.

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