UNITED REPUBLIC OF TANZANIA

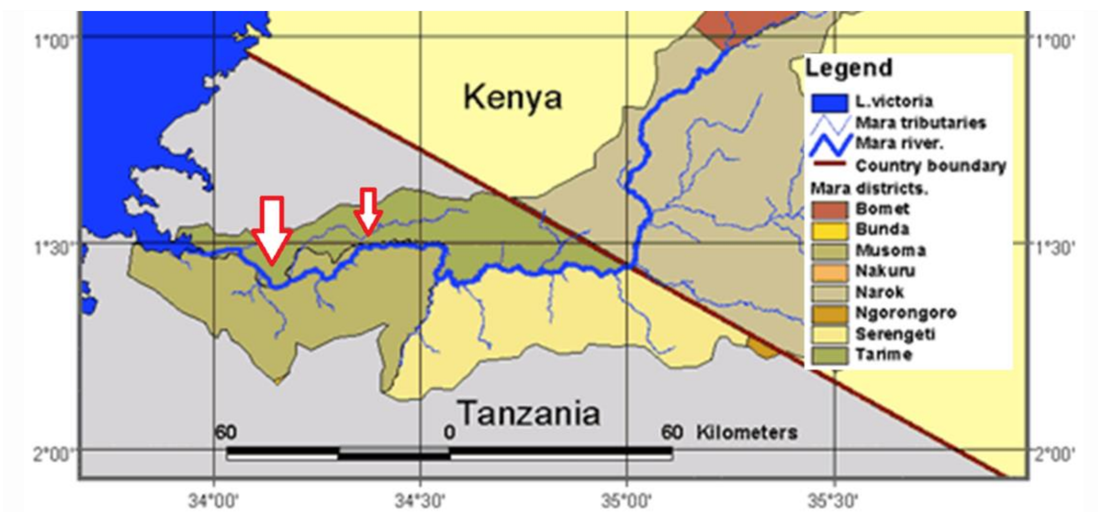
VICE PRESIDENT'S OFFICE
– UNION AND
ENVIRONMENT

THE NATIONAL
ENVIRONMENTMANAGEMENT
COUNCIL
(NEMC)

REPORT

ON THE

INVESTIGATION OF THE SOURCE OF MARA RIVER POLLUTION



SUBMITTED BY
THE NATIONAL SPECIAL COMMITTEE
APPOINTED BY
MINISTER OF STATE IN THE VICE PRESIDENT'S OFFICE – ENVIRONMENT AND UNION

22nd MARCH 2022

EXECUTIVE SUMMARY

The Mara River Basin (MRB) covers a surface area of 13,750 km^2, of which approximately 65% is located in Kenya and 35% in Tanzania (Tarime, Rorya, Serengeti and Butiama Districts). The Mara River Basin is impacted widely by human activities such as deforestation, expansion of agricultural land, settlement, mining, use of fertilizers and excessive livestock keeping. Some of these activities have been the source of adverse environmental impacts such as floods and pollution.

In early March, 2022 there were reports of intense, short-lived floods and pollution in the Mara River catchment that changed the state of water into black color with a bad smell. This event led into aquatic ecological disturbances that included fish deaths along the Mara River. The situation necessitated the Government to act by appointing a National Technical Committee of 11 experts from various public institutions to investigate the source and cause of Mara River pollution and provide recommendations.

The committee commenced by conducting field surveys of the Mara River wetland areas by use of cars and boats for taking in-situ rapid tests of polluted water mostly oxygen levels and pH measurements. When access to some parts of the wetlands proved impossible, and realizing the wetland extended for many kilometres upstream, use of surveillance light craft was undertaken to identify hotspots for pollution by use of cameras and binoculars. A helicopter was later engaged to facilitate collection of river water, well water, soil sediments from riverbed, decaying plants, and dead fish samples. Aerial assessment of the areas where access proved impossible was also undertaken using a helicopter.

Similarly, the affected villages of Kirumi, Ryamisanga, Kitasakwa in Butiama District; Kwibuse, Kwibwe, Bisarwi, Kuruya in Rorya District, and; Nyabichume, Matongo, Mjini Kati (Nyamongo), Bisarwi and Mrito in Tarime District, were subjected to assessment and questionnaires were administered to the residents of these villages adjacent to the Mara River wetland area. These questionnaires were meant to collect data related to livelihood status and opinions in respect of the pollution on the Mara River wetland area. Respondents included farmers, fishermen, livestock keepers, and miners. The

Committee conducted surveys in the company of ward and village leaders of the mentioned villages, who assisted in identifying the respondents and providing further information on Mara River.

The appointed committee observed high intensity blackwater with strong odor covering the upstream and downstream portions of the river from the Kirumi Bridge. Water, sediments, fish and biota samples collected were sent to the laboratories for detailed analysis. Laboratories engaged were the Government Chemist Laboratory Authority (GCLA), National Fish Quality Control Laboratory (NFQCL) and Lake Victoria Basin Water Board Laboratory (LVBWB). Based on the laboratory results, aerial observations and in-situ measurements of the samples, the findings were as follows:

a) No Polycyclic Aromatic Hydrocarbons (PAHs) were detected, implying there was no pollution that was caused by petroleum products in the river. The hydrocarbons detected on the surface of waters within the wetlands were mostly biogenic in nature having been generated from dead and decomposed plants in the area over a period of time;
b) Levels of both (Biological Oxygen Demand) BOD and (Chemical Oxygen Demand) COD, which were high in the samples taken, have direct implications to the depletion of dissolved oxygen;
c) The extreme low levels of Dissolved Oxygen (DO) tested in the river water have largely contributed to the observed deaths of fish that were seen floating;
d) The high load of organic matter seen within the wetland area which, is directly linked to severe depletion of DO, is attributed to decomposed plants biomass (*Papyrus, Typha, Water Hyacinths, etc*.) and cow dung from the large number of herds of cattle pasturing in the higher wetland areas;
e) The committee further observed that the concentration of suspected toxic chemicals tested in the water and dead fish samples were insignificant and were found to be within acceptable levels based on Tanzania Bureau of Standard (TBS) and World Health Organization (WHO) standards;

f) Also, based on in-situ well-water samples tested, most were found to be within the acceptable levels, reflecting that there was no infiltration of polluted water from the river into the nearby wells used by the villagers.

Data from LVBWB monitoring programs show oxygen levels range of (4.00 - 2.90 mg/L) at Kirumi River upstream and downstream the bridge, a site where fish kills have occurred in March 2022. Measured DO levels at the site following the fish kills was recorded as 0 mg/L. The COD was also recorded higher than usual (659.78 - 694.080 mg/L) during the fish kills than the monitored value (58 - 79 mg/L) in 2018 at the same site. This indicates that there is an increased demand and hence consumption of oxygen in the river at the time when fish kills occurred. The increased COD in the river had resulted in oxygen depletion to sub lethal effects to fish.

Potential causes of oxygen depletion could be attributed to inhabiting aquatic biota such as vegetation cover in the wetland, decomposed biomass underneath the water, and organic discharges by large numbers of animals such as hippopotamus inhabiting at the site and higher concentration of livestock in the wetland. Although hypoxia conditions in lowland rivers can be a natural phenomenon, increasing human activities could have resulted in increased events, magnitudes and longevity of the events.

In conclusion, decomposition of organics that were seen covering a large portion of the wetland area, mostly invasive species that multiply much faster than indigenous ones, were the major cause for oxygen depletion, blackening and odorization which was verified by high levels of BOD and COD. Additionally, the existence of a large number of livestock in the Mara River wetland area for most part of the year, over the past few years has been generating significant quantities of waste (mostly cow dung and urine). This waste accelerates the levels of nutrients in water, hence nourishing growth of invasive plant species in the wetland area. This adds organic matter in the water which together with decaying plant materials are responsible for the bad smell in the wetland area as well as black coloration.

The committee therefore, recommends the following as short-, medium- and long-term interventions by the Government:

1. Short-Term Mitigation Measures

(i) Based on the results of the tests undertaken on water samples from the river and water wells in several locations adjacent the wetland, the suspected hazardous chemical substances contained in them do not pose any threat to human health. The committee therefore, recommends for acceptable economic and social activities that are friendly to the environment to continue as it was before;

(ii) Tests on a variety of dead fish undertaken, revealed absence of toxicity, hence may be consumed by the public without causing threat to human health;

(iii) Based on the literature, the blackish water colour and odour is expected to persist for some time because of lack of rains in the area. Rains in the area did not continue after a heavy short spell of rains end of the month of February 2022 that would have washed away and diluted the blackish colour seen in the wetland. Currently, this water may be consumed after some level of treatment;

(iv) The Committee recommends active and effective enforcement of relevant Laws and Regulations governing the wetland and water resources in the area.

2. Medium-Term Mitigation Measures

(i) The Committee recommends Gazetting of the Mara River Wetland Area as a PROTECTED AREA in view of its uniqueness in terms of the large size (More than 423 sq. km), its proximity to the Lake Victoria, as a water source and its proneness to encroachment/invasion from livestock keepers and peasants who are in search of pastures and other resources available in the area. This will strengthen enforcement in the management of the conservation and protection of the wetland;

(ii) The Committee recommends further detailed research in the wetland to determine the available species (flora and fauna) and develop means of eradicating invasive species which, are thriving and expanding daily covering the Mara River surface waters;

(iii) The Committee recommends establishment of a joint conservation programme of Mara River Wetland which, will involve all sectors that have a stake to the wetland; namely Water, livestock, land, environment, natural resources, fisheries and local government authorities.

3. Long-Term Mitigation Measures

The committee recommends establishment of sufficient rangelands across the country to accommodate an increasing number of livestock to reduce pressure on sensitive wetlands and water sources.

ACKNOWLEDGEMENT

The work and report of the National Special Committee would not have been effectively completed without the help and cooperation of many stakeholders who offered their support and resources to make this investigation a success. Foremost, the committee wishes to thank our Almighty God for His Grace and Protection during the whole period of 7-days of field work, receiving and analysing data and report writting to complete this work.

The Committee similarly, wish to extend its sincere thanks and appreciation to the following key persons, who offered their support and resources to search for the cause of water pollution on Mara River. That is:

- General Venance S. Mabeyo, the Chief of Defense Force, for providing staff to command the helicopter;
- SCP Simon N. Sirro, the Inspector General of Police, for securing and providing a helicopter for field surveys of the inaccessible Mara River wetland areas;
- Hon. Ally Hapi, The Mara Regional Commissioner, Mr. Albert G. Msovela, the Mara Regional Administrative Secretary, and Mara Districts Commissioners for the full support provided during the entire period when the Committee was working on this matter;
- Commissioner William S. Mwakilema, Conservation Commissioner of TANAPA for providing the Light Aircraft for initial reconnaissance survey of the Mara River wetland area to map hotspot areas for detailed survey;
- Prof. William Anangisye, the Vice Chancellor of the University of Dar es Salaam, for providing staff as experts on this special Committee;
- Dr. Fidelis Mafumiko, the Chief Government Chemist, for facilitating laboratory tests of samples;
- Dr. Mussa Budeba, the Chief Executive Officer of Geological Survey of Tanzania, for providing geophysical and geological maps of the area;
- Dr. James Mataragio, the Chief Executive Officer, Tanzania Petroleum Development Cooperation for his input on the study of petroleum hosting rocks in the Country, and;

- Dr. George Lugomela, the Director of Water Resources, for analysis of samples from different points of the Mara River.

Lastly but not least, the Committee would like to express sincere appreciation to Captains of the Helicopter Lt. Col. O. J. Makimboka and Lt. Col. G. E. Mwakikyo, Sgt. C. A. Nyakao (helicopter engineer), A/ISP W. M. Wambura (Helicopter logistics) and TANAPA Aircraft Capt. Ramadhani Bakari for flying the Committee through various sites over the whole Mara River wetland area in search of the pollution source and assisting sampling. Furthermore, appreciation goes to our Photographer Mr. Aldimilablis Novatus Mchele, who was always on the helicopter and light aircraft taking photographs for our study.

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LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrometry
BDL	Below detection limits
BOD	Biological oxygen demand
CV-AAS	Cold Vapour Atomic Absorption Spectrometry
DO	Dissolved Oxygen
EIA	Environmental Impact Assessment
EMA	Environmental Management Act
GC-MS/MS	Gas Chromatography and Mass Spectrometry
GCLA	Government Chemist Laboratory Authority
GPS	Global positioning system
ICP-OES	Inductively coupled plasma - optical emission spectrometry
LC-MS	Liquid chromatography–mass spectrometry
LVBWB	Lake Victoria Basin Water Board
NEMC	National Environmental Management Council
NM	Not mentioned
NS	Not specified
PAHs	Polycyclic Aromatic Hydrocarbons
RAS	Regional Administrative Secretary
TAFIRI	Tanzania Fisheries Research Institute
ToR	Terms of Reference
TPHPA	Tanzania Plant Health and Pesticides Authority
TPRI	Tropical Pesticides Research Institute
TSF	Tailings Storage Facility
UDSM	University of Dar es Salaam
VPO	Vice President’s Office

1.0 INTRODUCTION

1.1 Background Information on Global Significant Death of Fish

Globally fish kills is most frequently linked to natural causes such as ecological hypoxia (low dissolved oxygen) or anoxia (no or zero dissolved oxygen), harmful algal blooms (toxic and non-toxic freshwater cyanobacteria, marine dinoflagellates), diseases, extreme or abrupt changes of temperature (e.g., winter fish kills, summer fish kills), salinity or turbidity; floods, black water events (flood events that give the water column a dark tea colour), overturns of lakes and upwelling of the oceans. Mass mortalities of fish can be defined as a sudden and significant death of fish. This is characterized by a large number of fish dying over a short period of time within the defined area. The number of fish killed in specific instances can range from a few thousands to more than one million (Golam, 2014).

The minor and occasional natural causes of fish kills are volcanic eruptions, earthquakes, and meteorite. Human activities are also responsible for a number of fish kills, for examples, accidental spills (e.g., oil), runoff and drainage discharge of pesticides and herbicides from agriculture farm lands into water bodies. In addition, mass killing in the name of recreational fishing may also be responsible for significant fish kills in some countries. Generally, fish kills event is an indicator that the ecosystems health and water quality have been deteriorated. It may indicate that water may have been contaminated with biotoxins (algal blooms) or chemicals (pesticides/herbicides) or microbial pathogens. As a consequence, environmental water may be unsafe for beneficial water usage for a period of time.

Examples of global fish kills include; on 6 January 2011, 2 million fish died as a result of cold stress (Maryland, USA), and red tide was responsible for the death of 22 million fish alone in the Gulf of Mexico, USA in 1986. Red tide is a toxic algal bloom caused by certain marine algae (dinoflagellate, Gymnodinium breve) that turns the sea water red. On December, 2010 black water event and low dissolved oxygen (DO) in Murray River, Victoria killed: > 100 fish species killed. On November, 1987 black water event; low dissolved oxygen concentrations (1.2 mg/L); organic toxins (bark and leaf compounds) in Donkey camp pool, Katherine River system, Northern Territory (NT); killed: 5000 fish and 200 prawns. The killed species include Fish: Arius graeffei, Lates calcarifer, Nematalosa erebi and Prawn- Macrobrachium rosenbergii.

1.2 Mara River Basin

Mara River originates from Kenya and drains into Lake Victoria after running downstream in the Mara Region, Tanzania. The Mara River Basin (MRB; Figure 1) covers a surface area of 13,750 km^2, of which approximately 65% is located in Kenya and 35% in Tanzania (Tarime, Rorya, Serengeti and Butiama Districts) (Kairu, 2008; Tran et al., 2017). Soil type and distribution in the basin are governed by the geology, topography and rainfall. Along with rainfall variability in space, the basin of Mara River is also famous for its rainfall variability in time. The basin has a bi-modal rainfall distribution of which the first major rainfall occurs between mid-March and June and the second and relatively intermittent, rain is between September and December. The rainfall is generally highest on the highlands with a mean annual rainfall value of 1400 mm/year and the lowest in the lowlands with a mean value of 600 mm /year (Tran et al., 2017). The Mara River Basin is impacted widely by human activities such as deforestation, expansion of agricultural land, settlement, mining, use of fertilizers and excessive livestock keeping. Some of these activities have created a lot of negative consequences such as floods and pollution (Tran et al., 2017).

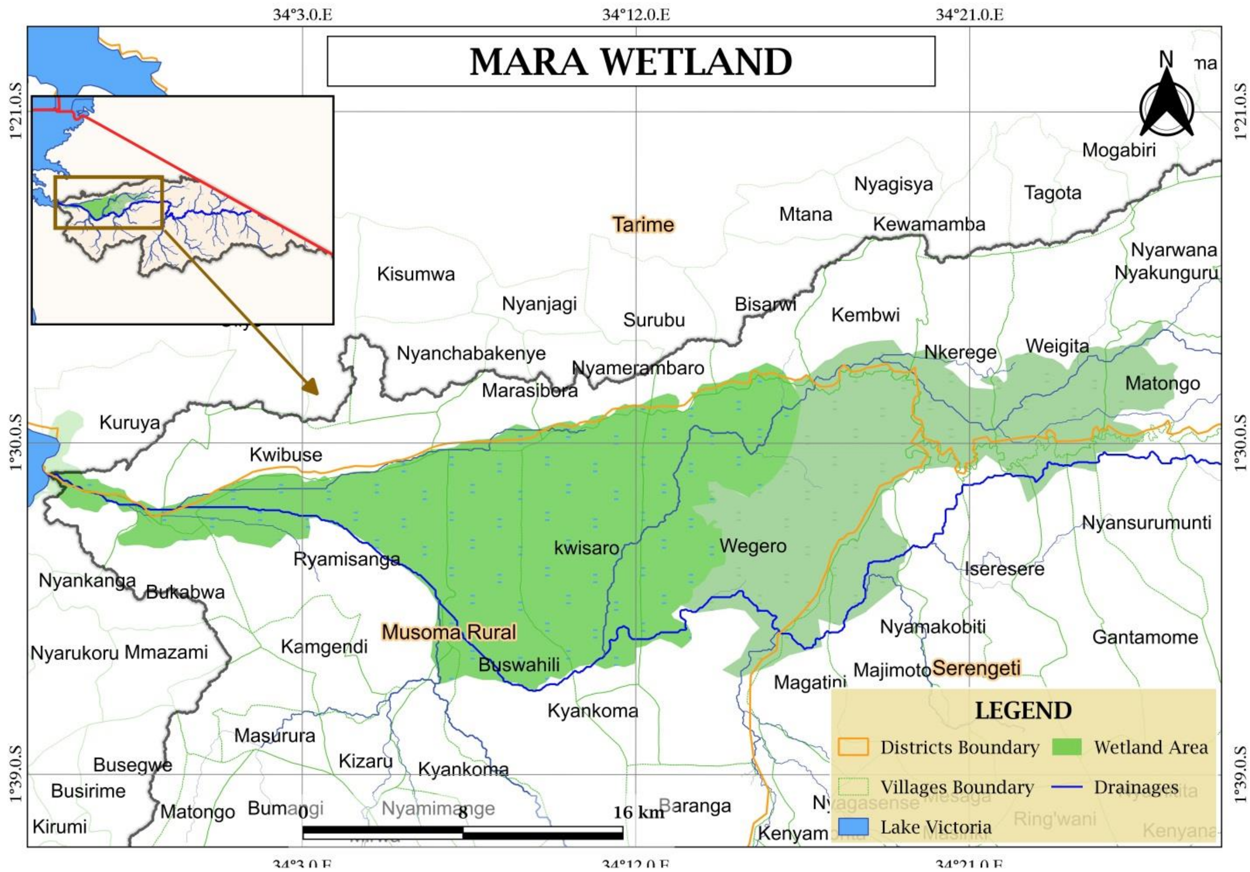

Figure 1: A regional geographical map showing the location of the Mara River catchment in Tanzania. The top left square insert shows the regional setting of the Mara River catchment.

Water shortage, poor water quality and environmental degradation has become a threat to human settlement along the river. Ever-growing population, expansion and intensification of agriculture, deforestation, livestock raising, mining industry, and tourism are the driving forces of water quality and ecosystem problems for Mara River. The basin highlands are favorable for agriculture, pastoralism and wildlife activities, which attract an increasing number of immigrants. This growing population is the root of all anthropogenic activities and resultant pressures exerted on the Mara River Basin land and water resources.

In early March, 2022 there were reports of a huge pollution of Mara River water which changed the water into black color with a bad smell. The occurrence of black color and bad smell were accompanied by fish death. The situation necessitated the Government to act in order to establish a possible source of such unique pollution.

1.3 Inspection Visit by Hon. Dr. Selemani Said Jafo, Minister of State in the Vice President's Office – Environment and Union

On the 12th March 2022, Hon. Dr. Selemani Said Jafo, Minister of State in the Vice President's Office – Environment and Union visited the Mara River after receiving formal reports and complaints from the residents and leaders of Mara Region, especially from Rorya District. The purpose of the visit was to inspect the status or extent of pollution in the Mara River, and the environmental damage associated with the pollution. The complaints were initiated by the observed change of water colour in the Mara River from normal to dark and dead fish floating in the water.

These signs indicated that the river environment was no longer safe. Also, the Social Media reports were already circulating showing photographs and comments, indicating the problem of dead fish in the Mara River (with slight exaggerations). The social media and local politicians in Mara Region were associating the Mara River pollution problem with Mine discharges into the river, to be the source of the pollution.

Based on the raised alarm, the Office of the Vice President decided to send experts from NEMC, GCLA from Headquarters and Zonal Offices in Mwanza. Other experts were from Lake Victoria Basin Water Board from Mwanza and those in Musoma. The Special Committee of experts was led by Director General (NEMC). The composite Special Committee of experts visited the affected area in Mara Region from 9th March 2022, so as to take necessary immediate measures.

Upon arrival to Musoma, the Hon. Minister was informed that, on arrival to Musoma and upon paying courtesy call to the Regional Commissioner's Office, they Special Committee of experts learned that the Regional Secretariat together with Regional Security Committee, led by the Regional Administrative Secretary (RAS), have already taken immediate safety steps by issuing warning messages to the Mara region residents. The residents were advised not to use water from the riser and to stop fishing activities until the Government issues another advise. The Regional Secretariat included also the leaders form Rorya, Tarime, Musoma and Butiama districts.

The Hon. Minister acknowledged the extent of pollution in the river, and decided to take immediate steps.

1.4 Preliminary Assessment Results for Mara River

The site visit by Hon. Minister to Mara Region especially to the affected area allowed the former to acknowledge the fact that the river was in bad conditions. The site visit allowed the Hon. Minister to meet, discus and speak with key stakeholders and residents of the affected area. Among the regional leadership, the Hon. Minister met with the RAS and the Regional Secretariat, Rorya, Butiama, Musoma and Tarime District Secretariats, the latter were led by the respective District Commissioners.

Before addressing the audience, the Hon. Minister received a preliminary report on assessment of the pollution extent in the Mara River, prepared by the Regional Secretariat. The report identified the following key scenarios:

a) It was true that the Mara River has been heavily polluted.
b) Samples of water and fish were being continuously collected and tested which indicated that there was a very low level of dissolved oxygen concentration in the water (to the level of 0 mg/L)
c) The situation was reported to be worse 2 km from the bridge upstream and along the river from the Kirumi bridge up to 500 m into the Lake Victoria.
d) It was reported that, in some areas, the water was neutral (pH = 7.0) despite of black colouration.
e) The water upstream the river, about 1 km from Kirumi bridge indicated highly alkaline conditions with pH = 9.0, indicating high level of pollution in the Mara River.
f) The reports on the deaths of fish reported by Social Media have been highly exaggerated. The photos circulating in social media were not from Mara River.

g) The preliminary report revealed the dead fish were of only one category (Sato). Other fish species like Sangara, Kambale etc., were not among the affected fish.
h) Reports from residents along the Mara River indicated that the black coloration of the water in the river is not a new phenomenon, it has happened several times in the past. The only difference is that this time, the extent of pollution and coloration of water is in excess.
i) Based on preliminary results and observations, the excessive pollution was spotted/identified to be 2 to 4 km upstream of the river from Kirumi bridge. This was revealed from DO, pH data and visual observation where presence of large lumps of black mass were observed floating.
j) No deaths of livestock were reported due to this problem.
k) In Tarime district, where the Mara River originates in Tanzanian Catchment area, the water was reported to be clean and no dead fish were observed.
l) A number of water and fish samples were collected and transported to laboratories in Mwanza (TAFIRI, LVBWB and GCLA) for toxicological analysis and identification of the cause of death for fish.

1.5 Appointment of the National Special Committee for Identifying the Source of Pollution in Mara River

The Hon. Minister insisted on the need for thorough assessment of the true source of pollution in the Mara River. In order to address that matter, the Hon. Minister appointed the national Special Committee to carry out the assessment and submit a report in 7 days from 12^{th}-19^{th} March, 2022 as follows:

S/N	Name	Position	Institution
1	Prof. Samwel V. Manyele	Chairperson	Chemical and Mining Engineering Department, UDSM
2	Dr. Samuel G. Mafwenga	Secretary	Director General, NEMC
3	Dr. Kessy F. Kilulya	Member	Head, Chemistry Department – UDSM
4	Dr. Charles Kasanzu	Member	Geology Department – UDSM
5	Mr. Daniel W. Ndiyo	Member	Director of Chemicals Management (GCLA)
6	Mr. Renatus Shinhu	Member	Director, LVBWB
7	Ms. Baraka Sekadende	Member	Director, TAFIRI
8	Dr. Neduvoto P. Mollel	Member	TPHPA/TPRI
9	Ms. Asnath A. Kauya	Member	President's Office
10	Mr. Yusuph Kuwaya	Member	Office of the Regional Commissioner, Mara
11	Mr. Faraja Ngerageza	Member	Assistant Director – VPO

1.6 Terms of Reference for the Assignment

The Terms of Reference (ToRs) for the Special Committee were to establish:

1) The source of Pollution in the Mara River
2) The cause of Pollution in the Mara River
3) The cause of fish death and other aquatic species
4) Evidence from the local community on the source of pollution
5) Experiences from other countries on such kind of pollution and death of fish
6) Contribution of nature to such kind of pollution
7) Contribution of human activities to the pollution of the Mara River and death of fish
8) Prepare a technical report with recommendations on short-, medium-, and long-term action to be taken by the Government in curbing Mara River Pollution problem.

2.0 LITERATURE REVIEW

2.1 River Water Pollution to the Extent of Blackening and Odorization; Experience from Other Countries in the World

Blackwater events occur in rivers and wetlands world-wide and are natural phenomena caused by flooding that leads to decomposition of organic matters, depletion of dissolved oxygen and alteration of physical-chemical parameters in watersheds (Hladyz et al., 2011; Whitworth et al., 2012). Water appears black due to the release of dissolved carbon compounds, including tannins, as the organic matter decays, similar to the process of adding water to tea leaves (Musat et al., 2008). Under oxygen-less or even anaerobic conditions, the pollutants are converted to black substances such as NH_3-N (ammonia nitrogen), H_2S (hydrogen sulfide), volatile organic acids, and other substances such as Fe, Mn, and organosulfur compounds. All these substances have unpleasant colors and disgusting smells, which are obvious to human senses and perception (Zhang et al., 2017, Liang et al., 2018). Black matter in rivers comprises black metallic precipitates and precipitates of brown, green, or other colors that together form a dark color. In O_2-depleted surface waters, metals precipitate with sulfide and stain the water black (Liang et al., 2018).

In these pollutants the biorecalatrant humus which are dominant fully decomposed organic matter accounts for more than 40% of total organic matter are resistant to further microbial degradation and form black chelates with metal ions. Abundant metals in the earth's crust such as iron (Fe) and Manganese (Mn) are the major blackening ingredients. Li et al. (2010) proposed a transformation of Fe and S in rivers which verified a clear relationship between the transformation and black-odor water (Zhang et al., 2017). To some extent inorganic fertilizer pollutants such as phosphorus and nitrogen highly contribute to river black water odorization (Liang et al., 2018). It has also been reported that, decomposition of lacustrine vegetation such as mangroves can lead into the formation of greasy substances as by products that can impend oxygen inputs into watershed (Ho et al., 2013; Bergamaschi et al., 2011). All these phenomena in turn, cause a sudden depletion of dissolved oxygen in water, which is essential for aquatic organisms that need to breathe underwater, hence death of aquatic organisms including fish.

Liang et al, 2018, reported on a number of rivers with black water with a bad smell in China at different years through their review paper titled; "***Blackening and odorization of Urban Rivers: A Bio-geochemical Process***". In this article a number of rivers are reported to have pollution which caused water blackening and odorization. Numerous black-odor rivers occur in heavily populated areas, thereby severely restricting the sustainable development of cities. More than 80% of urban rivers are contaminated in China, and most of these rivers have turned into black-odor rivers (Zhang et al., 2017). Table 1 summarizes different instances in various parts of the world on fish kills and black river water.

Table 1: Reported fish kills due to Blackwater Events in lakes, ponds, flood plains and rivers (Golam, 2014)

Country	Leading causes	Remarks	Date
Congo and Rwanda	Methane emissions from lakes	Lake Kivu	N/A
India	Low dissolved oxygen (2.3mg/l), higher concentrations of metals (Cd and Cu), pesticides	Yamuna River. Death of fish, species: *Wullago attu*	2001 (August)
Cameroon	Deoxygenation due to methane	Lake Nyosi	1986
Bangladesh	Oxygen deficiency, cyanobacteria	Fish ponds, killed silver carp, tilapia	2002 (April)
Australia	Blackwater event; low dissolved oxygen concentrations (1.2 mg/l); organic toxins from leaf compounds	5000 fish killed, 200 prawns killed	1987 (January)
Australia	Blackwater event, low dissolved oxygen (DO)	Goulburn River; Killed 100 fish	2004 (January)
Tanzania	Upwelling of deep anoxic waters during dry season	Killed fish	1980's
USA	Low oxygen (DO = 0.1-3.7)	Killed 9770 fish	1992 (April-Aug)
Tanzania	Mara River pond, low dissolved oxygen due to hippo paste	Killed fish (experimental)	N/A
Germany	Spills from chemical warehouses	Rhine River; killed 500,000	1986 (January)

Massive and abrupt fish kills is most frequently linked to natural causes such as ecological hypoxia (low dissolved oxygen) or anoxia (no or zero dissolved oxygen) (see Figures below), harmful algal blooms (toxic and non-toxic freshwater cyanobacteria, marine dinoflagellates), diseases, extreme or abrupt changes of temperature (e.g., winter fish kills, summer fish kills), to mention just a few.

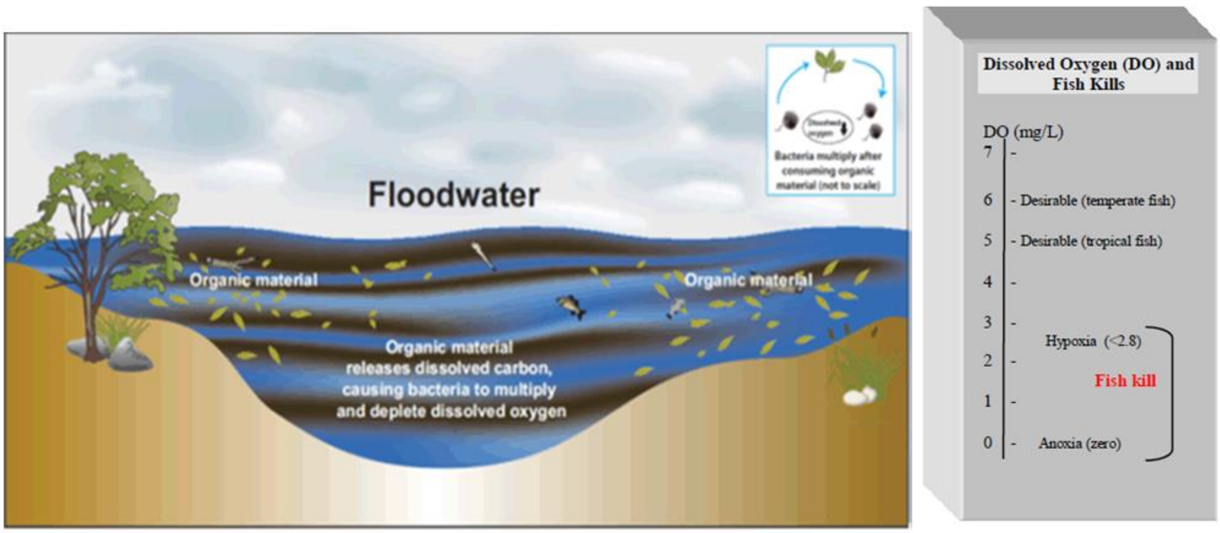

Figure 2: Schematic representations of blackwater events and DO systematics during hypoxia conditions.

2.1.1 Possible Control Measures

Cui et al. (2011) used a composite vertical flow constructed wetland system to strengthen the treatment of black-odor water, thereby proving that wetlands have a significant function in improving the purification of black dirty water. Kutovaya and Watson (2014) studied the application of analytical inspection technology in the monitoring and control of black-odor water and noted that volatile organic sulfide was the main odor-producing substance.

2.1.2 Blackening and Odorization of Rivers as a Bio-geochemical Process

Rivers and lakes serve populations as water resources and drainage systems. They play important roles as domestic, industrial and agricultural water resources. Rivers are also a convenient route of transportation and as centers for aquatic recreation impact on property prices and city development decisions. However, fast population growth often does not keep pace with construction of sewage treatment systems, resulting in visible and smellable pollution of urban rivers. Historically, rapid urbanization has always been accompanied by urban river pollution. In London in 1855, the English scientist and inventor Michael Faraday wrote to The Times after his passage across the river Thames: ‘The smell [of the river] was very bad, and common to the whole of the water; it was the same as that which now comes up from the gully-holes in the streets; the whole river was for the time a real sewer’. More recently, many developing countries have experienced the problem of polluted urban rivers as well. River pollution’s most visible manifestation is a change in color, usually to black, often accompanied by strong unpleasant odors.

2.1.3 Hypoxia and Blackwater Events in Rivers

Hypoxia and blackwater events occur in lowland rivers and wetlands world-wide and can be a natural phenomenon associated with changes in various environmental factors such as rising temperature, floodplain inundation and the subsequent decomposition of organic material (Dutton et al., 2018; Hladys et al., 2011; Whitworth et al., 2012; Howit et al., 2007). Increasing levels of organic materials, nutrients or rising temperature, can trigger acute episodes of hypoxia and water chemistry changes. Hypoxic blackwater events are usually characterized by increased dissolved organic carbon concentrations, black coloured water, low dissolved oxygen concentration (Whitworth et al., 2012; Howit et al., 2007) and reduced pH associated with the release of organic acids and polyphenols from terrestrial organic matter; some of which may be toxic (Gerhke, 1993). Consistent annual cycle of floodplain inundation may result in Blackwater rivers, as opposed to sporadic episodes of hypoxic blackwater (Meyer, 1990).

Fish inhabiting rivers and wetlands where hypoxia occurs may be adapted to tolerate low dissolved oxygen concentrations and variable water quality using a variety of mechanisms ranging from air-breathing to behavioral avoidance (Chapman and Mckenzie, 2009). Many species of fish rise to the surface when hypoxia occurs in an attempt to extract oxygen from the thin surface layer of water that is contact with the atmosphere. However, severe, widespread, or prolonged low-oxygen events may lead to sub-lethal effects and mortalities (Whitworth et al., 2012; Gerhke, 1993; La and

Cooke, 2011; King et al., 2012). Severe hypoxic blackwater events have been documented to cause extensive fish kills in Rivers.

Dutton et al. (2018) showed that organic matter loading from hippopotami is a cause for repeated occurrence of hypoxia in the Mara River, East Africa. Thirteen (13) events were recorded resulting in hypoxia (Dissolved Oxygen 0.04 to 5.5 mg L^{-1}) in Mara River and causing 9 fish kills over 5 years (Dutton et al., 2018). Sub lethal levels were noted as below 2 mg L^{-1}. IN this case, the hypoxia events were correlated with flushing discharge events of standing hippo pools resulting in hypoxia in the downstream.

Data from LVBWB monitoring shows oxygen levels range of (4.00-2.90 mg/L) at Kirumi River upstream and downstream the bridge, a site where fish kills have occurred in March 2022. Measured dissolve oxygen levels at site following the fish kills was recorded as 0 mg/L. Chemical oxygen demand was also recorded higher than usual (659.78-694.080 mg/L) during the fish kills than the monitored value (58-79 mg/L) in 2018 at the same site. This indicates that there is an increased demand and consumption of oxygen in the river at the time where massive fish kills occurred. The increased ecological demand by the river had resulted in oxygen depletion to sub lethal effects to fish.

Potential causes could be attributed to inhabiting aquatic biota such as vegetation cover in the wetland and organic discharges by large numbers of animals such as hippopotamus inhabiting at site. Although hypoxia conditions in lowland rivers can be a natural phenomenon, increasing human activities such as pollution could have resulted in increased events, magnitudes and longevity of the events.

2.2 Subsidy Overload Organic Matter Loading by Hippopotami: Downstream Hypoxia and Fish Kills

Aquatic ecosystems often receive substantial loading of organic matter and nutrients from natural sources in the watershed as well as from anthropogenic discharges. Higher levels of loading can lead to eutrophication, hypoxia, potential loss of diversity, and altered ecosystem functioning. Loading of organic matter and nutrients above a critical threshold results in an overload that switches the system from an aerobic to an anaerobic state. Hypoxia in rivers is uncommon due to the high rates of re-aeration in flowing waters, and it is typically associated with high anthropogenic nutrient loading when it does occur. However, natural hypoxic events have been documented in some tropical rivers during floodplain inundation after seasonal drying, and fishes in ecosystems that regularly become hypoxic display a variety of adaptations to endure hypoxic stress. Although rare, hypoxia in rivers that do not experience hypoxia regularly can be catastrophic for river biota, often leading to widespread fish kills or other alterations in fish community composition and behavior. Frequent, reoccurring hypoxic events are seldom if ever documented in non-floodplain river ecosystems but may be possible under conditions of very high organic matter loading.

Figure 3: Hipopotamus wallowing in a wetland during dry season for thermal regulation of the body.

Numerous wildlife species transport substantial amounts of nutrients and organic matter from terrestrial into aquatic ecosystems. These resource subsidies can have strong effects on recipient ecosystem function. The hippopotamus (*Hippopotamus amphibius*), which has long been recognized as an ecosystem engineer through its grazing and wallowing activities, transports massive amounts of organic matter and nutrients from terrestrial grazing lands into aquatic ecosystems through egestion and excretion. In East Africa, there are an estimated 70,000 hippopotami, potentially loading 52,800 metric tons year of organic matter directly into aquatic ecosystems. Hippopotami are dependent on water bodies for wallowing during the day to thermoregulate and to protect their sensitive hides from desiccation and ultraviolet exposure. As flows are reduced in the dry season, hippopotami congregate in high densities within the remaining aquatic habitat, hereafter called hippo pools. Hippo pools thus become “hot spots” of biogeochemical cycling, fueled by organic matter and nutrient loading from hippopotamus egestion and excretion. Hippopotamus activity in pools may stir and thus aerate and mix the water column. However, without enough aeration, chemical stratification and bottom water anoxia can develop through the decomposition of organic matter and accompanying biochemical oxygen demand (BOD; Dutton et al., 2018).

The Mara River of East Africa flows through the Maasai Mara National Reserve of Kenya and the Serengeti National Park of Tanzania. There are over 4000 hippopotami in the Kenyan portion of the Mara, distributed across an estimated 171 hippo pools along both tributaries and the main channel. The hippopotami of the Mara load over 8500 kg of organic matter into the aquatic ecosystem each day. The river channel is deeply incised, which is fairly typical geomorphology for rivers in this region, so during elevated discharge the river remains within its channel rather than extending onto floodplains. Sufficiently large increases in discharge (>2× above calculated base flow conditions, defined hereafter as a flushing flow) often result in dissolved oxygen (DO) decreases, sometimes to hypoxic levels, in the river channel.

In the Mara River basin, very high rates of organic matter and nutrient loading by hippopotami cause a subsidy overload which results in the rapid development of anoxic bottom waters in hippo pools. This degradation of water quality by hippopotami extends downstream when episodic high flows flush the chemically stratified bottom water and hippopotamus feces out of the hippo pools. These flushing flows carry oxygen-depleted water with high BOD downstream through tributaries and into the main stream Mara River, consuming DO faster than it can be resupplied by re-aeration and by upstream inputs of oxygenated waters. The entrainment of bottom waters also carries the byproducts of microbial activity (ammonium, hydrogen sulfide, methane) into downstream reaches. During flushing flows, downstream reaches experience an immediate and rapid decrease in DO attributable to both mixing and oxygen consumption processes, although the effect is eventually diminished as the water moves downstream and DO returns to normal through re-aeration. The re-suspension and downstream transport of hippopotamus feces with high BOD produces a more protracted reduction in DO that may extend further downstream than the effect of entrainment of oxygen-depleted water alone.

2.3 *Cyperus papyrus* as the Dominant Plant Species in the Mara River Wetland

2.3.1 Historical Background of *Cyperus papyrus*

Cyperus papyrus (Papyrus) is the major dominant wetland plant species in the Mara River basin. It is a tropical wetland plant (sedge) in the plant family Cyperaceae. It can grow up to 6 m high under optimal conditions. Papyrus long culms support a 50 cm diameter umbel inflorescence characterized by hundreds of cylindrical rays radiating from the tip of the culm. This canopy effectively shades the vegetation underneath.

Papyrus is considered native to central and eastern Africa and the Nile valley and is found from southern, central and eastern Africa to Egypt and Ethiopia. Major extensive papyrus wetlands occur in the lacustrine and floodplain wetlands of the White Nile River basin along the shoreline of Lake Victoria (East Africa), the largest tropical lake and second largest freshwater lake in the world.

The unique features of papyrus are its propagation and expansion patterns and the ability to form floating mats. Papyrus mats are a result of intertwining rhizomes that can be secure in relatively firm soils towards the edge of the swamp substratum or may in muddy zones give rise to floating mats whenever the water level rises. Papyrus exhibits high growth rates compared to many other wetland plants, attaining heights up to 3.5–4 m within 4 months thus, high biomass productivity and a higher standing biomass than many emergent macrophytes and terrestrial herbaceous vegetation. (Thenya, 2006). Papyrus has an exceptional ability to respond to nutrients through root recruitment and growth in length as well as biomass accumulation compared to most other vegetation (Kipkemboi et al. 2002).

Papyrus wetlands are important fish nursery areas. Moreover, wetlands support the livelihoods of rural populations such as livestock herders especially during prolonged draughts, fishermen and craft makers. Although fish and birds are some of the animals in papyrus other animals can be found associated with papyrus wetlands such as the swamp antelopes and hippos (Hippopotamus amphibious).

Many wetland plants fit the definition of “invasive plants” as species that rapidly increase their spatial distribution by expanding into native plant communities (Richardson et al., 2000). Wetland plant species roots in ponds, stream edges, floodplains, and wet croplands, and it expands vegetatively via hollow stems that facilitate flotation (Sainty et al., 1998). Such invasive plants not only affect biodiversity and ecosystem functioning but also human use and enjoyment of wetlands.

Invasive plant species in Mara river basin impacts the ecosystem functions both directly and indirectly. Direct impacts involve increased productivity that consequently increases litter breakdown rates which alter nutrient regimes, and either increase or decrease flammability. Indirect impacts concern associations with microorganisms such as bacteria and mycorrhizae and larger invertebrate and vertebrate animals. *Tamarix* spp. also growing as invasive in the Mara river basin contribute to the down-cutting river flow channels, resulting in narrow, deep channels that reduce the ability of river to meander and flood. The ultimate effect is to inhibit the natural regime of overflow pulsing (Ellis et al., 2002). At the same time, increased little density increases fire frequency and intensity (Cox 1999), the condition observed in Mara river basin as well. Moreover, when flooding occurs, sediments resulting from plants litter are both scoured and deposited along the basin or carried into the lake (Lake Victoria).

Invasive species might be one of the greatest threats to the long-term health and sustainability of Mara river basin because of their excessive water consumption due to their high transpiration rates. This poses a significant threat to water security, particularly in water-scarce areas. The impacts are devastating during drought, and this is a major threat to irrigated agriculture and animal watering.

2.3.2 Some Dominant Invasive Plant Species in Mara River Wetland

Figure 3 shows some dominant species observed in Mara River, which are known to be invasive and which are covering most the wetland, leading intensive decomposition underneath the water and mat.

Cyperus papyrus **(Family Cyperaceae; Common name Papyrus)**

Papyrus inflorescens

Eichhornia crassipes (Family Pontederiaceae; Common name water hyacinths)

Typha latiflolia (Family Typhaceae; common name Typha)

Acacia mearnsii (Family Mimosoideae; common name black wattle)

Figure 4: Some dominant invasive plant species in Mara River wetland.

Figure 5: C. papyrus plants showing different growth stages with their associated plants.

2.4 The Challenge of Water Hyacinths in Rivers

Water hyacinth is a free-floating and flowering invasive aquatic plant which has spread mainly to the tropics and subtropics. The reproduction systems of water hyacinth are both sexual and asexual reproduction. The invasive plant doubles itself within 5–15 days. The most favorable conditions for the optimum growth of water hyacinth are nutrient-rich water, temperature ranges from 28°C to 30°C, pH value between 6.5 and 8.5, salinity < 2%, 20 mg/L N, 3 mg/L P, and 53 mg/L K (Segbefia, 2019).

2.4.1 Effects of Water Hyacinths in Rivers and Lakes

Water hyacinth is a type of invasive floating plant found in water bodies across the world. These invasive species block the sunlight reaching and oxygen level in water systems, which results in damaging water quality and serious affecting various life-forms in the ecosystem.

Water hyacinth is a perennial, free-floating aquatic plant native to tropical regions of South America, and now present on all continents except Antarctica. Plants rapidly increase biomass and form dense mats. Water hyacinth can completely cover lakes and wetlands, outcompeting native aquatic species, reducing oxygen levels for fish, and creating ideal habitat for disease-carrying mosquitoes. Lake Victoria, Africa, and the water-ways of Papua New Guinea are prime examples where massive populations have limited transportation and fishing, and increased the incidence of diseases.

2.4.2 Growth Characteristics for Water Hyacinth

Water hyacinth has a reputation for its formidable growth rate, a major factor in its success as a weed. The following statistics quoted by Gopal (1987) are an indication of what can happen under favorable conditions of climate and nutrient availability:

a) sevenfold increase in spread in 50 days (India);
b) edge of the mat extends by 60 cm per month (USA);
c) 2 plants can multiply to 1,200 in 120 days;
d) 1 plant can multiply to 65,000 in a normal spring season (Louisiana);
e) surface area increases by an average of 8% per day (USA);
f) the cover can double every 6.2 days;

g) 50% increase in weight can occur in 7 days

2.4.3 Negative Impacts of Water Hyacinth on Ecosystem Services

a) Limiting social benefits that people obtain from an ecosystem.

b) It significantly affects the lake hydrology by increasing the evapotranspiration of water bodies.

c) It creates a favorable environment for the production of snails and mosquito that cause diseases like Bilharzia and malaria.

d) The mat of water hyacinth affects recreation and tourism facilities in large water bodies, impacts fishing, irrigation, and hydropower infrastructures in water bodies infested by the nuisance weed, water hyacinth.

e) Water quality can be affected by the invasion of water hyacinth.

f) Large infestations of water hyacinth can prevent river transport, fishing, damage bridges, and clog dams.

2.4.4 Methods of eradicating or controlling water hyacinths

Table 2 summarizes the methods used for combating the invasiveness of the water hyacinths.

Table 2: Methods used to eradicate water hyacinths

The physical (mechanical and manual) method	Employed by directly harvesting, cutting, and removing the plant using machines or manual removing by hands and hand tools. Mechanical removal requires the purchase of harvesters, many of them too costly for most of developing countries. Manual removal requires a large labor force; one has to consider the means to pay for this operation. Manual removal demands a high labour force but, if systematically implemented it may be of great value to reduce a moderate stand of the weed. Mechanical removal is more effective in highly infested areas, but here some harvesters would be needed plus fuel and maintenance costs of the machinery.

	Physical removal poses a serious problem with the mass of water hyacinth removed. It is true that the mass may be used either for mulching in perennial plantations.
Biological methods	Involve applying arthropods and pathogens on the infested areas. Arthropods feed the leaves of water hyacinth but pathogens make the plant infected by diseased and finally decompose by bacterial actions. It is well known that biological control is one of the most successful methods to control water hyacinth. The method, practised for example successfully in Australia through the regular release of the weevils Neochetina eichhorniae and N. bruchi, and the moth Sameodes albiguttalis, has been recently adopted in some countries of Latin America and Africa and it is expected to have the same impact as in Australia. However, in many countries the water bodies present very heavy infestations in different sites (fish landing areas, docks, hydroelectric power stations, rivers and dams). In nearly all cases institutions and agencies working on water hyacinth control rate biological control as a key component in control programs. The most popular bioagents have been the weevils Neochetina spp., but little has been done with Sameodes albiguttalis. In many cases where the bioagents were to be introduced difficulties were faced because not every institution working with these bioagents is able to provide sufficient number of the insects and sometimes the distance is too great to bring the insects into the country.
Chemical control	Chemical (herbicides and pesticides), which either conventional or nonconventional can be applied directly or indirectly on the infested areas to eradicate or reduce the growth of the weed. Through the use of certain herbicides such as 2,4-D or glyphosate, seems to be an economically feasible option in some countries, but not in others with less economic development. In addition, in many countries, public opinion is strongly against the use of chemicals in water, which is used for drinking purposes.

NB: Applications of any of these herbicides should be made in specific infested sites, but never in overall application to the whole infested area to avoid a depletion of water oxygen due to rapid incorporation into the water of the destroyed water hyacinth mass. When to implement any of these methods and how to combine them with biological control? These questions may be raised but unfortunately may be left unanswered.

As stated in Table 2, it is possible that these insects might undergo some sort of adaptation or genetic change which would allow them at a later stage to attack other plants. In fact, when we tested adult weevils in the laboratory, they fed on banana, cabbage, but they were not capable of reproducing on these plants.

2.4.5 Mechanical Options for the Control of Water Hyacinth

The relevance to Mara River of the three main categories of control, physical (manual and mechanical), are discussed in Table 3, together with preventative measures that can be taken.

Table 3: Mechanical options for controlling water hyacinths

Method	Description
Mechanical control	Mechanical control has the advantage that it is environmentally benign, providing that water hyacinth is removed from the water before it is destroyed. It can then be utilized for mulch, compost, etc. or destroyed by desiccation or burning. The problem is to remove the water hyacinth.
Manual methods	Manual removal of water hyacinth with simple hand tools is probably the most widely practiced method of control used in developing countries. It can involve rakes, booms and boats to collect, remove and extract the weed from waterways. It is a very labor-intensive method of control but it can be practical for small lakes, narrow streams or canals and for removing small infestations on large water bodies. Manual control is impractical for large water bodies and is not, therefore, appropriate for the lagoons and marshes in the Lower Shire, except to clear small areas around landing beaches and in the fishing grounds for setting nets.
Floating barriers	Barriers can be used to accumulate floating clumps of water hyacinth to prevent the weed from reaching, for example, water intakes and sluices on dams and barrages. Water hyacinth has to be removed at regular

	intervals to avoid damage to the floating barriers. There is little or no practical application for this method of control in the Lower Shire but it might have utility for the Liwonde Barrage.
Mechanical harvesters	Many mechanical devices have been developed for removing water hyacinth from water. They are usually mounted on floating platforms and consist of belts, cutters, forks, etc. to remove the weed from the water after which it is ejected onto the bank, placed in barges, transported on conveyor belts, with or without crushing to remove excess water. Water hyacinth is an easier target for mechanical control and reliable equipment is available, but at a high price.

2.4.6 The Administrative challenges:

a) Currently, the expansion rate of water hyacinth is too severe which requires coordination of all stakeholders to control it.

b) The science of water hyacinth management is known, but the knowledge on how to apply the integrated water hyacinth control approaches is challenging.

2.5 Decomposition of Organic Matter

The process of decomposition — the breakdown of raw organic materials to a finished compost — is a gradual complex process, one in which both chemical and biological processes must occur in order for organic matter to change into compost.

Decomposition of organic matter is controlled by several factors including water temperature, pH, dissolved oxygen concentration, and the chemical composition of the organic matter to be decomposed. Bacteria and other organisms of decay decompose organic matter work favorably at a temperature ranging from 30 to 35 degrees. Microorganisms for decomposition (i.e. bacteria) function better at the pH ranging from 7 to 8.5. When the pH is lower, decomposition by fungi is favored over that by bacteria — especially at pH less than 6.

Organic matter that contain higher nitrogen content are easily decomposed than organic matter of lower nitrogen content. One reason is that organic matter of higher nitrogen content contains less fiber, but an equally important reason is that microorganisms of decay need nitrogen to produce their cells (biomass).

In the water column and surface layer of sediment, there is usually high concentration of dissolved oxygen (aerobic conditions), but at a depth of a few millimeters into the sediment, microbial activity depletes molecular oxygen (anaerobic conditions). It is important to note that when organic matter decomposes, its components do not decompose at the same rate. Proteins, fats, and simple carbohydrate compounds decompose faster than fibrous components such as cellulose, lignins, tannins, and waxes.

The majority of an organic residue will decompose within a few weeks or months, but some of the material will persist for years. Moreover, the microorganisms of decay excrete organic compounds, and when they die they become organic matter. The excretions of microorganisms and resistant remains of decomposing organic matter form large complex molecules of humic substances. Organic matter analogous to humus also accumulates in the sediment of water body. This material decomposes very slowly as compared to fresh organic matter that deposits on the bottom.

3.0 THE LEGAL MANAGEMENT OF MARA RIVER WETLAND

Mara wetland is located in the southwest of Mara River Basin and it covers the area of 390 km^2 in Mara region.[1] Despite being considered as an important Bird and Biodiversity area, this wetland does not have any protection status. This wetland of significant biological and economic importance to the people of Mara region and nation at large. The wetland is resourceful in its natural resources for agriculture, fishing, water supply and animal grazing. The wetland provides ecosystem services in terms helping to clean the air, minimization of natural calamities such floods and landslides. The utilization of natural resources from the wetland such as unregulated water abstraction, crop farming, animal grazing, water discharge from industrial and mining activities has led into distraction of this wetland. This short article is therefore going to assess how laws regulating an aspect which utilizes resources of Mara wetland can adequately protect the wetland.

3.1 Sectoral Laws

The laws regulating economic activities which utilizes natural resources of Mara Wetland includes; the Water Resources Management Act, 2009, the Wildlife Act, 2009, the Village Land Act [Cap. 114 R.E. 2019], the Land Act [Cap. 113 R.E. 2019], the Fisheries Act, 2003, the Irrigation Act, 2013, the Animal Diseases Act, 2003, the Livestock Identification, Registration and Traceability Act, 2020, the Grazing-Land and Animal Feed Resources Act, 2010, Mining Act [Cap 123 R.E. 2019] and the Environmental Management Act, 2004.

The Water Resources Management Act, 2009 is the main legislation on water management in the country. The objective of the Act is to ensure the nation's water resources are protected, utilized, developed, controlled, managed and conserved in fundamental principles of water management. The Act has arranged management of water by assigning management into different bodies including the Minister, National Water Board, Basin Water Boars, Catchment and Sub-Catchment Water Committees

[1] http://pdf.usaid.gov/pdf_docs/PA00SZ1C.pdf

and Water users' associations. Water sources have been classified and restrictions on water consumption depending availability in the source. The Act has established water use permit to control consumption. The Act manages water pollution through issuing of discharge permits, the permits which requires one to treat their water into required standards before emitting into the environment including discharge into water bodies. The Act creates different offenses for unpermitted water use, pollution and destruction of water sources. Section 37 of the Act allows for establishment of protected areas after consultation with institutions responsible for land management. The Act has made a put a responsibility to the Director of water resources to carry out strategic environmental assessment for water major projects and any duty to carry out environmental impact assessment for specific development has been tasks to developers of those development whether public or private.

3.1.1 Livestock Sector

The sector has three pieces of legislation which are worth mentioning in the protection of the Mara Wetland; these are the Animal Diseases Act, 2003, the Livestock Identification, Registration and Traceability Act, 2020, the Grazing-Land and Animal Feed Resources Act, 2010. The Animal Diseases Act, 2003 provides for measures to check and handle livestock diseases outbreak by regulating disposal of carcasses, animal produce, feed and handling of animal wastes. The Act restricts grazing within 200 Meters from the public road and requiring export permit for animals, animal product and fish and compulsory identification of animals but rest of the provision are aimed at curbing spread of animal diseases by restricting infected animals and their products within infected area.

The Grazing-Land and Animal Feed Resources Act, 2010 provides for provision of grazing land demarcated in accordance with ***the Village Land Act [Cap. 123 R.E. 2019*** and ***the Land Use Planning Act, 2007*** with attention to vegetation management, livestock management and marketing infrastructure as well as environmental conservation and development for water sources for livestock use. The Local government authorities have been tasked to prepare grazing-land inventory, trend conditions and land use planning for sustainable grazing-land sustainability. Inspectors have been given power to order livestock owners to harvest so as to fit the grazing-land. Lastly, ***the Livestock Identification, Registration and Traceability Act, 2020***. The Act establishes the National Livestock Identification, Registration and Traceability System to identify, register and control movements of livestock. Abattoirs, meat processing plants, livestock markets and quarantine facilities will be committing an offense if they will deal with livestock without having established the source of livestock they have dealt with and not submitting such information to the local government authority within 72 hours.

3.1.2 Fishing Sector

In the Fishing Sector we have fishing activities; aquaculture and fish processing plants are governed by ***the Fisheries Act, 2003*** and its Regulations. The Act has tasked the Director of Fisheries to ensure aqua culture development is ecologically sustainable by allowing rational use of resources, aqua culture does not negatively affect livelihood, culture and traditions local communities and local community has access to fishing ground. Section 53 of the Act has mandated all development activities to undergo EIA prior to their commencement. Thus all impacts of aqua culture and fish processing activities will be checked prior to their actual happening. These impacts include effluent discharge, nutritional addition which may be consumed by both wild fish and plants including papyrus.

3.1.3 Agricultural Sector

On Agricultural Sector we may have impacts from excessive water consumption for irrigation, fertilizers and pesticide effluents into the wetland. ***The Irrigation Act, 2013*** has put up a requirement to conduct EIA and obtain construction permit before engaging in developing an irrigation scheme. An irrigation scheme is required to return treated water into the source after irrigation. Where an EIA has been conducted and water is being treated before discharge into the source we will be spared from excessive water use for irrigation and no fertilizers and pesticides will be introduced into the wetland.

3.1.4 Environmental Management Framework

The Environmental Management Act, 2004 as amended in 2016 and 2021 provides for general and overall management of environment in the country. Significant provisions on the protection of the wetlands include: requirement to carry EIA for all scheduled investments which will be conducted in water bodies or in lakeshore and cost lines; creation of offenses in respect of water pollution, legal mandate to declare any area as protected or sensitive so as to restrict its accessibility to the public. Other provisions which could useful in water protection include creation of local government authorities for environmental management from the village level to regional, designating other public officers with environmental studies background as environmental inspectors so as to give them power to enforce the Act and issuance of Protection Orders to stop activities which are detrimental to the environment. Sections 47 and 51 which allow for declaration an area of land as an Environmental Protected Area and Environmental Sensitive Area respectively. Section 47 applies for an area which has no protection status as it is the case for Mara Wetland while section 51 applies to an area with an existing protection status but requires more protection.

3.1.5 Wildlife Sector

On the Wildlife Sector we have the ***Forest Act [Cap. 323 R.E. 2002]*** and ***the Wildlife Conservation Act, 2009***. The later bans grazing in the ***wetland reserve*** and thereby creating an offense punishable with up to five years of imprisonment, hunting in the wetland reserve is restricted unless by permission of the Director of Wildlife. Digging and construction in the ***wetland reserve*** is restricted. The keyword, however, is ***wetland reserve*** not just ***any*** wetland. I am afraid the restrictions do not apply automatically to Mara wetland.

3.1.6 Mining Sector

The Mining Act [Cap. 123 R.E. 2019] among other things it subject medium and large mining activities into the ambit of *the Environmental Management Act, 2004* by making EIA a mandatory requirement before a Mining License is issued and the same are subjected under the ambit of the Water Resources Management Act, 2009 by requiring Mining tailing to be dumped into tailings storage facility (TSF) which have to be approved by the Director of Water Resources. An approved TSF assures as that fluid mining wastes don't enter water bodies including Mara Wetland. The act has exempted Primary Mining License from the ambit of ***section 81 of the Environmental Management Act, 2004*** thereby creating a loophole for Mining Firms/Individuals to pollute the environment from their mining activities

3.2 International Agreements

Mara wetland stem from Mara river which originates in Kenya as such one would expect International regulation of this River. However, neither the Wetland nor the River has obtained international protection. Kenya and Tanzania governments have started to accord this River the accolades it deserves; Resources Ministers signed an agreement for joint management of Mara River. The Permanent Secretaries of Ministries responsible for water and environmental in the two countries sat in the Joint Steering Committee of Permanent Secretaries. 15th of September is celebrated as Mara Day aiming at sensitizing the protection of the River. This year's event will be 11th celebrations.

Ramsar Convention on Wetlands of International Importance 1971 entered into force on 21st December 1975, Tanzania ratified the Treaty on the 13th day of August, 2000. Wetlands to qualify for recognition they should be wetlands of international significance in terms of ecology, botany, zoology, limnology or hydrology. In Tanzania there are only four Ramsar Sites namely; Lake Natron with catchment area of 932 km^2, Malagarasi-Muyowosi with the size of 11,430 km^2, Kilombero Valley with an area of 7,967.35 km^2 and Rufiji-Mafia-Kilwa Ramsar Site covering 5,969.08 km^2.

The Mara wetland needs protection status to rescue the catchment. As of 2005 there were satellite lakes in the wetland which have now disappeared together with their ecosystem; such lakes include lake Kirumi (Chande, 2008) which has been replaced by papyrus. ***Section 47 of the Environmental Management Act, 2004*** would provide a suitable protection.

4.0 PLAN OF ACTION AND METHODOLOGY ADOPTED BY THE NATIONAL SPECIAL COMMITTEE

4.1 Study Area

Mara River discharges its water and sediments into Lake Victoria. The river basin lies between 35.78° E and 0.43° S in the southwest of Kenya and 33.78° E to 1.48° S in northeast of mainland Tanzania. The river is shared between Kenya and Tanzania. The coverage area of its basin is about 13,750 km^2, where 65% belongs to Kenya and the remaining 35% is located in Tanzania (Fig. 1). The River meanders through large-scale agriculture lands and crosses the Maasai-Mara and Serengeti National Parks in Tanzania and Kenya (Edgar 2016).

4.2 Source of Pollution at the Mara River

The Special Committee employed several means in order to assess and establish the source of pollution in the Mara River. These approaches included survey of the river by physical visit to accessible areas or by using Vehicles, Boat Engines, Charter engine flight and Helicopter. The purpose was to get access and identify the source of pollution in the Mara River.

4.3 Cause of Pollution, Source of Fish Death and other Species in the Mara River

The Special Committee employed various means in order to determine the cause of pollution included physical visit along and within Mara River, collection of various types of samples at different hot spot points for laboratory analysis

4.3.1 Samples and Sampling Sites

To accomplish this study different working materials were collected which include water (river and well water), sediments and dead fish samples. Sampling sites were selected randomly. In order to cover the polluted side of the river, fourteen sampling sites were selected for water samples, two sampling sites were selected for sediments, whereas samples for water quality parameters analyses were collected from 6 sampling sites, Fish samples were two (one live and 1 dead). Samples for decayed plant was one sample.

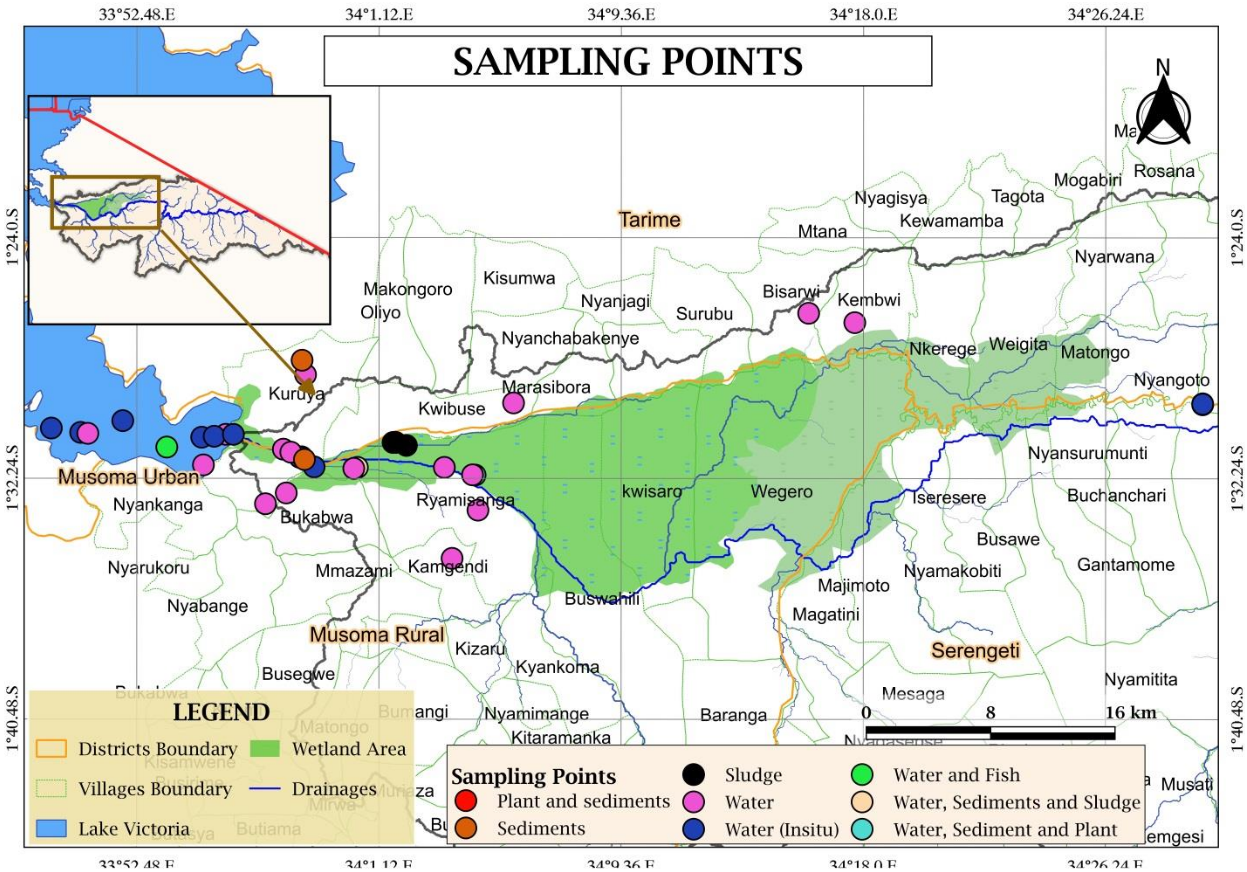

Figure 5: A map showing the sampled localities within the Mara River catchment.

Measured parameters in fish and plant samples were Arsenic, lead, cadmium, mercury and pesticide residues. The selected sampling sites were Kirumi Bridge, Ryamisanga, Downstream (5 samples), North Mara downstream of a discharge point, Fish cage, River junction and wells from 8 randomly selected from 7 villages (Kirumi, Kembwi, Ryamisanga, kwibuse, Kitasakwa, Bisarwi, Kuruya). Respective location name, GPS coordinates, and observed site characteristics were taken accordingly.

2.3.2 Experimental Methodologies

Water quality parameters were measured in in situ and in laboratories in which measurements were performed by gravimetric, trimetric, hach mult-parameters, turbidity meter, GC-MS/MS, LC-MS, Spectrophotometry and Atomic Absorption Spectrometry (AAS).

4.4 Evidence from the Local Community on the Source of Pollution

The Special Committee prepared and administered structured questionnaires for collection of responses from local communities who are involved with agricultural activities particularly fishing, farming and livestock keeping. In the implementation of such structured questionnaire, the Special Committee visited the following villages: 23 respondents from Wegero Village, Buswahili Ward in Butiama District; 15 respondents from Matongo Village, Matongo Ward in Tarime District; 14 respondents from Kuruya Village, Komuge Ward in Rorya District; 16 respondents from Kwibuse Village, Kisumwa Ward in Rorya District; 15 respondents from Kirumi Village, Bukabwa Ward in Butiama District; and 10 respondents from Ketasakwa Village, Bwiregi Ward in Butiama District.

The Special Committee also prepared and administered the questionnaires for collection of responses from local communities who are involved in Artisanal Small Scale Gold Mining on which; the Special Committee visited interviewed 18 respondents involved mining activities particularly Gold Processing and extraction from Nyabichume and Mjini Kati Villages, Matongo Ward in Tarime District; Five (5) respondents from Mrito Village and Five (5) respondents from Kerende Village both from Kemambo Ward in Tarime District.

4.5 Experiences from other Countries on Such Kind of Pollution and Death of Fish

The Special Committee consulted a series of literatures in order to establish evidence if the same scenarios had happened both globally and locally. The findings helped to make comparisons on current status of the Mara River and the existing information in the literatures.

4.6 Contribution of Nature or Climate Change to such Kind of Pollution

The Special Committee assessed the overview on the impact of climate change to Mara River in relation to pastoralism activities by gathering information direct from the local community. Moreover, the Special Committee assessed the number of livestock statistics in the respective area.

4.7 Contribution of Human Activities to the Pollution the Mara River and Death of Fish

The Special Committee conducted a survey to Mara River by physical visit on accessible areas or by using Vehicles, Boat Engines, Charter engine flight and Helicopter. The purpose was to get access and identify contribution of human activities to the pollution and substantial amount death of Fish.

5.0 ANALYSIS, RESULTS AND SYNTHESIS

5.1 Establishment of Hot Spots by Aerial Survey

On the 15th March, 2022, the representatives of the Special Committee surveyed the Mara River using Charter engine flight in order to get access and identify the source of pollution. Survey involved establishment of water status in the river, taking coordinates for each identified hot spot and allocation of each hop spot area to the respective village. The water of the river and respective coordinates are as follows.

Table 4: Hot spots relating to Mara River pollution

S/N	Latitude	Longitude	Location Name	Water Status
1	Latitude: 1° 30' 53.13"	Longitude: 33° 56' 8.72"	River Mouth	Black water
2	Latitude: 1° 31' 41.98"	Longitude: 33° 58' 25.00"	Krumi Bridge West	Black water
3	Latitude: 1° 31' 42.50"	Longitude: 33° 58' 40.61"	Krumi Bridge East	Black water
4	Latitude: 1° 31' 54.51"	Longitude: 34° 0' 39.97"	Converging channels	Left - Black water; Right - Normal water
5	1° 31' 55.90"	34° 4' 7.12"	Wetland burning	Black water
6	1° 32' 22.35"	34° 6' 33.32"	Centre of Ryamisanga and Marasibora	High intensity Black water
7	1° 33' 5.81"	34° 7' 4.19"	Centre of Ryamisanga and Marasibora	Mix of black and normal water
8	1° 33' 21.43"	34° 8' 32.11"	Centre of Wegero and Marasibora	Normal water
9	1° 31' 24.19"	34° 11' 20.50"	North of Wegero	Livestock Tarime side
10	1° 29' 48.72"	34° 13' 18.73"	South of Surubu A	Livestock and settlement
11	1° 29' 27.25"	34° 13' 40.64"	South of Surubu B	Livestock and settlement
12	1° 28' 50.44"	34° 13' 45.36"	South of Surubu C	Livestock and settlement
13	1° 29' 30.19"	34° 14' 3.50"	South of Surubu D	Another Black Water
14	1° 31' 26.69"	34° 14' 45.35"	North East of Wegero A	Livestock and settlement

15	1° 32' 0.70"	34° 14' 29.17"	North East of Wegero B	Livestock and settlement
16	1° 33' 11.51"	34° 14' 23.77"	North East of Wegero C	Livestock and settlement
17	1° 31' 59.65"	34° 17' 11.30"	North of Magatini Village	Normal water and fishing
18	1° 30' 3.07"	34° 21' 37.93"	Matongo settlement West of TSF for NMGM - A	Normal Water
19	1° 30' 41.67"	34° 24' 1.40"	Matongo settlement West of TSF for NMGM - B	Normal Water
20	1° 29' 12.37"	34° 28' 58.67"	Artisanal miners - Nyangoto Village	Normal water
21	1° 28' 39.01"	34° 28' 58.14"	TSF for NMGM - Matongo Village	Normal water
22	1° 30' 3.91"	34° 31' 4.73"	Upstream Discharge for NMGM TSF	Normal water

5.1.1 River Mouth to Lake Victoria

This area is the entrance of Mara River to Lake Victoria found between Latitude: 1° 30' 53.13" and Longitude: 33° 56' 8.72. The water at and along the area are with Black Colour.

Figure 6: Different photos showing status of water at the Mara River mouth.

5.1.2 Kirumi Bridge

This area is found between Latitude: 1° 31' 41.98" and Longitude: 33° 58' 25.00". The water at and along the area are with Black Colour.

Figure 7: Different photos showing status of water at the Kirume Bridge.

5.1.3 Converging Channels

This is the area where the Mara River is separated into right and left channels and is found between Latitude: 1° 31' 54.51" and Longitude: 34° 0' 39.97". The water status is Black to Left channel and Normal to the Right.

Figure 8: Different photos showing status of black water at the left channel of Mara River.

5.1.4 Point Between of Ryamisanga and Marasibora Village

This area is located between Ryamisanga and Marasibora Village and it is found between Latitude: 1° 32' 22.35" and Longitude: 34° 6' 33.32". The water at and along the area are of very high intensity of Black Colour.

Figure 9: Different photos showing status of high intensity black water at the point located between Ryamisanga and Marasibora Village.

5.1.5 Point Between of Ryamisanga and Marasibora Village

Another point located between Ryamisanga and Marasibora Village which is found between Latitude: 1° 33' 5.81" and Longitude: 34° 7' 4.19" North of Mara River. The water at and along this area is of mix of black and normal colour.

Figure 10: Different photos showing status of mixed black and normal colour at another point located between Ryamisanga and Marasibora villages.

5.1.6 Point Between of Wegero and Marasibora Village

This point is located between Wegero and Marasibora village and is found between Latitude: 1° 33' 21.43" and Longitude: 34° 8' 32.11". The water at and along this point is of normal colour.

Figure 11: Different photos showing status of normal water colour at point located between Ryamisanga and Marasibora village.

5.1.7 Point South of Surubu Village

This point is located at the Southern part of Surubu Village and is found between Latitude: 1° 29'30.19" and Longitude: 34°14'3.50". The water at and downstream along this point is of black colour.

Figure 12: Different photos showing status of water with black colour located at the Southern part of Surubu village.

5.1.8 Various Point with Normal Water to the North of Mara River

There are several points with normal water towards North of Mara River located at between Latitude: 1° 31' 59.65" and Longitude: 34° 17' 11.30" North of Magatini Village; Latitude: 1° 30' 3.07" and Longitude: 34° 21' 37.93" and Latitude: 1° 30' 41.67" and Longitude: 34° 24' 1.40" Matongo Village Settlement West of TSF for North Mara Gold Miming; Latitude: 1° 29' 12.37" and Longitude: 34° 28' 58.67" Matongo Vilage; Latitude:

1° 28' 39.01" and Longitude: 34° 28' 58.14" TSF for North Mara Gold Miming; and Latitude: 1° 30' 3.91" and Longitude: 34° 31' 4.73" Upstream Discharge for North Mara Gold Miming TSF point. The water status in all these points is of normal colour.

Figure 13: Different photos showing status of water with Normal Colour towards Northern Part of Mara River.

5.1.9 Various Human Activities in Mara River

The Special Committee surveyed the whole areas covering Mara River and observed existence of large quantity of livestock and settlements particularly in the wetland areas. These human activities are located in various locations including: the area located between Latitude: 1° 31' 24.19" and Longitude: 34° 11' 20.50" North of Wegero Village the area has large quantity of livestock. Latitude: 1° 29' 48.72" and Longitude: 34° 13' 18.73", Latitude: 1° 29' 27.25" and Longitude: 34° 13' 40.64", Latitude: 1° 28' 50.44" and Longitude: 34° 13' 40.64", and Latitude: 1° 28' 50.44" and Longitude: 34° 13' 45.36" Southern part of Surubu village, the whole area on the respective coordinates has large number of livestock and human settlements. Another areas are on Latitude: 1° 31' 26.69" and Longitude: 34° 14' 45.35" Latitude: 1° 32' 0.70" and Longitude: 34° 14'

29.17" and Latitude: 1° 33' 11.51" and Longitude: 34° 14' 23.77" North East of Wegero Village, have large amount of livestock and human settlement.

Figure 14: Different photos showing status of human activities including livestock keeping and human settlements within or along Mara River.

6.0 CAUSE OF POLLUTION, SOURCE OF DEATH OF FISH AND OTHER SPECIES IN THE MARA RIVER

6.1Report of Fish Analysis Results from TAFIRI

The report of lab analysis of fish as received from National Fisheries Laboratory Mwanza was presented. The members raised a concern that the results were not compared with the existing standards, and also some parameters such as heavy metals relevant to the health of fish and other living organisms were not analyzed. Hence the Special Committee member recommended more fish samples to taken for full analysis to have data which will enable the Special Committee to make proper recommendations. It was recommended that dead fish be sampled instead of live fish as taken previously.

6.2Results from Laboratory Analysis of Samples Collected in the Affected Areas

6.2.1 Water Quality Parameters Measured for Samples from Mara River

To determine the extent of water pollution in the river, concentration of chemicals related to water quality is normally determined. The observed values from laboratory analysis are compared with different water quality standards, such as TBS, EAC, WHO, US-EPA, EU, etc. When these values exceed the limits provided by standards, the water is regarded as polluted.

Table 5 shows the water quality data for samples collected from several areas of the Mara River. The water quality was tested for pH, temperature, conductivity, Total Dissolved Solids (TDS), colour and turbidity. Other parameters include: total hardnes as $CaCO_3$, calcium and magnesium as $CaCO_3$. Ions in the water including nitrite, total iron, chloride and sulphates were also tested.

The total alkalinity for the water samples was also tested $CaCO_3$. Dissolved oxygen, which determine the fate of aquatic life, such as fish, was also tested. The level of DO indicates one of the causes of fish death, since lack of it leads to death. While other aquatic organisms may die due to lack of dissolved oxygen, fish death os the most prominent indicator of river water pollution problem.

The Chemical oxygen demand (COD) and grease and oils were also among the tests conducted. The COD is an indication of the quantity of pollutants in the water that need to be digested for the water to be clean again.

Table 5. Water quality parameters measured on water samples collected from Mara River from 8th to 10th March, 2022.

Tested Parameter	Unit	TZS:2068 :2017 - Receiving water Category 1 (STD)	TZS 12:2018 , Natural Portable Water (STD)	KIRUMI UPSTREAM	KIRUMI DOWNSTREAM	KEMBWI	NYAMONGO UPSTREAM	NYAMONGO DOWNSTREAM	KETASAKWA
pH	pH units	6.5-8.5	5.5-9.5	7.830	7.070	7.630	8.280	8.610	7.100
Temperature	^0C	N.M	N.M	28.000	27.800	28.700	26.100	26.200	26.500
Conductivity	µS/cm	N.M	≤2500	361.700	365.900	365.700	448.000	447.700	306.100
Total dissolved solids	mg/l	≤2000	≤1500	200.000	202.200	203.300	248.900	248.400	165.300
Colour	Pt/Co	N.M	≤50	>55O	>55O	48.000	55.000	63.000	>55O
Turbidity	NTU	N.M	≤25	98.000	73.000	410.000	33.000	42.000	86.000
Total Hardness as CaCO3	mg/l	N.M	≤2600	238.000	215.000	192.000	115.000	126.000	264.000
Calcium as CaCO3	mg/l	N.M	≤150	71.920	66.800	66.200	79.000	74.600	19.200
Magnesium as CaCO3	mg/l	N.M	≤100	43.025	36.010	30.570	8.850	12.640	59.490
Nitrite	mg/l	N.M	≤0.9	0.037	0.025	0.508	0.264	0.295	0.123
Total Iron	mg/l	≤1.0	≤0.3	1.311	1.269	3.895	2.606	2.271	1.789
Chloride	mg/l	≤200	≤250	169.690	160.382	16.117	17.086	17.350	161.086
Sulphate	mg/l	≤600	≤600	61.110	56.102	115.254	102.881	120.847	37.797
Total alkalinity as CaCO3	mg/l	N.M	N.M	79.097	74.100	42.300	78.300	82.700	91.300
DO	mg/l	≥3	N.M	0.000	0.000	1.430	4.480	4.700	0.001
Grease & Oils	mg/l	≤0.5	N.M	43000.000	39000.000	0.200	0.290	0.440	61500.000
COD	mg/l	≤60	N.M	659.780	694.080	113.120	48.900	27.800	692.000
DO%	%	≥80	N.M	0.000	0.000	22.300	64.900	70.000	0.000

6.2.2 Spacial Presentation of Selected Water Quality Parameters from Mara River

Given the wide area of the wetland associated with Mara River, samples were strategically collected in different locations, to provide logical conclusions. This is important (so called study design) since the number of parameters is large and the area to be covered was also wide. The GIS mapping technique was employed to show the variations of water quality parameters on the wetland.

The number of samples was concentrated in the polluted are, and sparsely located in areas without observed water challenges. The legend shows district and village boundaries, as well as the wetland area and Lake Vioctoria, towards which the water flows.

Figure 15 shows the variation of pH in different locations on the wetland. The pH ranges were employed to reduce complexity of the map, whereby four ranges were used: one range in the acidic range and three levels in the alkaline range.

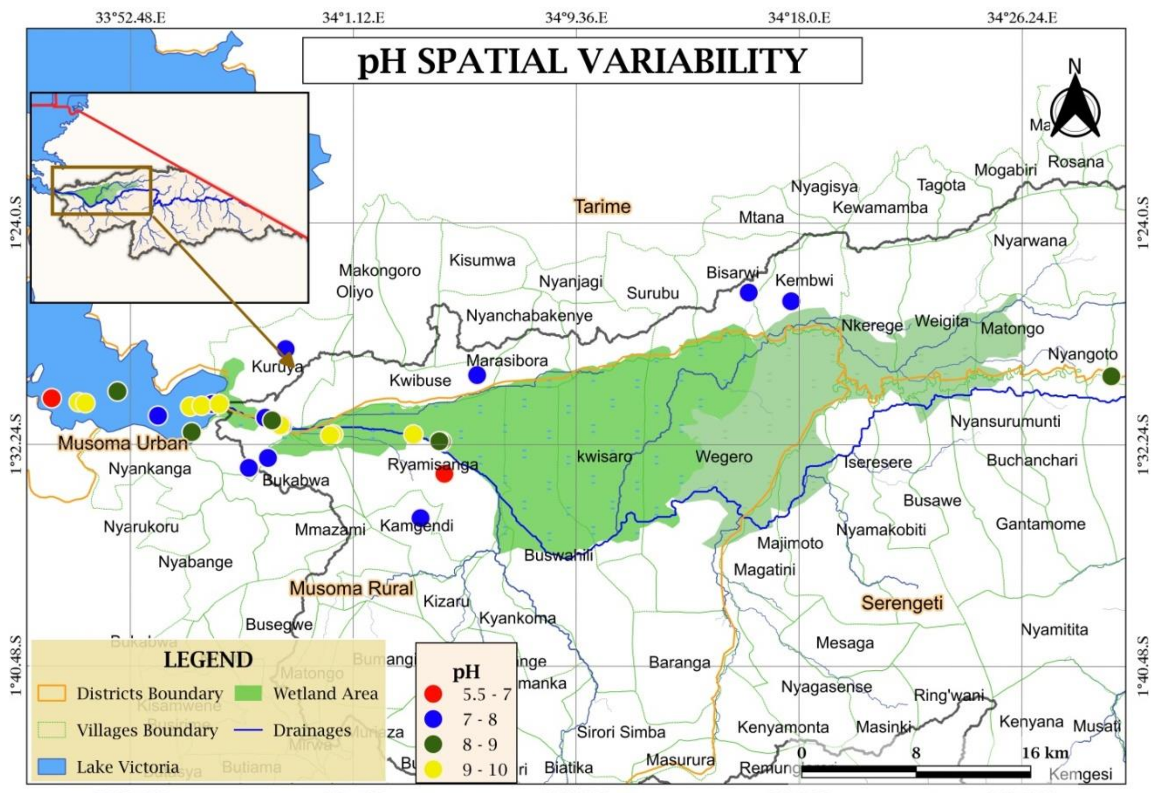

Figure 15: A spatial map showing the variations of pH values across the wetland area.

Figure 16 shows the variation of dissolved oxygen in different locations on the wetland. Abpout seven (7) different dissolved oygen concentration ranges were employed to reduce complexity of the map. Dissolved oxygen concentration is a key determinant of aquatic life and was determined to establish the cause of the reported fish death.

The red dots indicates areas where the dissolved oxygen concentration was near or exactly zero. These are the areas whefre dead fish is expected to be seen by the residents utilizing the river or lake. The ocean-blue dots shows acceptable dissolven oxgen values in water, observed in the samples collected from wells used by villagers nearby Mara River wetland.

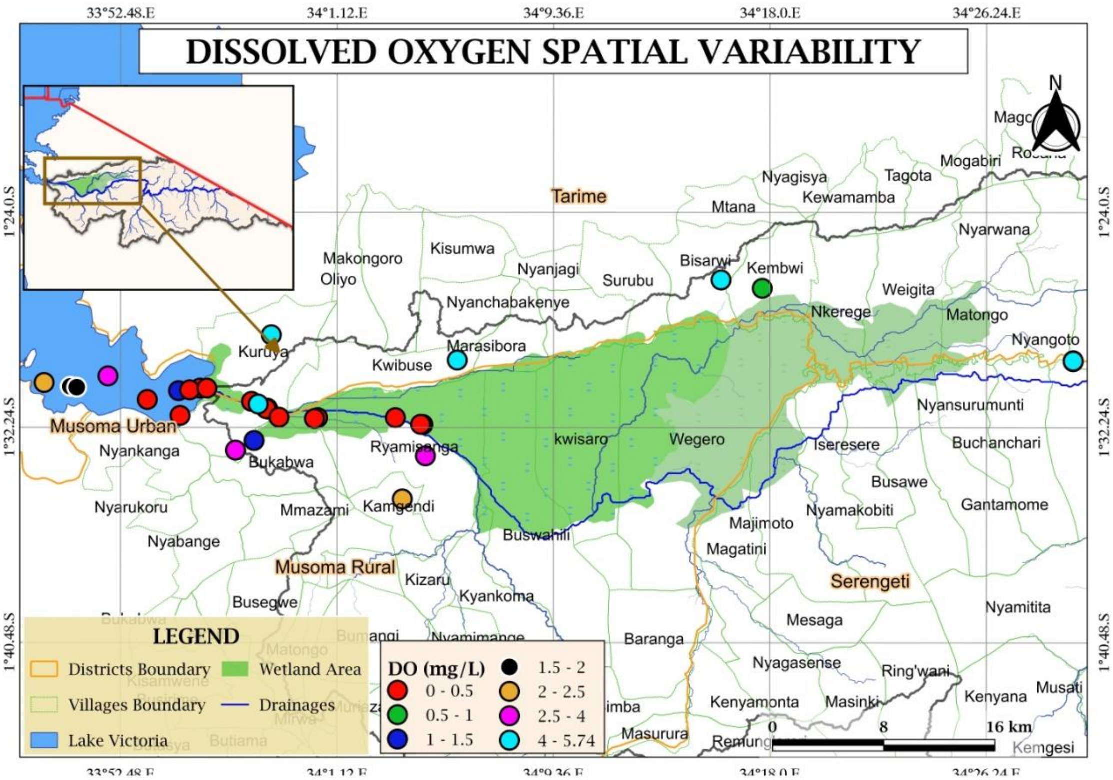

Figure 16: Map of the Mara River catchment showing variations of DO for each sampled point.

6.2.3 Analytical Results for Samples Submitted to GCLA from Mara River

As stated above, water quality is influenced by presence of chemical and biological substances. Since biological substances are more common in water, pollution level is normally measured based on chemical parameters. Biological contamination was not studied, and the fpocus was on chemical contamination which has acute effects on human health. The treatment for biological contamination is available in healthcare facilities uncomparable to chemical contamination disorders.

Table 7 presents analytical results including details of the samples submitted and top GCLA and values of parameters related to sediment collected under the water in the wetland of Mara River. Sediments particularly from the river bed, about 6 m deep were tested for heavy metals (Arsenic, Cadmium, Lead and Mercury) and pesticide residues. While some samples were below detection limit (BDL), the observed values were below the EMA Soil Quality Standards of 2007.

Arsenic concentrations in all sediment samples were not detected (below detection limit). Lead contents (71.5 – 92.93 mg/kg) are within the acceptable values according to EMA standards. Other heavy metals Cadmium and Mercury contents are also within range of the established standard.

Table 7: GCLA analytical results for water sediments collected from the riverbed.

A: Details of the Sample submitted to the Authority

1	**Lab No.** 752/2022	2	**Date of issue:** 18.03.2022	3	**GCLA Ref:** CDB.455/476/01/A/37
4	**Description of sample(s)/mark:** Water, Sediment, Fish, and Decayed plant materials				
5	**Date of submission:** 14.03.2022	6	**Client Ref. No:** EB.220/445/01/234		
7	**Sample submitted by:** Constatine Tenga (GCLA Analyst)				
8	**Customer's Address**: Director General, National Environment Management Council (NEMC), P.O.Box 63154, Dar es Salaam.				
9	**Analysis requested:** Physical appearance, general chemistry, heavy metals, Total Petroleum Hydrocarbons, Polycyclic Aromatic Hydrocarbons, and toxicological analysis.				

B: Laboratory Results:
The samples were analysed and the results are as indicated in Table 1 - 9.

Phase 1: Samples submitted 14.03.2022

Table 1: Analytical Results for Sediment Samples – 2 samples

S/N	Parameters	Results			Method
		Sediments	**Sediments from 6m area**	**EMA** (Soil Quality Standards, 2007)	
1.	Nitrite (mg/L), *Max*	0.15	0.19	Nm	DR 6000 Spectrophotometer
2.	Arsenic (mg/kg), *Max*	BDL	BDL	1.0	ICP - OES
3.	Lead (mg/kg), *Max*	72.93	71.05	200	
4.	Cadmium (mg/kg), *Max*	0.95	1.00	1.0	
5.	Mercury (mg/kg), max.	0.007	0.066	Nm	CV - AAS
6.	Pesticides residues (ppb)	Not detected	Not detected	Ns	LC –MS/MS & GC – MS/MS
7.	Polycyclic Aromatic Hydrocarbons (PAHs)	Not detected	Not detected	Nm	GC – MS/MS

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Table 2 shows the analystical results for decayed plants and fish samples from Mara River wetland. All the two fish samples returned undetectable contents in Cadmium and Arsenic. Only the fish sample (dead) collected nearby the Kirumi Bridge has Pb contents of 2.88 mg/kg. Mercury concentrations are 0.059 mg/kg for the fish sample (live) from nearby the bridge. On the other hand, the decayed plant sample returned contents of 5.9 mg/kg, 57.72 mg/kg and 4.67 mg/kg for As, Pb and Cd, respectively. No pesticide residues were detected in all samples.

Table 2: Analytical Results of decayed plant and fish samples – 3 samples

S/N	Parameters	Results			Method
		Decayed plant	**"Kitasakwa" (Samaki aliyechukuliwa akiwa hai)**	**Samaki - Pembeni ya daraja la Kirumi – aliyekutwa amekufa)**	
1.	Arsenic (mg/kg)	5.90	BDL	BDL	ICP – OES
2.	Lead (mg/kg)	57.72	BDL	2.88	
3.	Cadmium (mg/kg)	4.67	BDL	BDL	
4.	Mercury (mg/kg)	BDL	0.056	BDL	CV - AAS
5.	Pesticides residues (ppb)	Not detected	Not detected	Not detected	LC –MS/MS & GC – MS/MS

Note: BDL – Below Detection Limit

ICP – OES Detection Limit – 0.001 ppm for Arsenic and Cadmium

ICP – OES Detection Limit – 0.005 ppb for Lead

Nm – Not mentioned

NS - Not specified

ICP-OES: Inductively Coupled Plasma Optical Emission Spectrometer

AAS - Atomic Absorption Spectrometer

CV - AAS - Cold Vapour - Atomic Absorption Spectrometer

AAS Detection Limit – 0.001 ppb for Mercury

EMA (Soil Quality Standards, 2007): The Environmental Management Regulations, 2007

Table 3 shows the 14 water samples

PAHs and pesticide residues were not detected from all water samples in all 14 localities. The PAHs analysis was aimed at classifying the oil, that is, whether is resulting from petrogenic or biogenic sources. Absence of PAHs in the samples justifies the absence of petrogenic oil, which implies further that the material originated from biogenic sources.

Table 3: Analytical Results for Water samples (14 samples)

S/N	Sample ID	Results		
		Oil and Grease residues (mg/L)	**Polycyclic Aromatic Hydrocarbons (PAHs)**	**Pesticides residues (ppb)**
1.	Mlango wa Ziwa (1)	0.01	Not detected	Not detected
2.	Juu ya daraja (2)	0.56	Not detected	Not detected
3.	River Junction (3)	0.45	Not detected	Not detected
4.	Junction slage (4)	0.004	Not detected	Not detected
5	Chini ya daraja (5)	0.74	Not detected	Not detected
6	Chini ya daraja (6)	0.14	Not detected	Not detected
7.	Katikati ya mlima (7)	1.27	Not detected	Not detected
8	Lyamgasile (8)	0.92	Not detected	Not detected
9.	Junction slage (9)	0.01	Not detected	Not detected
10.	Lyamsanga (10)	0.01	Not detected	Not detected
11.	Kitasakwa (12)	0.004	Not detected	Not detected
12.	1 km kutoka daraja la Kirumi (13)	0.23	Not detected	Not detected
13.	Juu ya Daraja (14)	0.57	Not detected	Not detected
14.	Kitasakwa (11)	0.36	Not detected	Not detected
	TZS 860:2006	Max. 10 mg/L	Not specified	Not specified
	Method (s)	Gravimetric	GC – MS/MS	LC –MS/MS & GC – MS/MS

TZS 860: 2006 - Municipal and Industrial Waste Water (General Tolerance Limits for Municipal and Industrial Waste Water)

Table 4: Total Petroleum Hydrocarbons (TPHs) profile of 14 water samples

S/N	Sample ID	Results: Total Petroleum Hydrocarbons (TPH), mg/L				Method
		Diesel	**Gasoline**	**Kerosene**	**BTEX**	
1.	Mlango wa ziwa (1)	> 5 and < 10	>3.5 and < 4.0	>7.5 and < 14	>1.5 and< 2.5	DR 6000 Spectrophotometer (Method 10050)
2.	Juu ya daraja (2)	< 2	< 1.5	< 3.5	< 0.5	
3.	River Junction (3)	> 2 and < 20	>1.5 and <14	>3.5 and < 24	>0.5 and< 4.5	
4.	Junction slage (4)	< 2	< 1.5	< 3.5	< 0.5	
5	Chini ya daraja (5)	>10 and < 20	>4 and < 14	>14 and < 24	>2.5 and< 4.5	
6	Chini ya daraja (6)	>10 and < 20	>4 and < 14	>14 and < 24	>2.5 and< 4.5	
7.	Katikati ya mlima (7)	>2 and < 20	>1.5 and < 14	>3.5 and < 24	>0.5 and < 4.5	
8	Lyamgasile (8)	>2 and < 20	>1.5 and < 14	>3.5 and < 24	>0.5 and< 4.5	
9.	Junction slage (9)	< 2	< 1.5	< 3.5	< 0.5	
10.	Lyamsanga (10)	>10 and < 20	>4 and < 14	>14 and < 24	>2.5 and < 4.5	
11.	Kitasakwa (12)	< 2	< 1.5	< 3.5	< 0.5	
12.	1 km kutoka daraja la Kirumi (13)	>5 and < 10	>3.5 and < 4.0	>7.5 and < 14.0	>1.5 and < 2.5	
13.	Juu ya Daraja (14)	< 2	< 1.5	< 3.5	< 0.5	
14.	Kitasakwa (11)	< 2	< 1.5	< 3.5	< 0.5	
	EPA, 2002, max.	20 mg/L				

Note:

i) EPA, Envoronmental Protection Agency USA for ground water which has pontential to migrate to the surface water
ii) BTEX – Benzene, Toluene, Ethylbenzene, Xylene

Table 4: Total Petroleum Hydrocarbons (TPHs) profile of 14 water samples

S/N	Sample ID	Results				Method
		Total Petroleum Hydrocarbons (TPH), mg/L				
		Diesel	Gasoline	Kerosene	BTEX	
1.	Mlango wa ziwa (1)	> 5 and < 10	>3.5 and < 4.0	>7.5 and < 14	>1.5 and< 2.5	DR 6000 Spectrophotometer (Method 10050)
2.	Juu ya daraja (2)	< 2	< 1.5	< 3.5	< 0.5	
3.	River Junction (3)	> 2 and < 20	>1.5 and <14	>3.5 and < 24	>0.5 and< 4.5	
4.	Junction slage (4)	< 2	< 1.5	< 3.5	< 0.5	
5	Chini ya daraja (5)	>10 and < 20	>4 and < 14	>14 and < 24	>2.5 and< 4.5	
6	Chini ya daraja (6)	>10 and < 20	>4 and < 14	>14 and < 24	>2.5 and< 4.5	
7.	Katikati ya mlima (7)	>2 and < 20	>1.5 and < 14	>3.5 and < 24	>0.5 and < 4.5	
8	Lyamgasile (8)	>2 and < 20	>1.5 and < 14	>3.5 and < 24	>0.5 and< 4.5	
9.	Junction slage (9)	< 2	< 1.5	< 3.5	< 0.5	
10.	Lyamsanga (10)	>10 and < 20	>4 and < 14	>14 and < 24	>2.5 and < 4.5	
11.	Kitasakwa (12)	< 2	< 1.5	< 3.5	< 0.5	
12.	1 km kutoka daraja la Kirumi (13)	>5 and < 10	>3.5 and < 4.0	>7.5 and < 14.0	>1.5 and < 2.5	
13.	Juu ya Daraja (14)	< 2	< 1.5	< 3.5	< 0.5	
14.	Kitasakwa (11)	< 2	< 1.5	< 3.5	< 0.5	
	EPA, 2002, max.	20 mg/L				

Note:

i) EPA, Envoronmental Protection Agency USA for ground water which has pontential to migrate to the surface water

ii) BTEX – Benzene, Toluene, Ethylbenzene, Xylene

All of the samples do not suggest presence of petrogenic petroleum hydrocarbons. This further confirms biogenic nature of the material in the river, where samples were collected.

Table 5: General chemistry and heavy metals analytical Results for Water samples (15 samples)

S/N	Sample ID	Results						
		COD (mg/L)	BOD (mg/L)	SULPHATE (mg/L)	ARSENIC (mg/L)	LEAD (mg/L)	CADMIUM (mg/L)	MERCURY (µg/L)
1	Mlango wa Ziwa	115	60.52	<0.001	<0.001	<0.001	<0.001	<0.001
2	Juu ya Daraja	102	53.68	<0.001	<0.001	<0.001	<0.001	<0.001
3	River Junction	92	48.42	0.2424	<0.001	<0.001	<0.001	<0.001
4	North Mara Upstream	44	23.15	<0.001	<0.001	<0.001	<0.001	<0.001
5	Chini ya Daraja	99	52.1	<0.001	<0.001	<0.001	<0.001	<0.001
6	North Mara downstream	< 3.0	Nil	<0.001	<0.001	<0.001	<0.001	<0.001
7	Lyamgasile	61	32.1	<0.001	<0.001	<0.001	<0.001	0.0426
8	Katikati ya milima	100	52.63	<0.001	<0.001	<0.001	<0.001	<0.001
9	Lyamsanga	87	45.78	<0.001	<0.001	<0.001	<0.001	<0.001
10	1KM kutoka Daraja la Kirumi	87	4578	<0.001	<0.001	<0.001	<0.001	<0.001
11	Junction Sludge	101	53.15	ND	ND	ND	ND	2.6948
12	Kitasakwa Village	94	49.47	ND	ND	ND	ND	<0.001
P	Point	63	33.15	<0.001	<0.001	<0.001	<0.001	<0.001
K	Kirumi bridge downstream	80	42.1	<0.001	<0.001	<0.001	<0.001	<0.001
BW	Bwawa la samaki-Rest house ya jeshi	15	7.89	<0.001	<0.001		<0.001	<0.001
	EMA, 2007	60	30	500	0.2	0.1	1.0	0.005
	EAS 12: 2018	-	-	400	0.01	0.01	0.003	0.001
	Method (s)	DRB 200 Spectrophotometer		DR 5000 Spectrophotometer	AAS			CV - AAS

Note: EMA (Permissible Limits for Municipal and Industrial Effluents, 2007): The Environmental Management Regulations, 2007

Table 6 shows the laboratory results for samples collected and submitted in Phase 2, on 16/3/2022. All samples had no detectable heavy metals with the exception of one sample collected from Lyamgasile whose mercury level is 0.0426 micrograms/litre, as shown in Table 6. Another sample collected from the junction sludge has mercury contents of 2.6948 micrograms/litre. Presence of detectable mercury could indicate artisanal mining activities either in the vicinity or transported from sites by running water. All COD and BOD values were acceptable, based on East African potable water standards.

Phase 2: Samples submitted 16.03.2022

Table 6: Physical- Chemical Analytical Results for 15 Water Samples

S/N	Sample ID	Results					
		Alkalinity (mg/L), *Max*	**pH**	**Conductivity (μS/cm) *Max***	**Turbidity (FNU), *Max***	**Sulphate (mg/L), *Max***	**Nitrate (mg/L), *Max***
1.	Lyamisango Point 5 - 1	164	7.21	259	16.2	9.0	1.5
2.	Lyamisango Point 5 - 2	148	7.21	240	11.2	1.0	BDL
3.	Point 4 River Junction 1	192	7.32	240	10.3	BDL	
4.	Point 4 River Junction 2	140	7.36	238	10.0	BDL	
5	Kirumi Bridge Down stream 1	144	7.36	238	19.6	BDL	BDL
6	Kirumi Bridge Down stream 2	156	7.41	239	21.2	BDL	
7.	Kirumi Bridge Down stream 3	136	7.40	239	16.7	BDL	BDL
8	Kirumi Bridge Down stream 4	148	7.47	237	16.8	BDL	BDL
9.	Kirumi Bridge Down stream 5	124	7.42	237	18.5	BDL	BDL
10.	Point 1	136	7.00	238	14.0	36	BDL
11.	Point 3	120	7.25	274	9.0	42	BDL
12.	Bwawa la samaki – Rest house ya Jeshi	96	7.27	198.0	5.30	23	0.3
13.	Nje ya Bwawa	104	7.48	193.9	5.52	27	0.2
14.	North Mara Down Stream Discharge	160	7.97	367	130	18	6.4
15	Multi villa – Normal water	80	7.86	151.3	12.0	16	0.5
EAS 12: 2018		n.m	5.5 - 9.5	2500	25	400	45
EMA, 2007		n.m	6.5 – 8.5	n.m	300 NTU	500	20
Method (s)		Titrimetric	Hach Multi-parameter		Turbidity Meter	DR 6000 Spectrophotometer (Method 10050)	

EAS 12:2018: East African Standard for Portable water - Specification

All analyzed parameters including pH are in acceptable ranges. The detectable nitrates and sulphates in some localities imply enhanced bioactivity, as presented in Table 6.

Table 7 shows the concentration of oil and grease, polycyclic hydrocarbons and pesticieds in 15 water samples collected various points along the Mara River. In all water samples, PAHs and pesticides were not detected. It was observed, however, that oil and grease residues were relatively higher at Lyamisango and Kirumi Bridge (4.3 and 4.6 mg/l, respectively). The fact the the PAHs were below the detection limit, indicates that the oil and grease in the water samples and hence in the river water was due to biogenic sources.

Table 7: Oil and Grease, Polycyclic Aromatic Hydrocarbons (PAHs) and pesticides analytical Results for Water samples (15 samples)

S/N	Sample ID	RESULTS		
		Oil and Grease residues (mg/L)	**Polycyclic Aromatic Hydrocarbons (PAHs)**	**Pesticides residues(ppb)**
1.	Lyamisango Point 5 - 1	4.30	Not detected	Not detected
2.	Lyamisango Point 5 - 2	0.43	Not detected	Not detected
3.	Point 4 River Junction 1	0.04	Not detected	Not detected
4.	Point 4 River Junction 2	0.01	Not detected	Not detected
5	Kirumi Bridge Down stream 1	0.05	Not detected	Not detected
6	Kirumi Bridge Down stream 2	0.03	Not detected	Not detected
7.	Kirumi Bridge Down stream 3	0.06	Not detected	Not detected
8	Kirumi Bridge Down stream 4	4.60	Not detected	Not detected
9.	Kirumi Bridge Down stream 5	0.03	Not detected	Not detected
10.	Point 1	0.38	Not detected	Not detected
11.	Point 3	0.01	Not detected	Not detected
12.	Bwawa la samaki – Rest house ya Jeshi	0.04	Not detected	Not detected
13.	Nje ya Bwawa	0.02	Not detected	Not detected
14.	North Mara Down Stream Discharge	1.98	Not detected	Not detected
15	Multi villa – Normal water	0.01	Not detected	Not detected
	TZS 860:2006	Max. 10 mg/L	Not specified	Not specified
	Method (s)	Gravimetric	GC – MS/MS	LC –MS/MS & GC – MS/MS

Table 8 shows the laboratory results focusing on detection of Total Petroleum Hydrocarbons (TPHs), including diesel, gasoline (petrol), kerosene and Benzene, Toluene, Ethylbenzene and Xylene (BTEX) in the water. The levls of the above parameters, according to Table 8, are very low. The TPHs contents were detected at Lyamisango locality as well Kirumi Bridge. This suggests the influence of human activities. This observation could point to human activities such as washing of motorbikes *(boda boda)* or leakage from motorized fishing boats.

Table 8: Total Petroleum Hydrocarbons (TPHs) profile of 15 Water samples

S/N	Sample ID	Results				Method
		Total Petroleum Hydrocarbons (TPH), mg/L				
		Diesel	Gasoline	Kerosine	BTEX	
1.	Lyamisango Point 5 - 1	< 2	< 1.5	< 3.5	< 0.5	DR 6000 Spectrophotometer (Method 10050)
2.	Lyamisango Point 5 - 2	> 20	> 14	> 24	> 4.5	
3.	Point 4 River Junction -1	< 2	< 1.5	< 3.5	< 4.5	
4.	Point 4 River Junction - 2	< 2	< 1.5	< 3.5	< 4.5	
5	Kirumo Bridge Down stream -1	< 2	< 1.5	< 3.5	< 4.5	
6	Kirumo Bridge Down stream -2	< 2	< 1.5	< 3.5	< 4.5	
7.	Kirumo Bridge Down stream - 3	< 2	< 1.5	< 3.5	< 4.5	
8	Kirumo Bridge Down stream - 4	< 2	< 1.5	< 3.5	< 4.5	
9.	Kirumo Bridge Down stream -5	< 2	< 1.5	< 3.5	< 4.5	
10.	Point -1	>2 and < 5	>1.5 and < 3.5	>3.5 and < 7.5	> 0.5 and < 1.5	
11.	Point - 3	< 2	< 1.5	< 3.5	< 0.5	
12.	Bwawa la samaki – Rest house ya Jeshi	< 2	< 1.5	< 3.5	< 0.5	
13.	Nje ya Bwawa	< 2	< 1.5	< 3.5	< 0.5	
14.	North Mara Down Stream Discharge	< 2	< 1.5	< 3.5	< 0.5	
15	Multi villa – Normal water	< 2	< 1.5	< 3.5	< 0.5	
	EPA, 2002, Max.	20 mg/L				

i) EPA, Envoronmental Protection Agency USA for ground water which has pontential to migrate to the surface water
ii) BTEX – Benzene, Toluene, Ethylbenzene, Xylene

Table 9 summarizes the analytical results from 7 fish samples. The samples comprised of Kamongo and Mumi from which meat and ofals were tested. The samples were prepared and tested for presence of heavy metals (Arsenic, Lead, Cadmium), pesticide residues, and Polycyclic Aromatic Hydrocarbons (PAHs). The methods of detection are also shgown in Table 9. All fish samples had no detectable heavy metal contents, except for one Kamongo sample that had Pb content of 2.09 mg/kg. This was attributed to nearby human activities.

Table 9: Analytical Results for Fish samples – 7 samples

S/N	Parameters	Results							Method
		Kamongo 1	Kamongo 2			Mumi 1	Mumi 2		
			meat	Ofals (Utumbo)	meat	Ofals (Utumbo)	meat	Ofals (Utumbo)	
1.	Arsenic (mg/kg), *Max*	BDL	BDL	BDL	BDL	BDL	BDL	BDL	ICP - OES
2.	Lead (mg/kg), *Max*	2.09	BDL	BDL	BDL	BDL	BDL	BDL	
3.	Cadmium (mg/kg), *Max*	BDL	BDL	BDL	BDL	BDL	BDL	BDL	
4.	Pesticides resdidues (ppb)	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected	LC –MS/MS & GC – MS/MS
5.	Polycyclic Aromatic Hydrocarbons (PAHs)	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected	GC – MS/MS

6.3 Evidence from the Local Community on the Source of Pollution

6.3.1 Respondents for each Questionnaires

The Committee conducted surveys in the company of ward and village leaders of the adjacent villages to the Mara River, who assisted in identifying the key respondents and providing required information on Mara River water pollution. the adjacent villages surveyed were Kirumi, Ryamisanga, Wegero, Kitasakwa in Butiama District; Kwibuse, Kwibwe, Bisarwi, Kuruya in Rorya District, and; Nyabichume, Matongo, Mjini Kati (Nyamongo), Bisarwi and Mrito in Tarime District, These questionnaires were meant to collect data related to livelihood status and opinions in respect of the pollution on the Mara River wetland area. Respondents included farmers, fishermen, livestock keepers, and miners.

Table 8: Respondents distribution

Questionnaires category	Rorya	Butiama	Tarime	Number of Respondents
1) General Questionnaires				**90**
2) Livestock Keepers (Pastoralists)	3	10	2	**15**
3) Fishermen	10	13	0	**23**
4) Farmers	12	13	5	**30**
5) Peasants	0	0	19	**19**
Total per district	**25**	**36**	**26**	**177**

6.3.1.1 Livestock Keeping

The Committee visited a total number of 17 Pastoralists in a distribution of 10 (58.8%) from Wegero Village (Buswahili Ward), Kitasakwa village (Bwiregi Ward), Kongoto Village (Buswahili Ward) and Kirumi village (Bukabwa Ward) in Butiama District; 5 (29.4%) from Kwibwe village (Kisumwa Ward), in Rorya District; and 2 (11.8%) from Matongo village (Matongo Ward) in Tarime District. The selection and interview to respondents from these Villages, Wards and respective villages was based on the fact that, they are within or along Mara River Wetland. Moreover, 94.1% of the interviewed respondents are involved with pastoralism activities particularly livestock keeping (Figure 17).


Figure 17: Aerial photos showing livestock grazing and settlement in Mara River Wetland

The data collected revealed that, 94.1% of respondents reported to depend on Mara River as a source of water and feeding for their livestock and only 5.9% of respondents are involved by fishing as different activity from livestock keeping. Further information collected from District Live Stock Officers for Butiama, Serengeti, Rorya and Tarime Districts informed that, the total number of livestock which depend on Mara River for pasture and drinking in the Four Districts are 302,159 Cattle, 88041 Goats and 72,210 Sheep. The distributions of livestock for each district are as provided in Table 9. Furthermore, it was reported by the Livestock District Officers that, during dry seasons the wetland part of Mara River, receives more livestock with an estimate of 300,000 Cattle.

Table 9: Livestock population along Mara River in Mara Region

S/N.	District	Ward	Cattle	Goat	Sheep
1	Rorya	Kisumwa	9,301	3,691	2,347
		Komuge	10,378	6,214	4,149
2	Butiama	Buswahili	22,913	6,114	5,911
		Nyamimange	6,997	2,080	4,057
		Bwiregi	13,020	4,293	5,131
		Bukabwa	7,053	3,045	1,279
		Sirorisimba	11,554	2,815	3,578
		Butuguri	3,933	1,018	414
		Muriaza	7,990	3,273	1,594
		Buhemba	8,099	2,800	1,793

		Mirwa	11,441	2,496	2,318
3	Serengeti	Kenyamonta	28,179	7,696	8,190
		Majimoto	19,970	6,486	5,380
		Busawe	10,948	3,751	2,494
		Kisaka	23,317	6,628	7,586
		Nyansurura	11,186	5,150	5,603
4	Tarime	Kwihancha	17,249	2,171	1,341
		Kemambo	8,981	2,034	603
		Matongo	10,895	3,201	843
		Kibasuka	25,739	4,114	2,141
		Kiore	9,212	3,102	774
		Manga	10,902	2,017	1,713
		Komaswa	12,902	3,852	2,971
Total			**302,159**	**88,041**	**72,210**

Source: Mara Regional Livestock Department

The data from the literature shows that, cow dung produced by cattle, goats and sheep can be of benefit or negative impact to human activities or environment. Cow dung is defined as the undigested residue of consumed food material being excreted by herbivorous bovine animal species. Being a mixture of faeces and urine in the ratio of 3:1, it mainly consists of lignin, cellulose and hemicelluloses. It also contains 24 different minerals like nitrogen, potassium, along with trace amount of sulphur, iron, magnesium, copper, cobalt and manganese (Gupta et al., 2016). A study by Gupta et al. (2016) shows that India has 69.9 % population of cow (*Bos indicus*) as major cattle residing in rural areas and generates and that one cow produces 9–15 kg dung/day. Further study by Zhu (2020), conducted in Kenya shows that, an adult cattle can excrete up to 25 kg fresh dung and 21 L urine per day. This implies that, large number of livestock in the wetland during the eight months of prolonged dry season may have contributed to the high load of organic matter decomposed in the wetland of Mara River.

Based on the literature and data from the survey, it is indicated that cow dung produced over the eight month period for 302,159 herds of cattle settled in the wetland can be a minimum of 652,320 tons (302,159 cows x ca. 9 kg cow dung x 240 days) and a maximum of 1,812,954 tons (302,159 cows x ca. 25 kg cow dung x 240 days) when India and Kenya studies are considered, respectively. In addition, the amount of urine produced based on the Kenya study, with reference to the population of cattle under review, is 1,522,882 cu. m.

6.3.1.2 Miners

A total number of 19 respondents were interviewed in Tarime District which account about 100% of all respondents where by 47.4% were from Kemambo and Ward, 52.6% of respondents were from Matongo Village. The results show that, 21.1% of respondents were from Kerende, 21.1%, from Mjini Kati, 26.1% from Mrito and 31.6% Nyabichune. Furthermore, the distribution respondents according to gender were 73.7% male and 26.3% female. The responds in the villages selected to be involved in the survey was based on the fact that, they are close to Mara River for their mining operations (Figure 18).

Figure 18: Aerial photo showing mining activities (Matongo Village – Tarime District)

The data from the survey revealed that, the technology used in the mining activities by the respondents is subdivided into two groups where by 21.1% of the respondents use Mercury as the only chemical for Gold extraction and 79.9% use Vat Leaching Technology which involves use of chemicals such as Sodium, Cyanide, Sodium Hydroxide, Calcium Carbonate, Carbon, Nitric Acid, Sulphuric Acid, Hydrogen Peroxide, Silver Nitrate and Lead Nitrate for Gold processing and extraction. The report further shows that, 36.5% of small scale miners use Mara River as a source of water using special vehicles (boozers) made for such purpose to the area of operations far from the river and 63.5% use water from own water-wells.

The the results that, about 100% of the respondents involved in small scale Mining activities do not discharge water directly from their mines to Mara River instead the water is continuously recycle/reused. Leading to the conclusion, no contamination of chemicals from small scale mining operations can be expected to cause pollution. All surveyed Gold processing sites are well constructed in such away that they do not allow chemicals or water used for processing to penetrate into the groundwater through surface seepage minimizing the possibility of river water contamination. To the other side 100% of the respondents do not use water direct from Mara River which also reduces the possibility of the Mara River to be contaminated from small scale mining activities. The observation from the Survey showed that most of the surveyed Miners are located far away from the point of River Mara where the incidence of pollution ostarted.

6.3.1.3 Fishermen

The questionnaires on fishing activities were administered to two Districts, namely Butiama and Rorya. The Districts were chosen due to the presence of fishing activities who in the Mara River wetland. In Butiama District, respondents were from three wards; Buswahili, Bukabwa and Bwinegi, while in Rorya, respondents were from two wards; Kisumwa and Komuge. Higher number of respondents was recorded in Butiama District (56.5%) as comparing to Rorya which had 43.5 % of respondents. All fishermen who were interviewed were men, mostly in the age group of 51-60, representing 56.5% of all age groups interviewed. The age group of 41-50 was least represented, contributing 4.3% of all fishermen who were interviewed. 65.2% of fishermen in both districts admitted that, the wetland was very important as a fishing area, while 34.7% added that, apart from fishing the wetland is also important as a source of food and income (Figure 19).

Figure 19: Aerial photos showing fishing activities in Mara River where the weeds have not covered surface completely.

The challenge which was reported by most of the fishermen (47.8%) was the accidents which are from different causes. Some are caused by animals such as hippos and crocodiles while others are the normal drowning. Some healthy challenges which were pointed out due to the River pollution during the survey were diarrhoea and skin irritation especially when polluted water comes into contact with the skin. Other challenges which are related to the ecosystem health are fish death, loss of some of the species, and water pollution in general.

About 83 % of fishermen acknowledged that, they have witnesses several changes which had occurred in Mara River, whereby, they witnessed changing of the water colour from the normal colour to blackish, brownish, reddish, green apple or milkish. All respondents (100%) indicated that, the changes are during heavy rains, especially from March to April. About 95.6% of fishermen use hooks as their fishing gears while the rest uses nets and traps. Fishermen were interviewed on why they burn the wetlands.

These evidences from fishermen lead to the conclusion that, the event of pollution occurred in Mara River, it is not the first incident to happen as it happens several times during heavy rain season (March – May), although with different magnitudes especially immediately after the first rains following prolonged drought periods

6.3.1.4 Peasants/Farmers

The survey touched base on 30 Peasant farmers in villages along the Mara River Basin. Among the three districts visited, 46.7% respondents were from Butiama district, 36.7% from Rorya and 16.7% from Tarime District. In Butiama, the survey was done in three wards (Bukabwa, Buswahili and Bwiregi), two wards in Rorya (Kisumwa and Komuge) and one ward from Tarime (Matongo). 76.6 % of the interviewed farmers were engaged in both agriculture and Livestock keeping and 23.4% were engaged in agriculture. 30% of farmers were not using any kind of fertilizer, 63.3% were using manure and 6.7% were using industrial fertilizer.

Approximately 46.7% of farms were located from within 60 Meters of the wetland and 53.3% of the farms were allocated away from 60 Meter as required by the law. 70 % of respondents were using pesticides and 30% were not using pesticides. 50% of the respondents are affected by the river especially during floods, when their farms are subjected to flooding and 50% are not affected by the river probably due to the distance between the river and the farm. The 28% reported that rain water caused erosion in their farms while 72% of respondents reported not been affected by soil erosion due to rain water. The means which are used to minimize erosion are tree planting, mulching and contouring.

6.4 Contribution of Nature to such Kind of Pollution

6.4.1 Possible Seismic Activities in the Vicinity of the River

Earth is a dynamic system whose surface is continuously re-shaped by extreme, sudden events that are linked to anthropogenic and/or natural processes. Such processes include fires, floods, storms, volcanic eruptions, earthquakes, and tsunamis. In particular, the consequences of earthquakes on lacustrine environments can lead to disturbances of the deposited debris and result into high turbidity in rivers (Horton et al., 2019). In organically decomposed debris, such tremors can trigger the release of free carbon that then acts as nutrient for bacteria communities. Accelerated populations of bacteria, that in turn consume oxygen, can lead to deprivation of dissolved oxygen in watersheds. This is detrimental to the livelihood of other organisms, mainly fish (Horton et al., 2019).

Mara River's pollution and increased turbidity can be associated with debris disturbances induced by tremors. An assessment and interpretation of possible impacts of seismic activities within or proximal to the river channel was conducted using an epicenter seismic map (Figure 20)

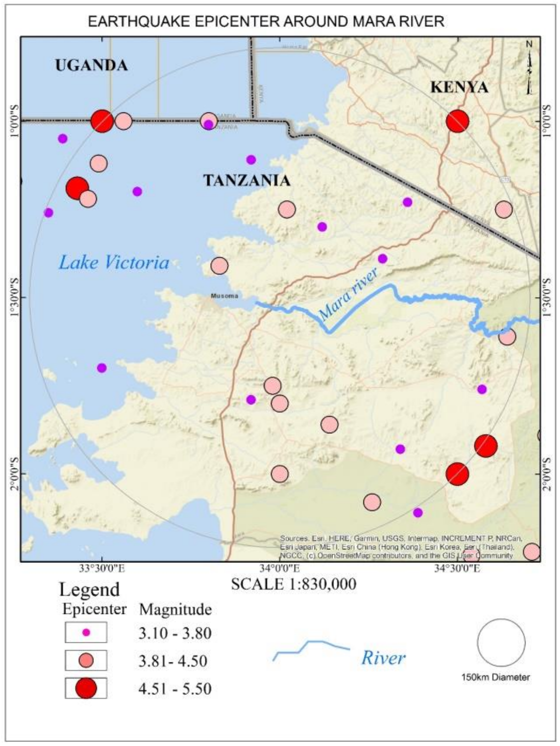

Figure 20: Magnitude of seismic activities recorded in the region covering Mara River.

6.4.2 Hydrological Trends and Pollution of Water

With an estimated aerial surface area of over 68,000 km^2, Lake Victoria ranks second largest fresh water lake in the world. It is distributed among Tanzania (52%), Uganda (42%) and Kenya (6%). The catchment area of Lake Victoria basin is one of the densely populated parts of Africa, which also includes Rwanda and Burundi. The lake receives it water from several rivers include the Mara River in the eastern part.

River water pollution poses a serious threat to aquatic ecosystems, ecological functioning and the health of the local communities. For instance, extreme floods can lead to pollution, turbidity, increased turbidity and death of fish. It is therefore prudent to monitor and control river flow in time-series so as extreme cases can be managed. With the Mara River catchment, there are several stationed flow measuring stations that provide insights about hydrological history of the river (Figure 21).

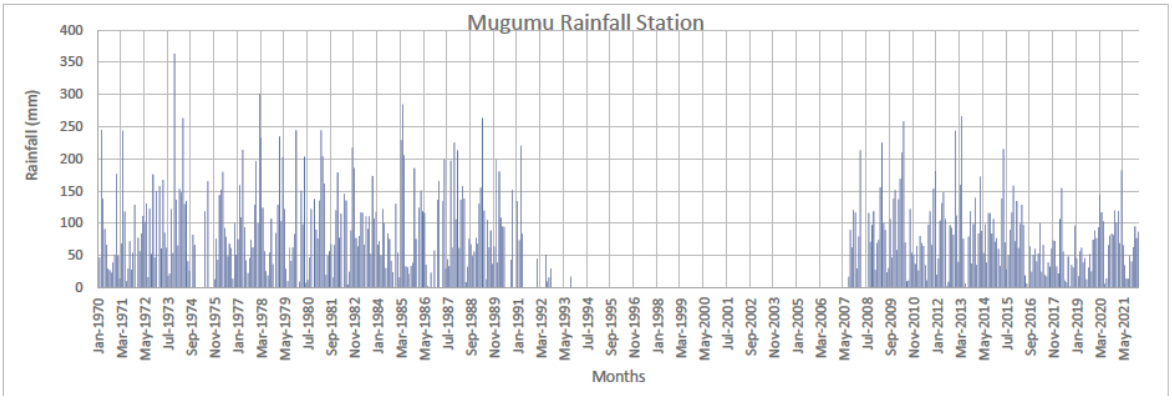

Figure 21: Rainfall precipitation history for Mara River spanning the period between 1970 to 2022.

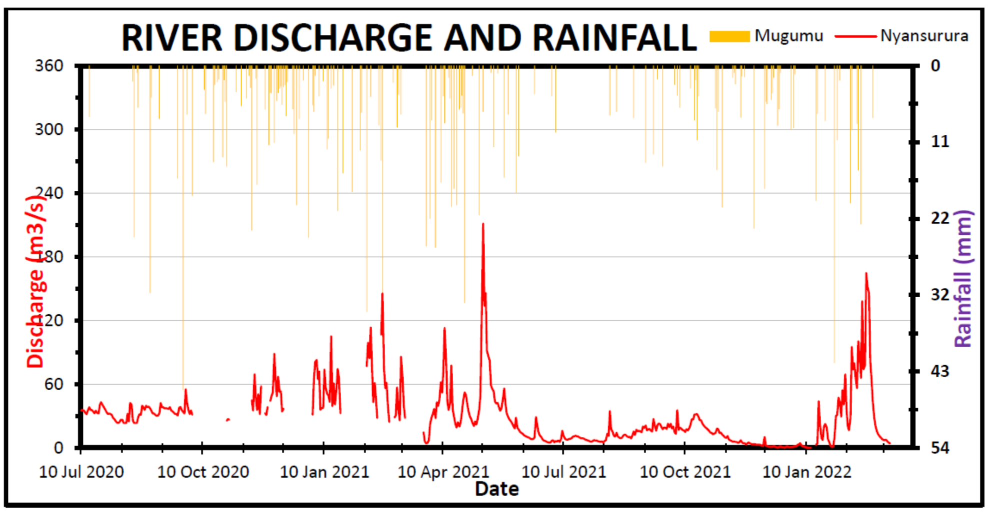

Figure 22: Rainfall and discharge history for Mara River spanning the period between 2020 and 2022.

Figure 22 shows variations of river discharge and rainfall magnitudes for three years consecutively. There is a trend of increasing rainfall from 2020-2021 reaching a maximum by mid-2021. This period was proceeded by a prolonged phase of draught that lasted for eight months. An abrupt increase of rainfall occurred from 24th February for three days.

Dialogues with residents in different wards and villages indicated that sharp rainfall variations influence pollution in the Mara River and its catchment areas. One common observation from interviews was that, pollution events are mostly preceded with prolonged severe draught periods. The March 2022 pollution event is revealed in the plot above where it followed after the 8-month draught period. This pollution event was accompanied with changes in both coloration and odour. That marked the commencement of blackwaters (dark tea colour) in the River.

Should the water continue to rain after the heavy rain event (which steers the underneath organic matter), washing phenomenon would have happened and the river would have been cleaned in few days. Because the rain stopped abruptly, the river water has remained dirty in the affected areas to date.

6.4.3 Blackening and Odorization Processes

Different factors, elements and compounds are known to contribute to blackening and odorization of river water. These include quantities of anthropogenic pollutants, both organic and inorganic pollutants and destabilized river ecosystems. Thus excessive pollution in the water is the main contribution to water blackening and odorization. Odorization is a common feature for polluted water in North Mara river waters. This observation was also noted.

6.4.4 Possibility of Polluted Water Infiltration to nearby Wells

Figure 23 shows the satellite map of the Mara River catchment near the discharge mouth, covering areas of the river observed with heavy water pollution. The identified sites indicate the location of water wells in the villages along the river.

Figure 23: Location of the water wells sampled for water quality analysis along the polluted section of the Mara River.

The surveyed wells generally showed clear water with pH ranging from 7.08 (Kirumi Village) – 7.85 (Ryamisanga Village) and dissolved oxygen of between 0.94 mg/l (Kembwe Village) – 4.04 mg/l (Komuga Well). Measurements were conducted in Kirumi, Kitasakwa, Ryamisanga, Kembwe, Kwikoma, Mkola and Kwibuse villages. These parameters conform to WHO and TZS2068:2017. Exceptions were noted in Kitasakwa Village at Kyangiwina well whose pH was 5.5.

Based on the obtained physico-chemical parameters above, it can be concluded that there is not notable infiltration of polluted water from Mara River to the wells. This is supported by the underlying geology which is dominated by hard igneous rocks (granitoids) that do not seem to have been fractured (negligible porosity).

7.0 OBSERVATION, CONCLUSION AND RECOMMENDATIONS

7.1 Observations

Based on the laboratory results and in-situ measurements the committee observed the following:

1) No Polycyclic Aromatic Hydrocarbons (PAHs) were detected, implying there was no pollution that was caused by petroleum products in the river. The hydrocarbons detected on the surface of waters within the wetlands were mostly biogenic in nature having been generated from dead and decomposed plants in the area over a period of time;
2) Levels of both (Biological Oxygen Demand) BOD and (Chemical Oxygen Demand) COD, which were high in the samples taken, have direct implications to the depletion of dissolved oxygen;
3) The extreme low levels of Dissolved Oxygen (DO) tested in the river water have largely contributed to the observed deaths of fish that were seen floating;
4) The high load of organic matter seen within the wetland area which, is directly linked to severe depletion of DO, is attributed to decomposed plants biomass (*Papyrus, Typha, Water Hyacinths, etc*.) and cow dung from the large number of herds of cattle pasturing in the higher wetland areas;
5) The committee further observed that the concentration of suspected toxic chemicals tested in the water and dead fish samples were insignificant and were found to be within acceptable levels based on Tanzania Bureau of Standard (TBS) and World Health Organization (WHO) standards;
6) Also, based on in-situ well-water samples tested, most were found to be within the acceptable levels, reflecting that there was no infiltration of polluted water from the river into the nearby wells used by the villagers.

7.2 Conclusion

From the above observations the committee concludes as follows:

1) The observed blackening and odorization of Mara river water is due to:

(i) Decomposition of organic matter generated from invasive plant species which, cover a significant portion of the wetland area. These plants die and decompose with time causing high consumption of oxygen by aerobic bacteria. This leads to oxygen depletion, blackening and odorization which was verified by high levels of BOD and COD.

(ii) Existence of a large number of livestock in the Mara River wetland area produce a large quantity of waste. This accelerates the levels of nutrients, hence growth of invasive plant species in the Wetland area. This adds organic matters which together with decaying plant materials are responsible for the bad smell of water in the wetland area as well as black coloration.

2) The effect of climate variability, as it has been reported and observed from the previous year's rainfall data caused the incidence of fish deaths. This often occurs in Mara river when severe prolonged drought is followed by short spell of heavy rains which do not adequately washout the waste within the wetland area.

7.3 Recommendations

7.3.1 Short-Term Recommendations

1. Based on the results of the tests undertaken on water samples for the river and water wells in several locations along the wetland, the chemical substances contained in them do not pose any threats to human health. The committee therefore, recommends acceptable economic and social activities that are friendly to the environment to continue as it was before.

2. Tests on variety of fish undertaken revealed absence of toxicity, hence may be consumed by the public without causing threat to human health.

3. Based on the literature, the blackish water colour and odour is expected to persist for some time because the rain did not continue after a heavy short spell of rains that would have washed away the blackish colour. Hence, this water may be consumed after conducting some level of treatment.

4. The Committee recommends for the Regulatory Authorities for Mara River Basin to take charge on the implementation of Laws and Regulations

7.3.2 Medium-Term Recommendations

1) The committee recommends for Gazetting the Mara River wetland as a protected area in view of its uniqueness in-terms of size, proximity to the Lake Victoria, water source and its proneness to invasion by livestock keepers and peasants. This will strengthen enforcement of legislations for conservation and protection of the wetland.
2) The committee recommends for further detailed study to determine the species available in the wetlands and develop means to eradicate invasive species.
3) The committee recommends establishment of a joint conservation programme of Mara River Wetland which will involve all sectors that have a stake to that wetland; namely Water, livestock, land, environment and local government authorities.

7.3.3 Long-Term Recommendations

The committee recommends for the Government to establish sufficient rangelands to accommodate increasing number of livestock nationally to reduce pressure on encroached sensitive wetland and water sources.

8.0 REFERENCES

Bich Ngoc Tran, Shashwat Dhungana, Nimnee Bhatta; A Case Study on Water Quality and Ecosystem Management in Mara River Basin -Kenya and Tanzania, 2017.

Alexander Y. Segbefia, Emmanuel Honlah, Divine O. Appiah. Effects of water hyacinth invasion on sustainability of fishing livelihoods along the River Tano and Abby-Tano Lagoon, Ghana , Cogent Food and Agriculture, 2019.

Chande A I. Mara River And Associated Wetland as Refuge Threatened Indigenous Tilapiines of Lake Victoria, Tanzania, Tanzania, Journal of Agricultural Sciences, 2008.

Cox, G. W. Alien Species in North America and Hawaii: Impacts on Natural Ecosystems. Island Press, Washington, DC, 1999.

Dutton, C.L., Subalusky, A.L., Hamilton, S.K. et al. Organic matter loading by hippopotami causes subsidy overload resulting in downstream hypoxia and fish kills. Nat Commun 9, 1951, 2018.

Ellis, L. M., Crawford, C. S., and Molles, M. C., Jr. The role of the flood pulse in ecosystem-level processes in southwestern riparian forests: a case study from the middle Rio Grande. In: Flood Pulsing in Wetlands: Restoring the Natural Hydrological Balance, Middleton, B. A. Ed., John Wiley & Sons, NY, 2002.

Golam K. Global fish kills: Causes and Consequences, Technical Report. 2014.

Gupta, K.K., Aneja, K.R. & Rana, D. Current status of cow dung as a bioresource for sustainable development. Bio-resource. Bio-process, 2016.

Jim K. Kairu, "Biodiversity Action Plan for Sustainable Management: Mara River Basin" WWF, 2008.

Kipkemboi J, Kansiime F, Denny P. The response of Cyperus papyrus (L.) and Miscanthidium violaceum (K. Schum.) Robyns to eutrophication in natural wetlands of Lake Victoria, Uganda. African Journal Aquatic Science, 2002.

Muraza, M., Mayo, A.W. and Norbert, J. Wetland Plant Dominance, Density and Biomass in Mara River Basin Wetland Upstream of Lake Victoria in Tanzania. International Journal of Scientific & Technology Research, 2013.

Richardson, D. M., Pysek, P., Rejmanek, M., Barbour, M. G., Panetta, F. D., and West, C. J. Naturalization and invasion of alien plants: concepts and definitions. Diversity Distributions 2000.

Sainty, G., McCorkelle, G., and Julien, M. Control and spread of alligator weed Alternanthera philoxeroides (Mart.) Giseb., in Australia: lessons for other regions. Wetlands Ecology Management, 1998.

Thenya T. Analysis of macrophyte biomass productivity, utilization and its impacts on various ecotypes of Yala swamp, Lake Victoria basin, Kenya. In: Vlek PLG, Denich M, Martius C, Rodgers C, (editors). Ecology and development series no. 48. Gottingen: Cuvillier Verlag, 2006.

Weizhen Zhang, Mengqi Jiang, Jian He and Zheng Zheng, Black-odor water analysis and heavy metal distribution of Yitong River in Northeast China Xiyan Ji, , Water Science and Technology, 2017.

Yuhao Zhu & Lutz M. The effects of climate on decomposition of cattle, sheep and goat manure in Kenyan tropical pastures, 2020.

Zhiwei Liang, Michael Siegert, Wenwen Fang, Yu Sun, Feng Jiang, Hui Lu, Guang-Hao Chen and Shanquan Wang, FEMS Microbiology Ecology, 2018.

APPENDICES

APENDIX A: TIME PLAN FOR IMPLEMENTATION OF RECOMMENDATIONS MADE BY THE COMMITTEE

S/N	MAPENDEKEZO	WIZARA/TAASISI/MAMLAKA KIONGOZI	MHUSIKA	MUDA WA UTEKELEZAJI
1.	Kutokana na matokeo ya uchunguzi uliofanyika kwenye sampuli za maji ya Mto Mara na katika visima vilivyo karibu na ardhi oevu ya Mto Mara, imebainika kwamba maji hayana kemikali ambazo zinaweza kuhatarisha afya ya binadamu. Kamati inapendekeza shughuli za kijamii ambazo ni rafiki kwa mazingira zilizokuwa zinafanyika katika ardhi oevu ya mto Mara ziendelee kama ilivyokuwa awali.	• Mkuu wa Mkoa	• Sekretariati ya Mkoa	March – April 2022
2.	Uchunguzi uliofanyika kwenye sampuli za aina mbalimbali za samaki zimeonesha kutokuwepo na sumu yoyote, na hivyo, samaki wanaweza kuliwa pasipo kusababisha madhara kiafya. *(Ufuatiliaji wa magonjwa ya mlipuko, ufuatiliaji wa ubora wa Samaki)*	• Mkuu wa Mkoa	• Mkuu wa Mkoa • Sekretariati ya Mkoa	March 2022 – May 2022
3.	Kufuatia tafiti mbalimbali zilizofanyika duniani, rangi nyeusi kwenye maji inatarajiwa kuendelea kuwepo kwa muda. Hivyo, Maji ya mto Mara yanaweza kutumika baada ya kuyatibu katika ngazi ya kaya.	• Mkuu wa Mkoa	• RUWASA • Sekretariati ya Mkoa • Kaya	March 2022 - April 2022
4.	Kuna uhitaji wa haraka wa kutangaza ardhi oevu ya Mto	• OMR	• OMR (EMA2004,	April 2022 – Septemba

	Mara kama eneo la hifadhi kutokana na upekee wake kama vile ukubwa (ni kati ya ardhi oevu kubwa katika nchi za Kusini mwa Jangwa la Sahara likiwa na kilometa za mraba zaidi ya 423 km^2), kuwa karibu na Ziwa Viktoria, kuwa chanzo cha maji pamoja na kukabiliwa na uvamizi wa wachungaji wa mifugo na wakulima.		Sect.47 – OMR/NEMC) • OMR Sect. 56 (LVBWB/LGA) • Sheria ya Maji • TAWA	2022
5.	Kuna umuhimu wa kufanya utafiti wa kina ili kutambua baioanuai zilizo katika ardhi oevu ya Mto Mara na kuainisha mbinu za kuondoa na kuteketeza magugu maji.	• OMR	• OMR • Baraza La Hifadhi na Usimamizi wa Mazingira (NEMC) • Bodi ya Maji – Bonde la Ziwa Viktoria (LVBWB) • Taasisi za Utafiti (UDSM, UDOM, SUA, TAWIRI, TAFIRI, ARU, TPHPRA, NM-AIST)	July2022 – June 2023
6.	Kamati inapendekeza kwamba, Serikali iongeze vyanzo mbadala vya maji kwa ajili ya matumizi ya nyumbani kwa jamii inayozunguka eneo la Ardhi Oevu ili kupunguza utegemezi kwa Mto Mara hasa kwenye Ardhi Oevu.	• Wizara ya Maji	• Wizara ya Maji • RUWASA • LVBWB	April 2022 – December 2022

7.	Kuna umuhimu wa kuanzisha program ya pamoja ya uhifadhi wa Ardhi Oevu ya Mto Mara utakaohusisha Sekta Wadau kama vile Sekta ya Maji, Mifugo, Ardhi, Mazingira, Maliasili na Serikali za Mitaa (LGA).	• OMR	• OMR • Wizara ya Maji • LVBWB • RUWASA • Mifugo(Range Land) • Kamishna ya Ardhi • Tamisemi (Serikali za Mitaa) • TAWA	July 2022 – June 2022
8.	Serikali itenge maeneo ya Malisho ili kutosheleza idadi ya Mifugo inayoongezeka nchini kupunguza kasi ya uvamizi kwenye maeneo nyeti ya ardhi oevu na vyanzo vya maji.	• Wizara ya Mifugo na Uvuvi	• Wizara ya Ardhi, Nyumba na Maendeleo ya Makazi • Mkuu wa Mkoa (Sekretariati ya Mkoa) • Land Use Commission (Kamisheni ya Ardhi)	April 2022 – December 2022

APPENDIX B: LIST OF COMMITTEE MEMBERS

JAMHURI YA MUUNGANO WA TANZANIA

OFISI YA MAKAMU WA RAIS
MUUNGANO NA MAZINGIRA

BARAZA LA TAIFA LA HIFADHI NA USIMAMIZI WA MAZINGIRA (NEMC)

Form No. 1

ORODHA YA WAJUMBE

KAMATI MAALUM ILIYOUNDWA NA MH. DKT. SELEMANI JAFO (WAZIRI WA NCHI, OFISI YA MAKAMU WA RAIS - MUUNGANO NA MAZINGIRA) ILI KUCHUNGUZA NA KUBAINI CHANZO CHA UCHAFUZI WA MAJI KATIKA MTO MARA

NA.	JINA	TAASISI	WADHIFA	MAWASILIANO	SAHIHI
1	PROF. SAMWEL MANYELE	UDSM	MWENYEKITI	0755499373	
2	Dr. Samuel Gwamaka	NEMC	KATIBU	0758-074630	
3	Faraja Ngerageza	VPO-DOE	Mjumbe	0715-270188	
4	Dr. Charles Kasanzu	UDSM	Mjumbe	0784775656	
5	Daniel W. Ndiyo	GCLA	Mjumbe	0754475517	
6	Dr. Kessy F. Kilulya	UDSM	Mjumbe	0763369858	
7	Yusuph G. Kuwaya	RS MARA	Mjumbe	0769813628	
8	Dr Ndeluvoto P Mollel	TPHPA-ARUSHA	Mjumbe	07542270	
9	ASNATH A. KAUYA	PO	Mjumbe	0764435303	
10	BARAKA C. SEKADENDE	TAFIRI	Mjumbe	0767384438	
11	Renatus Shinhu	LVBWB	Mjumbe	0752220142	