Kenya's Water Towers Protection and Climate Change Mitigation and Adaptation (WaTER) Programme

Baseline Report: Water Quality in Mt. Elgon and Cherangany Forest Ecosystems/Catchment

Photo: River Nzoia at Mumias Bridge

Component 4: Science to Inform Design of Community-Level Actions and Policy Decisions

Project Report of March, 2018

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Kenya Forestry Research Institute (KEFRI)

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EXECUTIVE SUMMARY

The recognition of Kenya's water towers economic importance and threats posed by their degradation has necessitated rehabilitation and restoration actions. The European Union is supporting the Government of Kenya through WaTER Programme to help improve the management of key water towers of the country. Under component 4 of the WaTER Programme, The Kenya Forestry Research Institute (KEFRI), Kenya Forest service (KFS), Kenya Wildlife Service (KWS), the Kenya Water Towers Authority (KWTA) and the participating County Governments are working together to improve the management of Mt. Elgon and Cherangany forest ecosystems. The management of these forested water towers involves application of scientific information in terms of the technologies required for restoration processes. Kenya's forested water towers store rainwater, regulate river flows and prevent runoff. The Mt Elgon and Cherangany forest ecosystems are part of the Kenya's water towers and are the major sources of the main rivers draining into Lakes Victoria and Turkana. These two forest ecosystems are threatened by increase in local population causing environmental degradation and disruption in the catchment area which result in drying up of streams, pollution and reduction in water level in rivers, lakes and the general watershed. The pollution of water resources come from both point and non-point sources and encroachment from water catchment areas. Water quality assessment defines the condition of the water to provide the basis for detecting trends and information on the cause-effect relationships.

The objective of this study was to conduct a baseline survey to provide information on the status of water quality in the catchment and an overview of pollution levels, sources and possible mitigation measures. Water and sediments from 26 spatial distributed sites on rivers in the catchment were sampled and analyzed. The water quality (physical, chemical and biological) was assessed through analysis of water and sediments. Both water and sediments were analyzed following the analytical standard methods. All the rivers in the catchment contained high levels of iron and turbidity which exceeded environmental limits in Kenya. There was no pollution of water from heavy metals. River Nzoia near Webuye town and Sigomre bridge were the most polluted waters with levels of nitrates, iron, copper, chromium, BOD and COD being above the accepted limits in the environment in Kenya.

For sediments; copper, magnesium and iron were high in the upper catchment of river Nzoia (foot slopes of Mt Elgon) due to highly intensive agricultural activities in Kiptogot, Chepchoina and Endebess regions. Nitrates and phosphates in sediments were high in the lower catchment.

The recommended interventions to manage point or non-point pollution sources include: land and soil conservation to reduce erosion, precision in fertilizer usage, proper sewage and industrial effluent treatment and disposal. The mitigation measures should be at the sub-catchment level to reduce land, soil and water pollution. Technologies for soil and water conservation including afforestation on bare lands, control of overland flow, reduction on river bank cultivation and conservation agriculture practices will reduce pollution and conserve the environment. Focus on agro-forestry practices and forest rehabilitation technologies like planting indigenous trees and bamboo on riparian areas should be given priority as they will contribute towards increasing forest cover in the country. For future water quality monitoring, hydrology of the rivers and soil characteristics for different land uses in the sub-catchments should be mapped to provide a holistic approach towards reducing water pollution in the catchment.

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BOD Biochemical Oxygen Demand

Cfu Colon Forming Units

COD Chemical Oxygen Demand

GESAMP Group of Experts on the Scientific Aspects of Marine Environmental Protection

KEBS Kenya Bureau of Standards

KEFRI Kenya Forestry Research Institute

KFS Kenya Forest Service

KWS Kenya Wildlife Service

KWTA Kenya Water Towers Authority

mS/m Millisiemens/meter

NEMA National Environmental Management Authority

NTU Nephelometric Turbidity Units

PPM Parts Per Million

PTFE Pertetrafluoroethylene

THMs Trihalomethanes

USEPA United States Environmental Protection Agency

WHO World Health Organization

CHAPTER ONE
INTRODUCTION

1.1 Background

Mt Elgon and Cherangany hills forest ecosystems are part of the Kenya's water towers and are the major sources of rivers draining into Lakes Victoria and Turkana (KFS 2016; Rhino Ark, 2014). These ecosystems also recharge ground-water aquifers, reduce soil erosion into rivers and regulate local climatic conditions as well acting as carbon reservoirs and sinks (Rhino Ark, 2014). The two forested ecosystems are threatened by human population pressure causing land, soil and water degradation in the catchment area (KFS 2016; Adoyo and Wangai, 2012). The degradation of land, soil and water lead to drying up of rivers, pollution and reduction in water bodies' levels in the catchment. Deforestation of these water towers as a result of human settlement and agriculture has increased surface runoff leading to soil erosion. The eroded soils cause siltation of water bodies reducing discharge volumes and causing floods. For instance, flooding is a perennial problem in the lower River Nzoia which sometimes causes loss of lives and property destruction (Shilenje and Ogwang, 2015). Water pollution in the catchment is from both point and non-point sources which are mostly anthropogenic (Hecky et al., 2000; Twesigye et al., 2011). High levels of phosphates, nitrates and banned compounds such as aldrin, dieldrin and DDT in water have been reported in River Nzoia Basin which has been attributed mainly to agricultural activities (Twesigye et al., 2011). Furthermore, nutrients mostly nitrates, phosphates, total organic carbon among others from surface runoff are a major cause for eutrophication in Lake Victoria resulting in massive algae blooms, water hyacinth infestation and oxygen depletion in water (Hecky et al., 2000; LVEMP, 2004; Wogenga'h, et al., 2004).

1.2 Component 4 of WaTER programme: Science to inform design of community-level actions and Policy Decisions

Scientific data and information provide the required ingredients for informed decision making in forest restoration processes as well as the baseline for monitoring and evaluation of the effectiveness of the interventions. For a long time, decisions on the management of Kenya's water and other key natural resources have neglected the incorporation of scientific information. This omission has often resulted in poor decisions which are often conflicting hence resulting in accelerated degradation of the resources.

The Kenya Forestry Research Institute (KEFRI), working with key collaborators in the sector including public, private and non-governmental organizations have developed technologies and procedures which can enhance decision making options and systems to help improve the management of key water towers of the country. Under component 4, KEFRI is working with key organizations including the Kenya Forest service (KFS), Kenya Wildlife Service (KWS), the Kenya Water Towers Authority (KWTA) and the participating County Governments to improve the management of Mt. Elgon and Cherangany forest ecosystems for the management of western Kenya water resources.

Overall Objective of Component 4 of WaTER programme

To contribute to poverty reduction and sustainable livelihoods by applying scientific principles to inform design of community level actions and national policy decisions on rehabilitation and conservation in Cherangany and Mt. Elgon water towers.

Specific Objectives of Component 4 of WaTER programme

1. To undertake a baseline survey on biophysical and socio-economic status of the 2 Ecosystems to inform rehabilitation and conservation actions
2. To pilot a Payment for Ecosystem services (PES) model for enhanced collaboration between land owners and water users
3. To explore livelihood opportunities associated with forest conservation and rehabilitation
4. To demonstrate intervention of selected rehabilitation and conservation technologies for improved NRM, SLM and AWM in the 2 water towers
5. To build capacity of the participating counties within the 2 Ecosystems in NRM, PES, and germplasm development
6. To promote large scale production of bamboo seedlings, planting and train artisans on value addition in the 2 Ecosystems
7. To promote the development of nature based enterprises targeting women, the youth and people with disabilities
8. To develop a communication and knowledge management strategy for the programme
9. To monitor and evaluate programme activities

Specific Objective1 of Component 4 of WaTER programme: To undertake a baseline survey on biophysical and socio-economic status of the 2 Ecosystems to inform rehabilitation and conservation actions**.** One of the outputs of this Specific Objective1 is to provide information on the current status of the 2 ecosystems in terms of water quality, sedimentation and erosion levels and hydrological features in the ecosystems to inform rehabilitation and conservation actions.

1.3 ER1:6: Water Quality Assessment and Monitoring

Water quality assessment and monitoring is one of the activities (**ER1:6**) to be implemented under this Project **(Specific Objective1 of Component 4 of WaTER programme)**. Therefore, as part of implementing this activity, a baseline report on the water quality status in the (Mt. Elgon and Cherangany forest ecosystems was required to form a basis for future monitoring activities.

Water quality assessment is defined as the overall process of evaluation of the physical, chemical and biological nature of water in relation to natural quality, human effects and intended uses, particularly uses which may affect human health and the health of the aquatic system itself (WHO, 1991); GESAMP (1988). Water quality monitoring is the actual collection of information at set locations and at regular intervals in order to provide the data which may be used to define current conditions, establish trends etc. (WHO (1991); GESAMP (1988). Water quality assessment includes the use of monitoring to define the condition of the water, to provide the basis for detecting trends and to provide the information enabling the establishment of cause-effect relationships. Important aspects of an assessment are;

- Interpretation and reporting of the results of monitoring
- Making of recommendations for future actions

The main reason for the assessment of the quality is to verify whether the observed water quality is suitable for intended uses. The use of monitoring has also evolved to help determine trends in the quality of the aquatic environment and how that quality is affected by the release of contaminants, other anthropogenic activities, and/or by waste treatment operations (impact monitoring). More recently, monitoring has been carried out to estimate nutrient or pollutant fluxes discharged by rivers or ground waters to lakes and oceans, or across international boundaries. Monitoring to determine the background quality of the aquatic environment is also now widely carried out, as it provides a means of comparison with impact monitoring.

It is also used simply to check whether any unexpected change is occurring in otherwise pristine conditions, for example, through the long range transport of atmospheric pollutants. Monitoring, survey and surveillance depend on the kind of data collected.

In Kenya, the Environmental Management and Coordination, (Water Quality) Regulations 2006 of the Environmental act of 1999, outlines the permitted levels of water quality parameters for different uses (Kenya Gazette, 2006). Changes in the physical and chemical parameters of water affect water quality and they mainly include: pH, dissolved oxygen, biological oxygen demand (BOD), chemical oxygen demand (COD), turbidity, phosphates, nitrates, electrical conductivity, and heavy metals among others. The pH of river water is vital to aquatic life and affects the ability of aquatic organisms to regulate basic life-sustaining processes. Alkalinity is a measure of all the substances in water that can resist a change in pH when acid is added to the water (USEPA), (1999). Turbidity is a measure of dissolved coloring compounds in water and can be attributed to presence of organic and inorganic materials. The suspended solids in water are closely linked to erosion and nutrient transport, industrial waste and chemicals used in agriculture. Nitrogen is of great importance to the quality of water in rivers, and as a nutrient in water may cause eutrophication. Nitrite which is an intermediate in oxidation of ammonia and nitrate is toxic to aquatic life and is commonly found in sewage effluents which are rich in ammonia.

The biochemical oxygen demand (BOD) measures biologically oxidized pollutants while chemical oxygen demand (COD) measures the chemically oxidized ones in water. BOD is mostly associated with wastewater from sewage systems while COD associated with industrial effluents. In the River Nzoia basin, the dissolved oxygen and BOD have been found to fluctuate with rainfall patterns which affect the discharge volumes (Kanda et al., 2015). The purpose of this study was to provide information on the water quality status in the catchment area and give an overview of the pollution levels, interventions and the mitigation measures. The water quality was assessed through analysis of water and sediments for physical and chemical parameters.

1.4 Purpose and objectives of the activity (ER1:6 Water Quality assessment and monitoring)

The purpose of this activity was to conduct a baseline study to provide information on the initial status of water quality in the catchment area and give an overview of the pollution levels. This was achieved by sampling, analyzing and mapping water quality along rivers and reservoirs in the catchment

The report provides baseline information on various indicators including:

- Status of water quality in the catchment which will form a benchmark for long-term monitoring of each pollutant
- Maps for pollutant levels and their sources mostly from anthropogenic activities like waste treatment and agriculture common in the catchment area
- Key interventions and mitigation measures on how to manage pollution levels and their sources in the catchment area. Focus mostly on agro-forestry and soil conservation technologies for rehabilitation.

CHAPTER TWO

METHODOLOGY

2.1 Study area: Mt. Elgon and Cherangany forest ecosystems/River Nzoia Catchment

Mt. Elgon forest ecosystem forms the upper catchment area for three major rivers: Nzoia, Malakisi and Sio which drain into Lake Victoria and transverse through Bungoma, TransNzoia, Kisumu, Siaya and Busia counties. The Cherangany hills forest ecosystem form the upper catchments of rivers Kerio and Turkwell which drain into Lake Turkana and transverses through West Pokot and Elgeyo Marakwet counties. The streams from Mt. Elgon forest and west of the Cherangany watershed feed the Nzoia river system, which flow into Lake Victoria and streams The River Kapolet originating from Kapolet Forest is a tributary and source of river Nzoia and provides water consumed in Trans Nzoia and Bungoma counties.

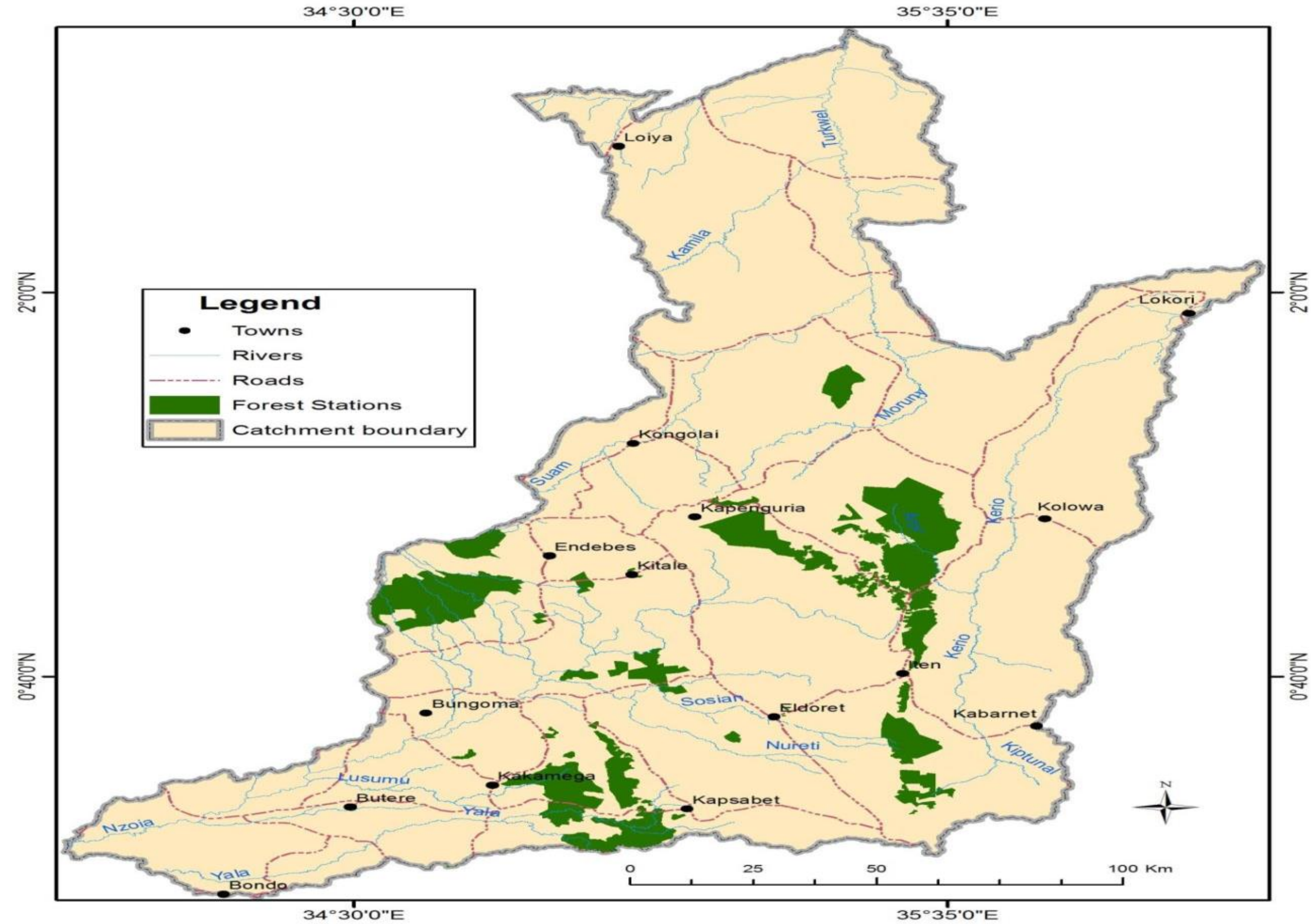

Figure 1: Mt. Elgon and Cherangany forest catchment areas

Table 1: Cherangany Hills and Mt Elgon catchment areas, Major rivers and Threats

Catchment Area	Location / County	Main Catchment / Major Rivers/streams	Threats
Mt. Elgon Consists of 1000km square of state forest, national park and national reserve located north of lake Victoria on the Kenya and Uganda border. Mt. Elgon forms the upper catchment area for two major rivers: Nzoia and Turkwell rivers. It also provides water to the Malakasi river that crosses the small scale farming area south of the mountain before entering Uganda.	Western Kenya (cross-border with Uganda). **Mt. Elgon** • Bungoma • Trans Nzoia • Kisumu • Siaya • Busia	Suam/Turkwell (Lake Turkana): Nzoia and Malakisi, Sio, Suam, Kaibei, Kimothon, Mubere, Kiptogot, Suam, Kapteka, Kamjong, Chepchoina, Labaa, Kibisi, Kimilili, Kapkateny, Kitamani, Chepkungwi, Kikuk and Chepbirbey (Lake Victoria)	Forest encroachment, high water use, illegal logging, charcoal burning, firewood collection, illegal grazing, over-cultivation, fires
Cherangany Hills Consists of a series of hills with natural forests and plantations form the western escarpment of Kerio Valley 1,900 – 3,000m a.s.l. This is 1,200 km square of state forest covering the North western range on the west of the Gregorian Rift Valley. The Cherangany hills form the upper catchments of the Nzoia, Kerio and Turkwell rivers.	Rift Valley **Cherangany hills** • West Pokot, • ElgeyoMarakwet • UasinGishu • Kakamega • Vihiga • Nandi	Lake Victoria, Turkana and Baringo Nzoia, Turkwel (source of Turkwel Gorge dam), Chebiemit (source of Chebara dam for Eldoret Municipality), Sosian, Chepkoilel, Kapteret, Suguta, Kerio and others	Forest encroachment, high water use, illegal logging, charcoal burning, firewood collection, illegal grazing, over-cultivation, fires

2.2 Spatial distribution of Sites/Rivers for water Quality monitoring

Table 2: Spatial distribution of sampling sites on rivers for water quality

Name of River/Site	GPS coordinates
1. River Chepkaitit near Kapcherop town bridge (S1)	E 759718 N 114865
2. River Seum at Mito mbili bridge (S2)	E 748821 N 109284
3. River Chepkaitit at chepkaitit bridge (S3)	E 749216 N 105057
4. River Kapterit at Mwaita bridge (S4)	E 744785 N 113891
5. River Nzoia at Kapolet North water treatment site (S5)	E 740840 N 125332
6. River Nzoia at Kapolet bridge (S6)	E 739806 N 126279
7. River Koitobos (Koitobos bridge) (S7)	E 73048 N 113274
8. River Nzoia at Moiben bridge (S8)	E 737301 N 102361
9. River Moiben at Moiben bridge (S9)	E 737336 N 101603
10. River Kiptogot near Chepchoina centre (S10)	E703463 N 10126765
11. River Mubere at Mubere bridge (S11)	E704720 N 10123541
12. River Kaibei/Koitobos (S12)	E 704883 N 10122810
13. River Sabwani at Endebess bridge (S13)	E 706436 N 119732
14. River Nzoia at Moi'sbridge Town bridge (S14)	E 735602 N 97701
15. River Sosian downstream at Kamagut bridge (S15)	E 742637. 20 N 61031.76
16. River Sosian Eldoret downtown bridge (S16)	E 754370. 32 N 56014.889
17. River Sergoit/Chepkoilel near Tarbo bridge(S17)	
18. River Kipkaren at Kipkaren Town bridge (S18)	E 718672.91 N 67095.70
19. River Nzoia at Brigadier bridge in Soysambu (S19)	E 729591.44 N 84121.08
20. River Kiminin at Kiminin bridge (S20)	E 714458.89 N 85338.48
21. River Nzoia at Webuye bridge (S21)	E 701083.88 N 64808.780
22. River Kuywa at Lake Victoria Basin water treatment site (22)	E 689170.71 N 68588.14
23. River Nzoia at Mumias bridge (23)	E 665470.78 N 40837.75
24. River Lusumu at Mumias-Musanda Road Bridge 24)	E 664630.91 N 33860. 39
25. River Nzoia bridge at Sigomre/Sigomere bridge (S25)	E 649271.31 N 27541.15
26. River Nzoia at Ruambwa bridge (S26)	E 621665.007 N 12979.32

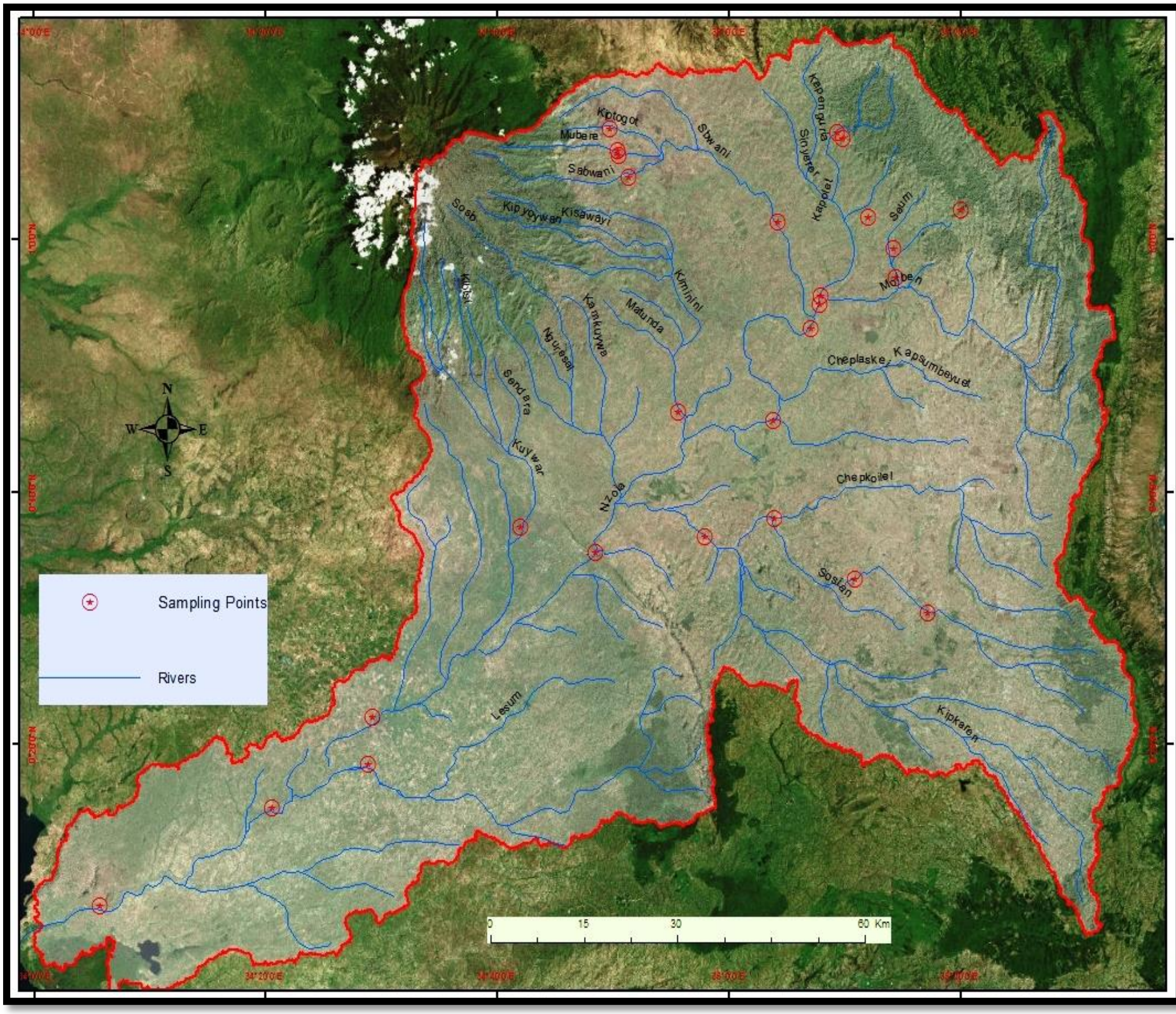

Figure 2: A map of water and sediment quality monitoring sites in the River Nzoia catchment

2.3 Assessment of Water Quality

The water quality was assessed through analysis of water, sediments and aquatic organisms (selected points). The analyses included: pH, micro- and macro element, hardiness, turbidity, BOD, COD, heavy metals and fecal bacteria compared against Kenyan, USEPA and WHO standards.

2.3.1 Sampling period and conditions

The sampling period for this activity was 22nd to 27th August 2017. This was done towards the end of long rains in the upper catchment areas of Mt. Elgon and Cherangany ecosystems at the time where the staple food crops mainly maize and potatoes had not been harvested.

The lower and middle catchment areas were experiencing shorts rains with maize being harvested and planting of other crops being done. The rains were being experienced in all of the sampling sites.

2.3.2 Water sampling

For rivers, the primary sampling point is in the surface water layer (0-5 cm from the surface) at the center of the main flow. However, the top 1-2 cm of the water surface layer was avoided so as not to collect floating dust, oil, solids etc. The sampling process ensured representative water samples were collected taking into account factors such as the weather. The samples were collected from three equidistant positions i.e. both sides of the river banks and at the center of the river to make 3 replicates. The plastic improvised grab sampler bottles were used for small rivers while plastic buckets attached to timber poles used for big rivers. The water samples were taken by plunging the bottle underneath the surface and water collected facing upstream direction.

The sample storage containers used were of pertetrafluoroethylene (PTFE) material which were sterilized and contamination free and rinsed several times with deionized water. The samples were mixed together from which a representative sample of about 500ml was taken for laboratory analysis. For the samples to be analyzed in the laboratory, the samples were transported in the cooler box.

2.3.3 Sediment sampling

In this activity, the sampling points were exact or near the points where water samples were taken because the sediment study was linked to a water quality study. The points were sited at those parts of the rivers where sedimentation was occurring (sediment deposition). The sediment samples came from three equidistant positions within a 50 m diameter radius i.e. at the either sides of the river banks and the center of the river. The plastic trowel/hand spades were used for sampling sediment/mud. The samples were mixed together from which a representative sample of about 500g was taken for laboratory analysis. The sediment/mud was scooped from 10 cm depth from the surface river bed. The sediment sampling was done at the same time as the water sampling. The following information was taken during sample collection and labeling

- Sampling date
- Sample name (code)
- Sampling site's name (code)
- Accurate position for the sampling site (G.I.S. position)
- General environmental conditions (landscape, the state of the tide or river flow)
- Weather conditions (cloud cover and air temperature)

2.4 Laboratory Analysis: Parameters and Protocols

The following parameters were measured for both water and sediment quality in the laboratory;

Table 3: Parameters measured for water

Parameters	**Units**	**Methodology**
Nitrate	Mg/L	Spectrophotometric
Nitrite	Mg/L	Spectrophotometric
Phosphate	Mg/L	Spectrophotometric
Lead	PPM	ISO 8288
Zinc	Mg/L	Spectrophotometric
Iron	Mg/L	Spectrophotometric
Copper	Mg/L	Spectrophotometric
Chromium	Mg/L	Spectrophotometric
Total Hardness	Mg/L	Spectrophotometric
Alkalinity	Mg/L	Spectrophotometric
Total Dissolved Solids	Mg/L	Potentiometric
Total Suspended Solids	Mg/L	Gravimetric
Turbidity	NTU	Potentiometric
Electrical conductivity	mS/m	Potentiometric
pH		Potentiometric
Temperature	°C	Potentiometric
COD	Cfu/100ml	Reactor Digestion
BOD	Mg/L	Respirometric
Cadmium	PPM	ISO 5961
Mercury	PPM	USEPA-245
Arsenic	PPM	ISO 11969
Faecal Coliforms	Cfu/100ml	Membrane Filtration
Total Coliforms	Cfu/100ml	Membrane Filtration

Table 4: Parameters measured for sediments

Parameters	Units	Methodology
Nitrate	PPM	Total (Spectrophotometric)
Phosphate	PPM	Total (Spectrophotometric)
Total Organic Carbon	%	Loss on Ignition
Zinc	PPM	Atomic absorption spectrophotometry
Iron	PPM	Atomic absorption spectrophotometry
Copper	PPM	Atomic absorption spectrophotometry
Magnesium	PPM	Atomic absorption spectrophotometry
Electrical conductivity	mS/m	Potentiometric

2.4.1 Parameters measured onsite in the field during sampling

- Temperature (water and sediments)
- pH (water and sediments)
- Electrical conductivity(water and sediments)
- Turbidity (water)

Figure 3: Bare and cultivated hill-tops of Cherangany

CHAPTER THREE
RESULTS FOR WATER AND SEDIMENT QUALITY ANALYSIS

3.1 Nitrates and Nitrites

In this study, river Nzoia at Webuye Bridge recorded the highest nitrate levels of 13.3 mg/L against acceptable limit of 10 mg/L (NEMA, 2006). Similarly, high levels of nitrites of 0.099 mg/L against acceptable limits of 0.1 mg/L (KEBS, 2014) were recorded at the same site. The highest nitrite levels of (0.167mg/L) were recorded at Sosiani river downstream at Kamagut bridge. The nitrate levels of rivers Chepkaitet (Chepkaitet bridge), Koitobos (Koitobos bridge), Sosian at Kamagut bridge and Kipkaren at Kipkaren bridge (6.3, 5.4, 5.1 and 5.1 mg/L) were below the acceptable limits of 10 mg/L but require close monitoring as their levels were relatively high (Figure 4, Figure 5, Figure 6, Figure 7 and Figure 8).

Nitrate and nitrite levels in both water and sediment had similar trends in selected sites notably Sosiani River whereby the high levels in water correlated with the sediment levels. In addition, the farming activities around the sampled areas could also have contributed to the nitrate levels in sediments (Figure 9). The undetected levels of nitrate in sediments in some sites were largely attributed to high solubility of nitrates in water (Figure 4).

The high levels of nitrates and nitrites were attributed to pollution from the nearby town industries and agricultural activities in the region. The high levels of nitrate in the river Nzoia catchment have been associated with water hyacinth and algae blooms in the Lake Victoria adversely affecting fish and other aquatic animals. According to the United States Environmental Protection Agency (USEPA) (1999), consumption of water by humans containing high levels of nitrate in excess of 10 mg/L could lead to adverse health effects such as methemoglobinemia ("blue baby" syndrome).

Figure 4: Nitrate levels in water

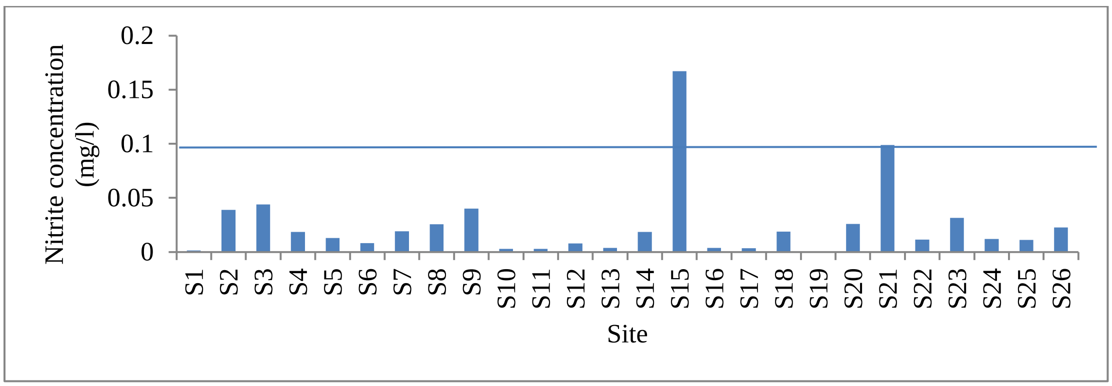

Figure 5: Nitrite levels in river water

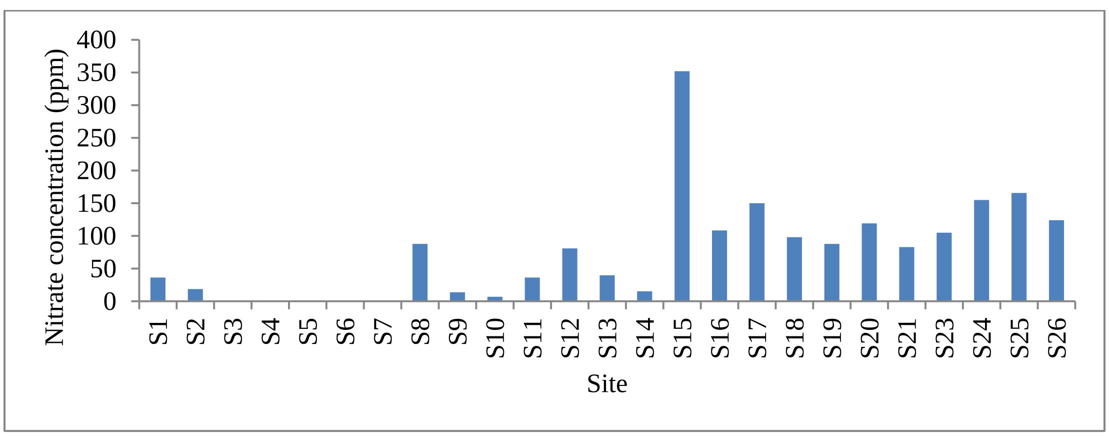

Figure 6: Nitrates in river sediments

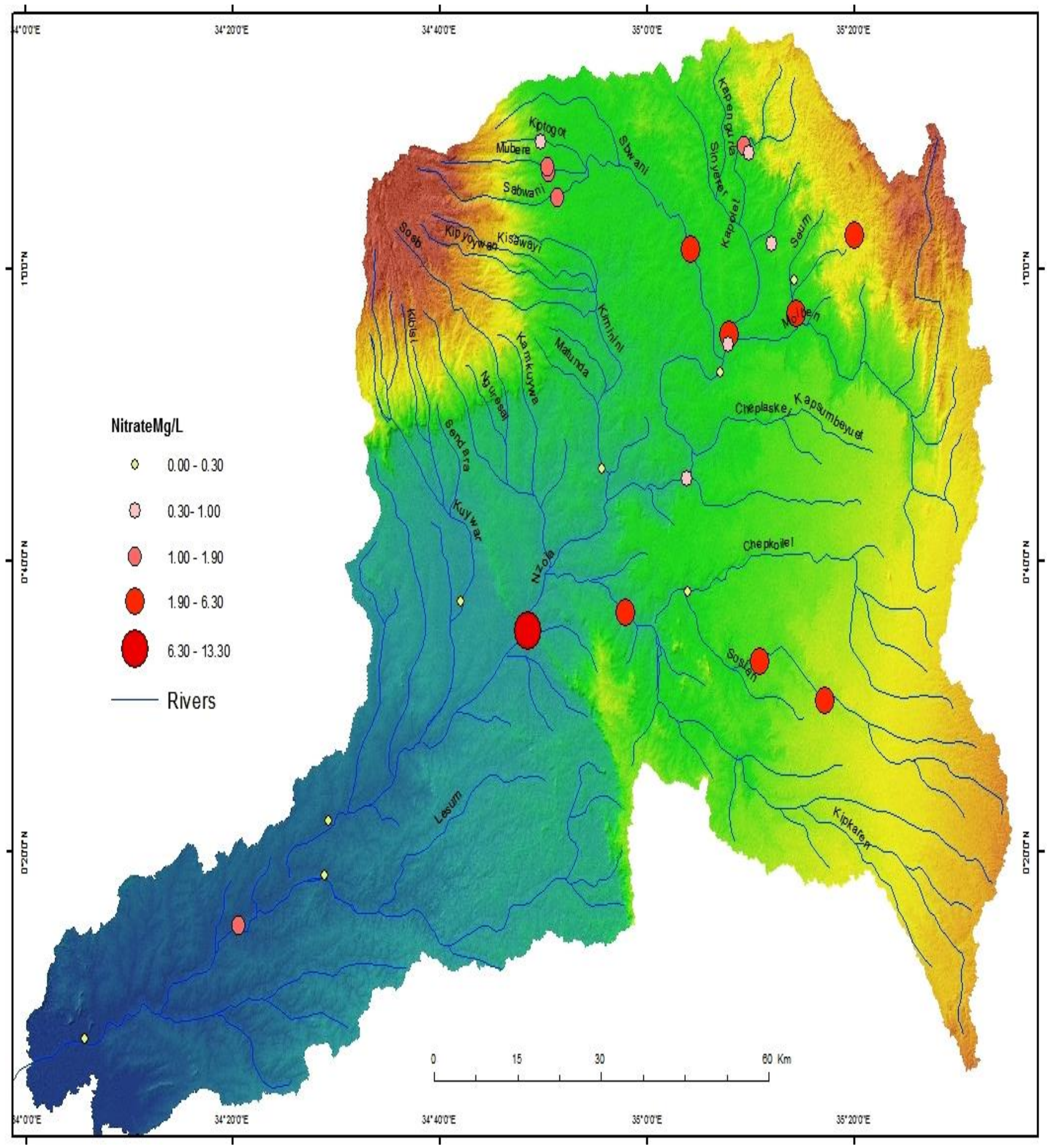

Figure 7: Pollution map for Nitrate levels in river water

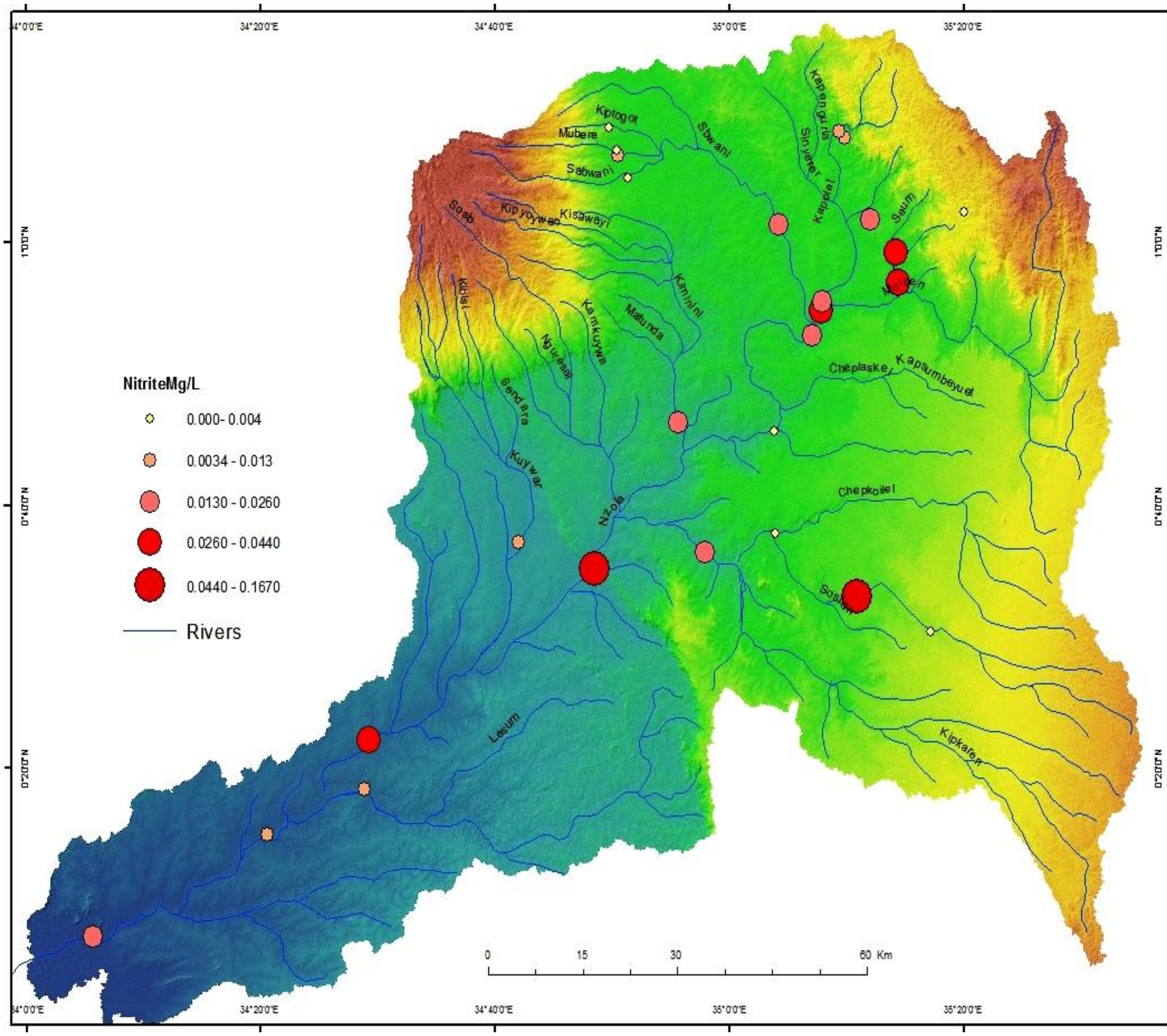

Figure 8: Pollution map for Nitrite levels in water

Figure 9: River Kaibey/Koitobos in Mt. Elgon Forest Ecosystem polluted due to intensive agricultural activities in the area

3.2 Phosphorus/Phosphates

Phosphorus, like nitrogen is an important nutrient for plants and algae. Since phosphorus is in short supply in most fresh waters, much of the phosphorus found in rivers originate from surface runoffs containing soil-bound phosphate from farms and fertilizers, effluent discharges from industries and wastewater treatment plants.

Phosphate concentrations recorded from the rivers sampled in Mt Elgon and Cherangany forest ecosystems, were significantly low except for rivers Sabwani, Sosian and Kiminini recording concentrations of 2.56mg/l, 2.49 mg/l and 41.5 mg/l respectively against acceptable limit of 2.2 mg/L (KEBS, 2014) as shown in figure 10 and 12. These high phosphate concentrations could mainly be attributed to surface runoffs from farming activities and livestock waste in the surrounding areas. For river Sosiani, the high levels of phosphates were attributed to municipal waste from Eldoret town. With this high levels of phosphates, there is likely to be eutrophication downstream (lower catchment) of river Nzoia resulting to problems like excessive growth of water hyacinth as witnessed at Ruambwa and Sigomre sites along River Nzoia. In addition, this eutrophication also depletes dissolved oxygen levels in water which is detrimental to aquatic life.

For sediments, total phosphorus concentrations in sediments varied considerably ranging from 29 ppm to 619 ppm. The lowest concentrations of 29 ppm recorded were at River Nzoia at Kapolet North water treatment site which is the source of River Nzoia in the Cherangany forested hills which was less polluted. High concentrations recorded at rivers Chepkaitet, Seum, Sosian and Nzoia at Webuye town of 544 ppm, 609 ppm, 619 ppm and 583 ppm respectively (Figure 11) could be as a result of erosion from run-offs, non-point sources of pollution such as municipal waste, waste water, sewerage, and farming activities; and point-source pollution from industries around Webuye town. The amount of phosphorus present in a water body depends on both the external phosphorus load and its release and retention in the sediments. Sediments act as a sink where phosphorus can be stored, and as a source of phosphorus for the overlying river water.

To manage these high levels of phosphates in rivers, mitigation measures should be centered at sub-watershed level because of diversity in pollution sources (non-point pollution).The interventions should be geared towards soil and land conservation.

This will entail a host of technologies for conservation including but not limited to afforestation on bare lands, putting up of structures to control overland flow, stop cultivation activities on the river banks and constructing silt/sediment traps mostly on roads to reduce sedimentation in rivers.

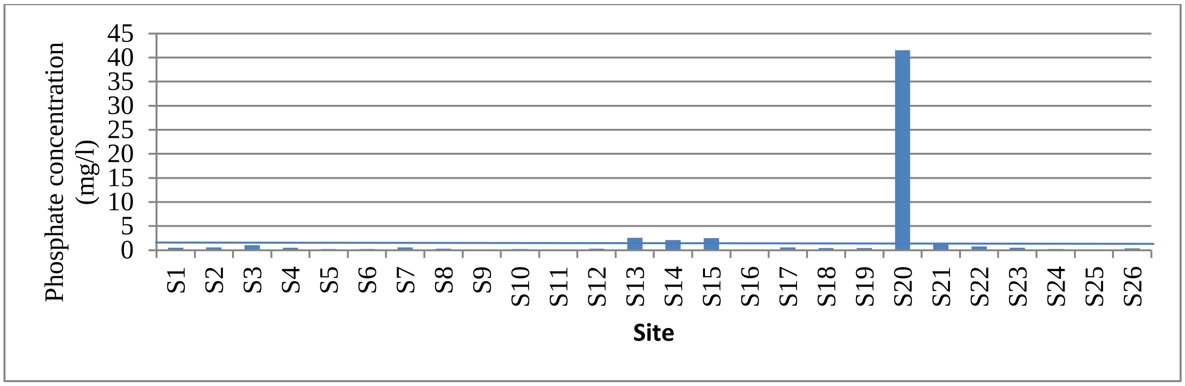

Figure 10: Phosphates levels in water

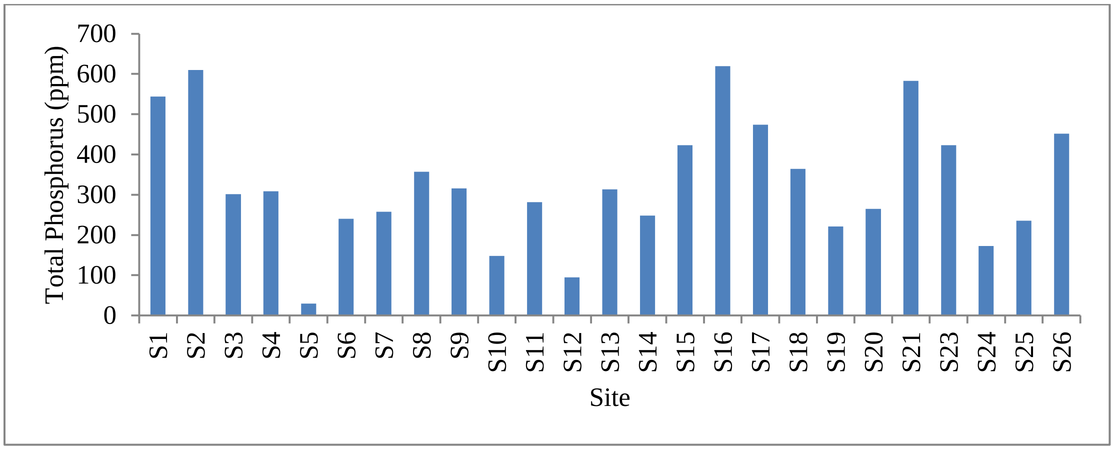

Figure 11: Total phosphorous in sediments

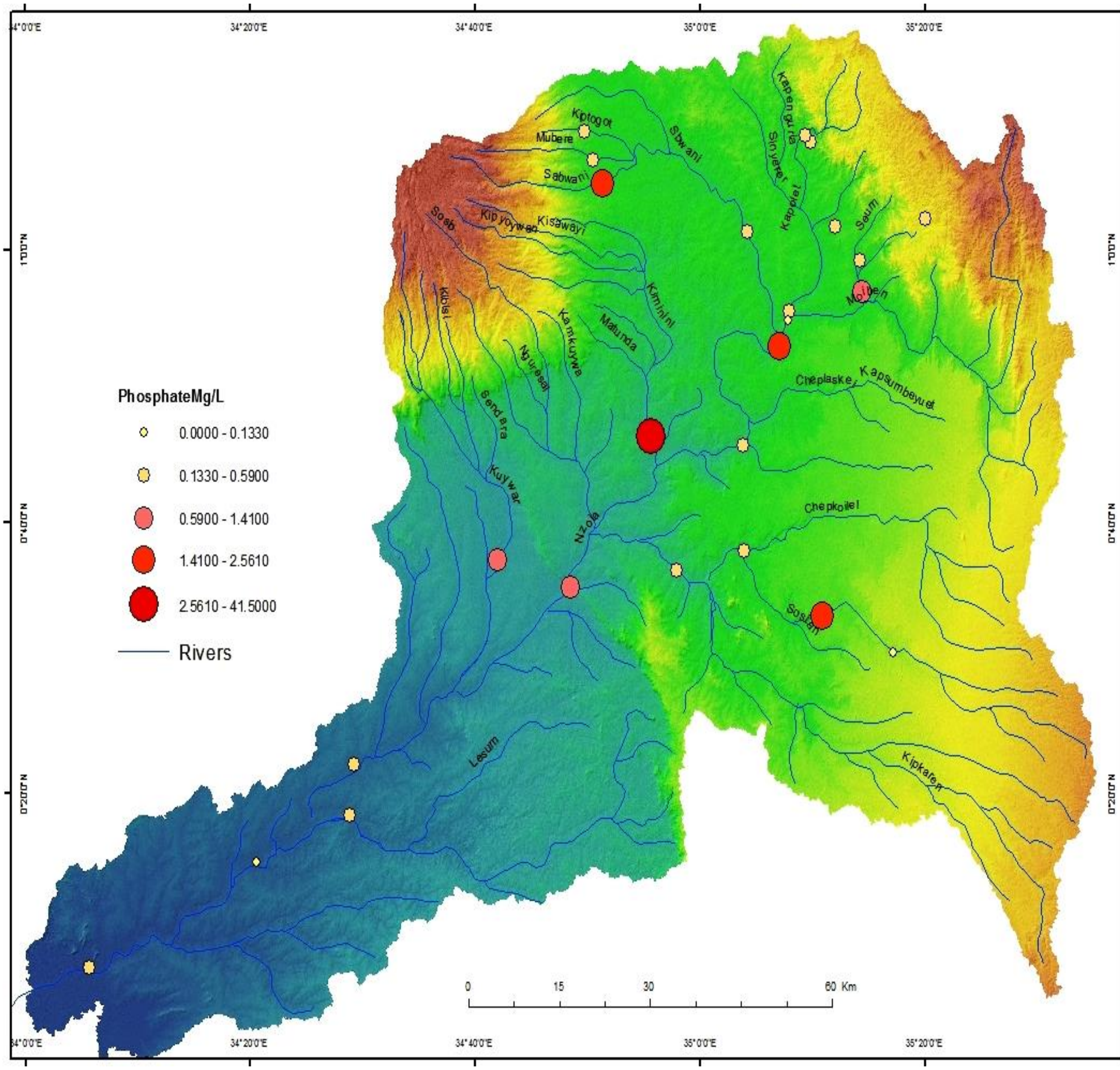

Figure 12: Pollution map for Phosphate levels in water

3.3 Turbidity

Turbidity indicates the clarity (murkiness) of water and provides an insight on the inorganic particles present as total suspended solids. Turbidity levels of the sampled rivers were high (45-700 NTUs) and beyond acceptable limits set for drinking water in the environment in Kenya (KEBS, 2014) i.e. 25 NTUs and therefore requires timely interventions. These high levels were attributed to seasonal weather variations and land use activities at the time of sampling whereby it was in a rainy season with high rates of soil being eroded into rivers through surface runoff (Figure 15). Furthermore, high turbidity was also synonymous with big rivers perhaps due to high sediment load as a result of high discharge volumes as shown both in the upper and lower catchment areas of river Nzoia near the mouth of Lake Victoria (Figure 13; Figure 14). For instance, River Nzoia at Kapolet Bridge (471 NTUs), River Koitobos at Koitobos Bridge (597 NTUs), and the larger River Nzoia at Moi'sbridge bridge (427 NTUs), Sigomre and Ruambwa bridge (664 NTUs), sites are big rivers which were very turbid (Figure 13). Low clarity levels in water reduce sunlight absorption causing high temperatures which in turn lower oxygen levels. This is detrimental to aquatic life as photosynthesis is also affected due to reduced light penetration.

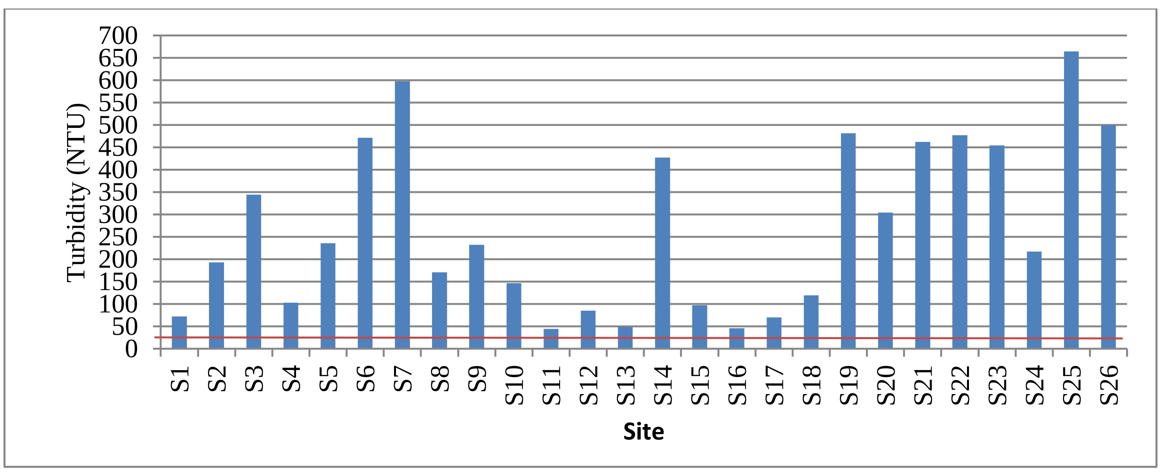

Figure 13: Turbidity levels of water

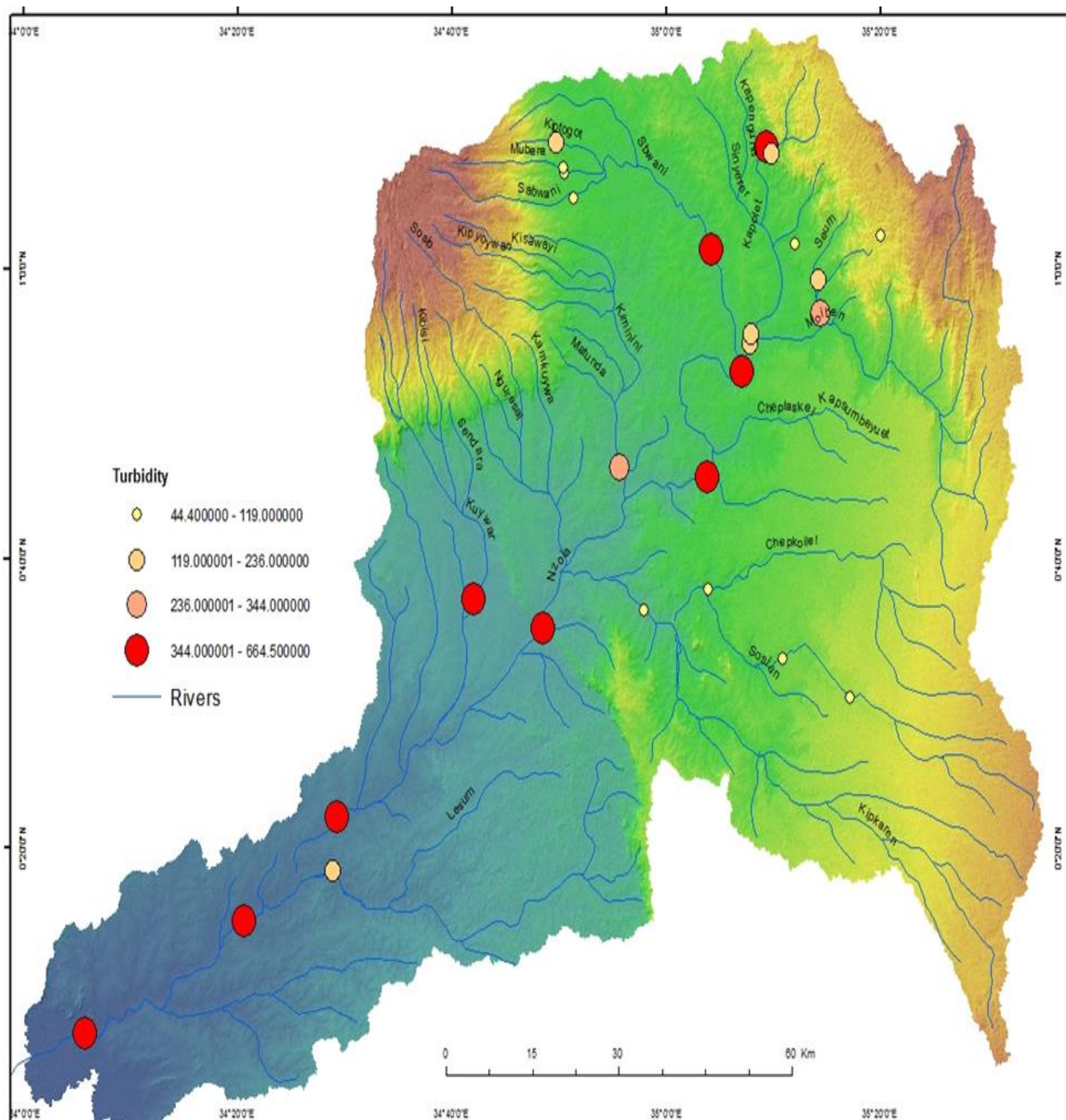

Figure 14: Pollution map for Turbidity levels in water

Figure 15: Highly turbid surface runoff waters caused by soil erosion from farms around Koitobos, Cherangany Forest ecosystem

3.4 Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)

The biochemical oxygen demand (BOD) is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period. BOD is similar in function to chemical oxygen demand (COD), in that both measure the amount of organic compounds in water. However, COD is less specific, since it measures everything that can be chemically oxidized, rather than just levels of biologically active organic matter.

Both parameters are used to grade the quality of waste waters mostly as industrial or domestic effluent discharges and their potential to pollute surface waters in the natural environment.

High BOD/COD levels in river water results in low levels of dissolved oxygen due to accelerated bacterial growth which may lead to negative ecological issues especially in the aquatic ecosystems mostly fish and many aquatic insects.

In this study, both BOD and COD levels had similar trends in the sampled sites with nearly all the sampled sites/rivers being within the acceptable limits in the environment. River Chepkaitet at Chepkaitet bridge, river Koitobos at Koitobos bridge and the larger river Nzoia near Webuye town had levels above the threshold value of 30 mg/l (BOD) and 50 mg/l (COD) permitted in the environment (NEMA, 2006) as shown in the figures 20, 21, 22 and 23. High BOD/COD levels in river Nzoia near Webuye town was attributed to industrial effluents from industries around the town and sewage treatment plants. For Koitobos and Chepkaitet sites, organic materials from highly fertilized farms and pesticides especially flowers and cereal maize farms in the area were the most likely causes of the high BOD/COD levels (Figures 16, 17, 18 and 19). In river water quality, BOD is mostly associated with wastewater from sewage systems while COD associated with industrial effluents. To reduce or manage high BOD/COD values, proper design of waste water and sewage treatment plants should be done especially aeration. Therefore, the waste water effluent and sewage discharges should be monitored in the affected areas as a way of reducing point source pollution in the rivers.

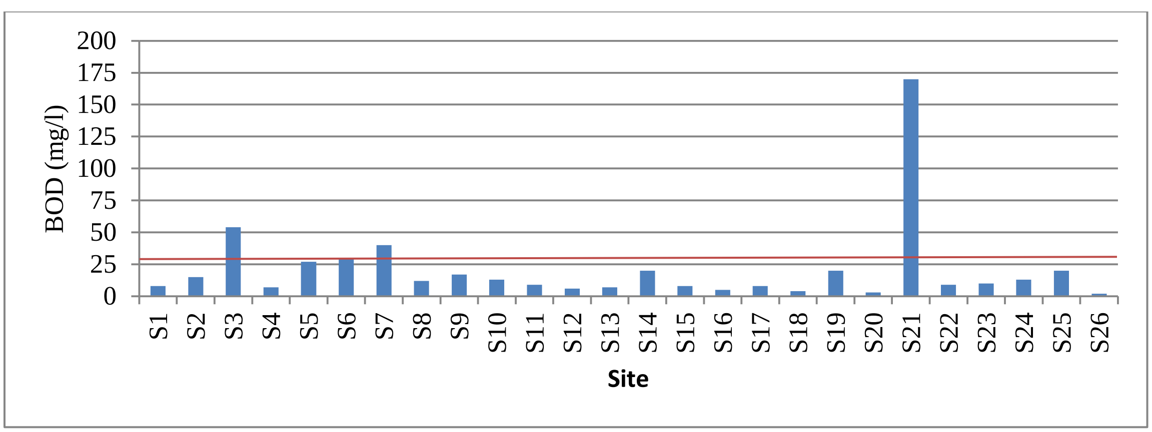

Figure 16: Biochemical Oxygen Demand (BOD) of water

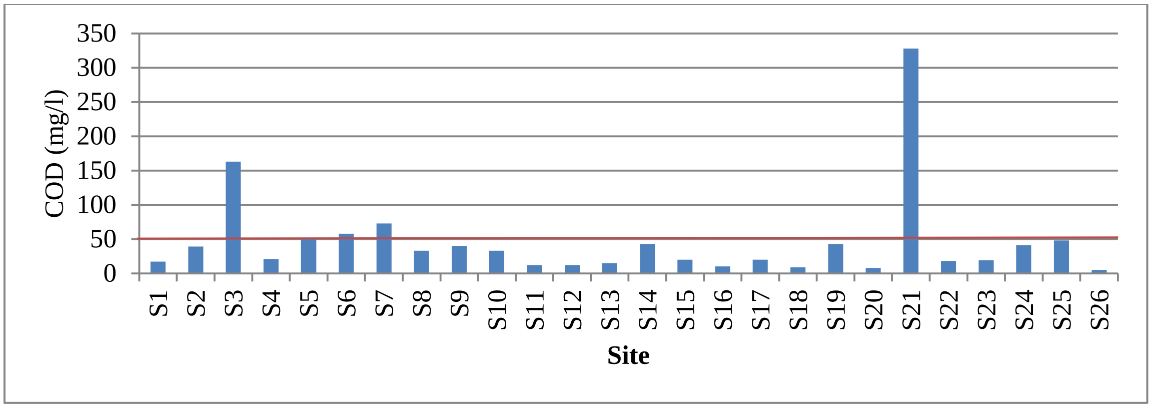

Figure 17: Chemical Oxygen Demand (COD)

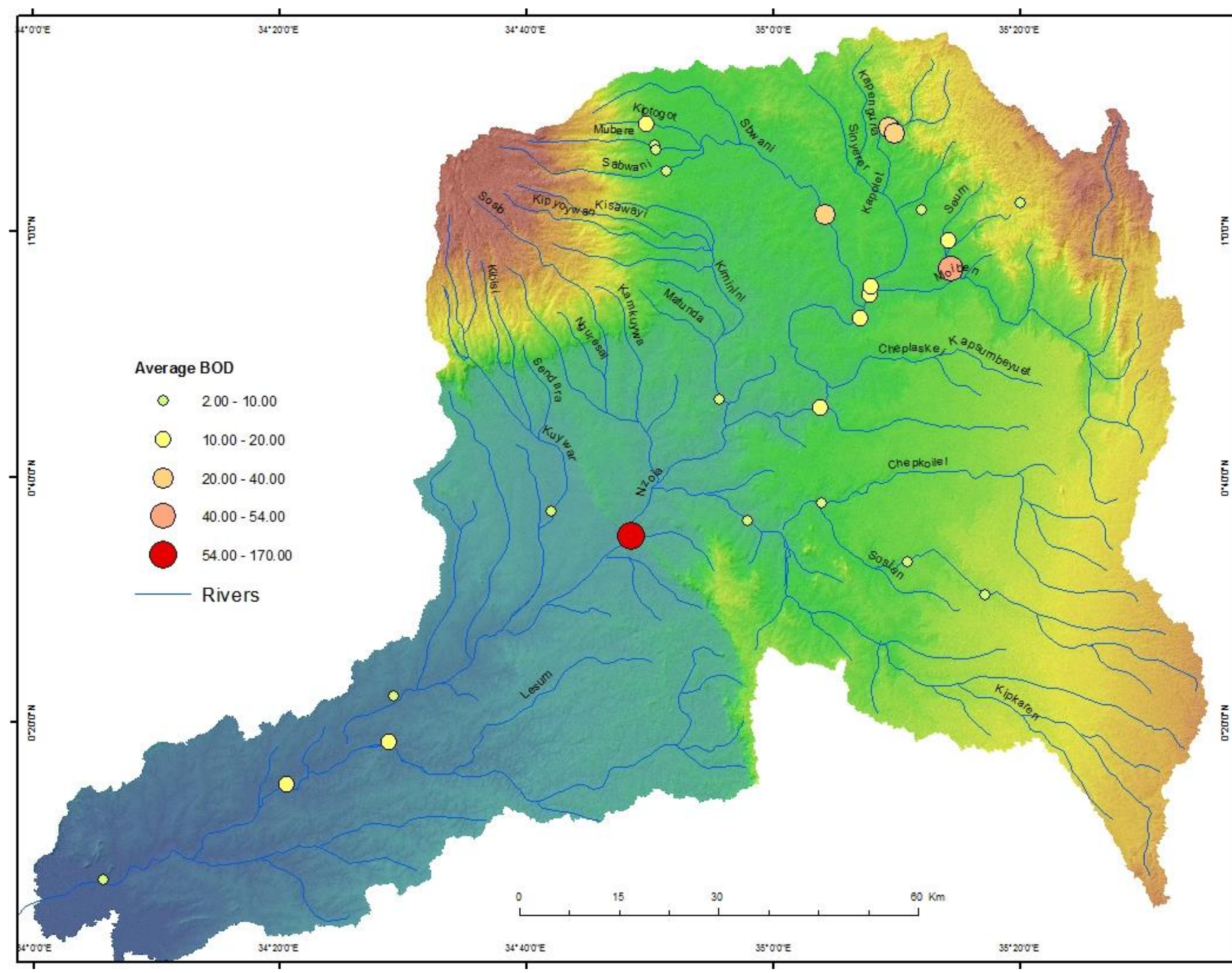

Figure 18: Pollution map for Biochemical Oxygen Demand (BOD)

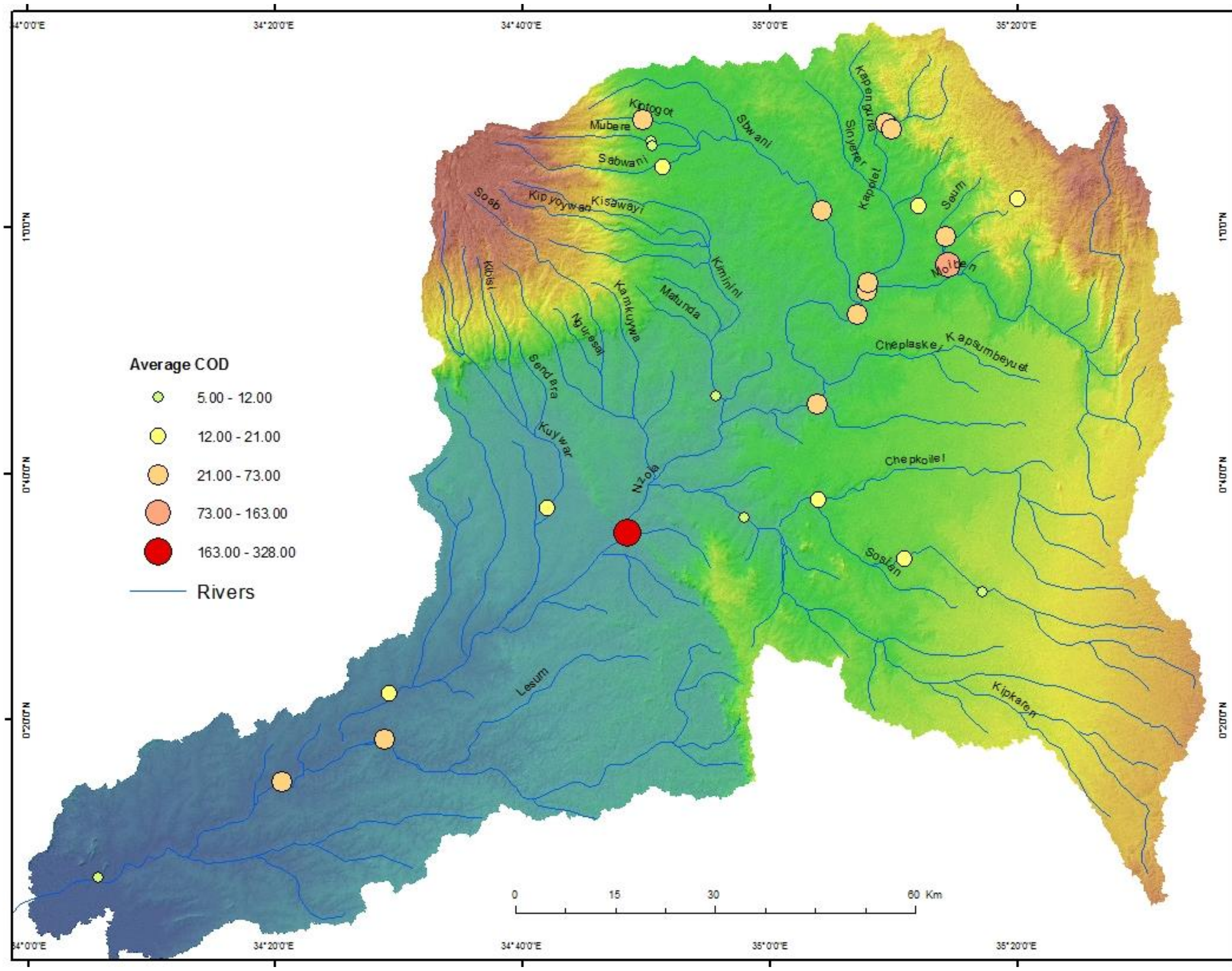

Figure 19: Pollution map for Chemical Oxygen Demand (COD)

3.5 Alkalinity

Alkalinity, expressed in mg/L of calcium carbonate (CaCO3) is a measure of all the substances in water that can resist a change in pH when acid is added to the water. Water with low alkalinity has a low capacity to neutralize incoming acids and is therefore susceptible to acidic pollution. In contrast, water with greater alkalinity, will have the ability to neutralize more of the incoming acidity and therefore resist rapid changes in pH.

In this study, all the sampled sub-water catchments had alkalinity values of between 11mg/L and 52 mg/L except for Kipkaren river in the Chepkoilel sub-catchment watershed which had the highest alkalinity value of 116mg/L, and this could be attributed to the extensive and intensive farming activities (Figure 20 and 21). These concentrations of alkalinity in water protect aquatic life against rapid changes in pH. There are no limits for water alkalinity set in Kenya.

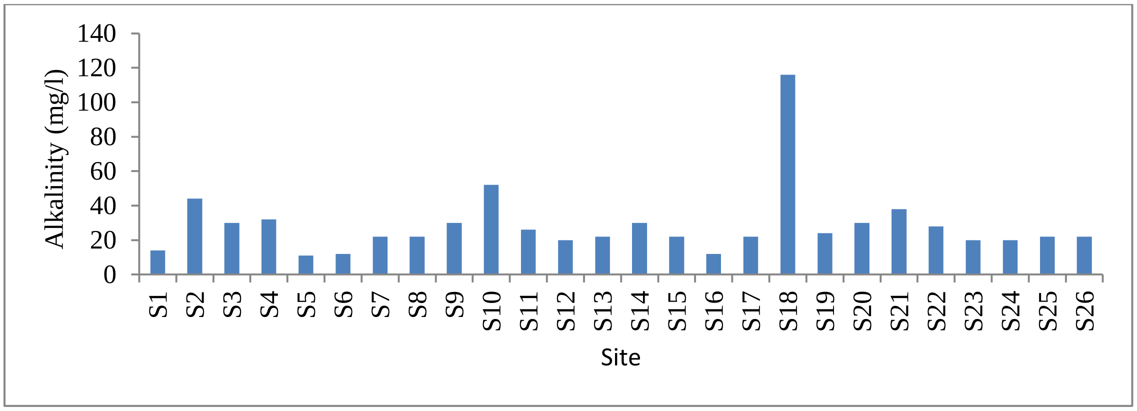

Figure 20: Alkalinity levels in water

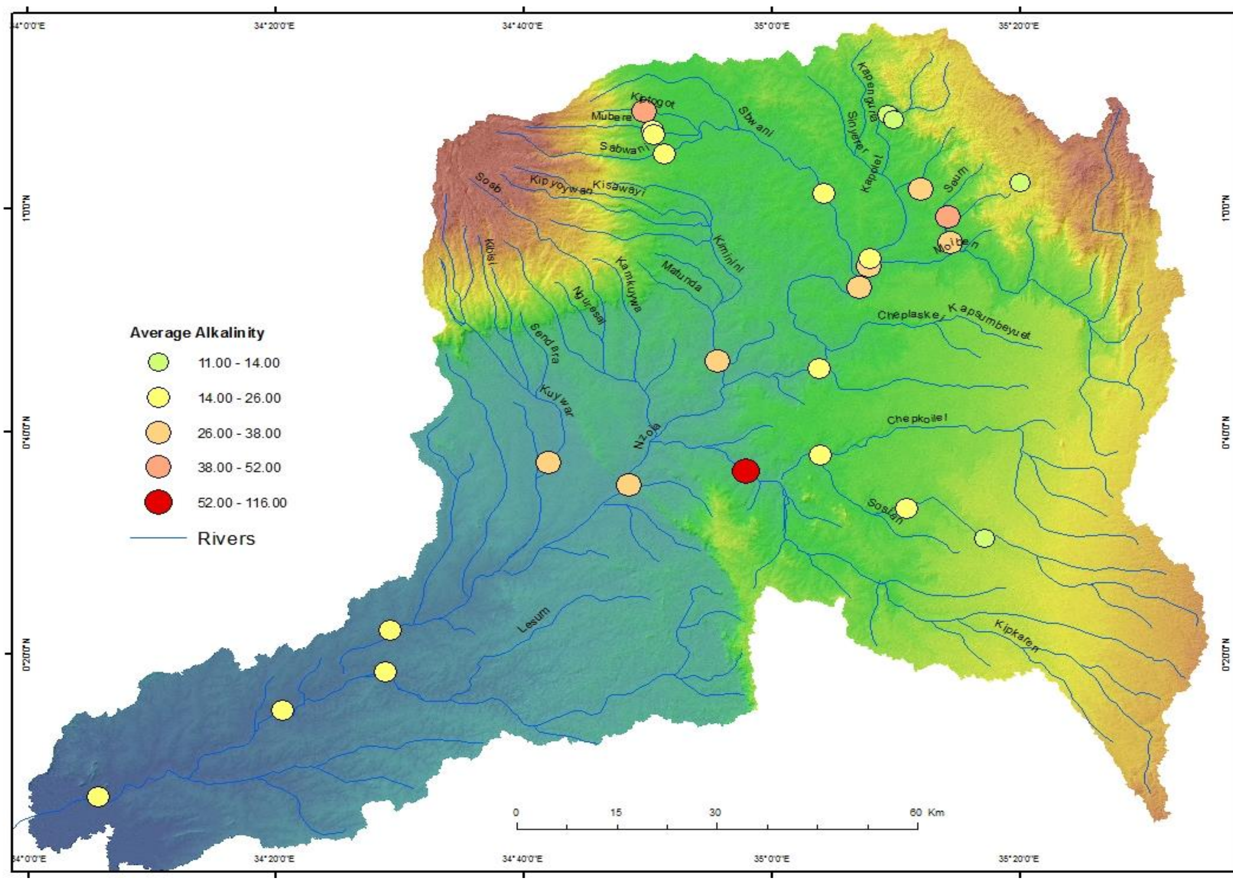

Figure 21: Pollution map for Alkalinity levels in water

3.6 Electrical conductivity and pH

The pH values of the sampled rivers were all within acceptable limits by NEMA, (2006) (6.5-8.5) and KEBS, (2014) limits of 5.5-9.5. The same trend was observed for sediments except for River Nzoia at Kapolet Bridge which recorded a low pH of 5.75 (Figure 22, Figure 23). The low pH could be attributed to anthropogenic activities mostly pollution from phosphates and nitrate fertilizers as well as animal watering points in the sub-catchment. Most aquatic organisms prefer water with pH range of between 6.5 and 8.4. Water with a pH of less than 4.8 or greater than 9.2 can be harmful to aquatic life.

The electrical conductivity of the river waters were within the acceptable limits (2.5 -11.5 mS/m) against maximum acceptable limit of 250 mS/m (KEBS, 2014) (Figure 24, Figure 25). This implied that there was a low pollution of ionic salts in the rivers from the catchment. For sediments, there was a correlation between the electrical conductivity and metal cations concentration for copper, zinc and magnesium (Figures 34- Figure 39).

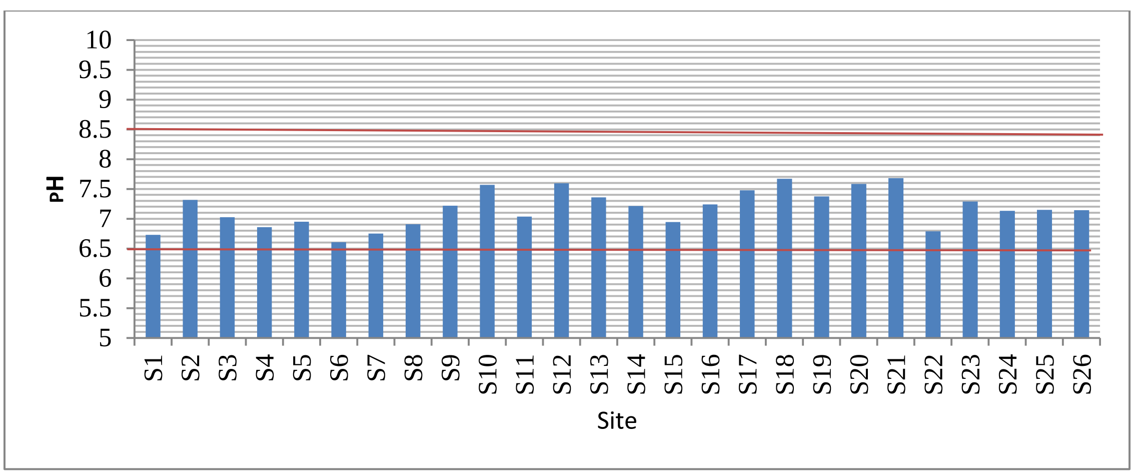

Figure 22: The pH levels in water

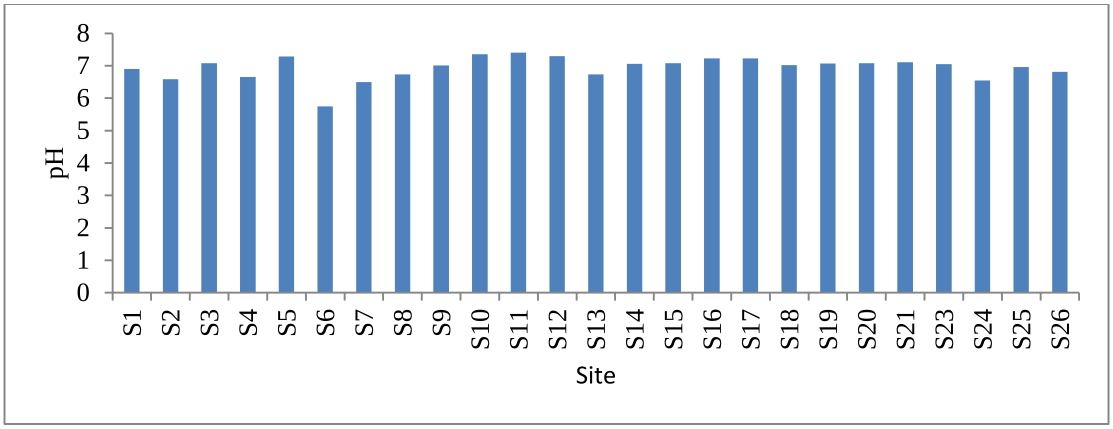

Figure 23: The pH levels for sediments

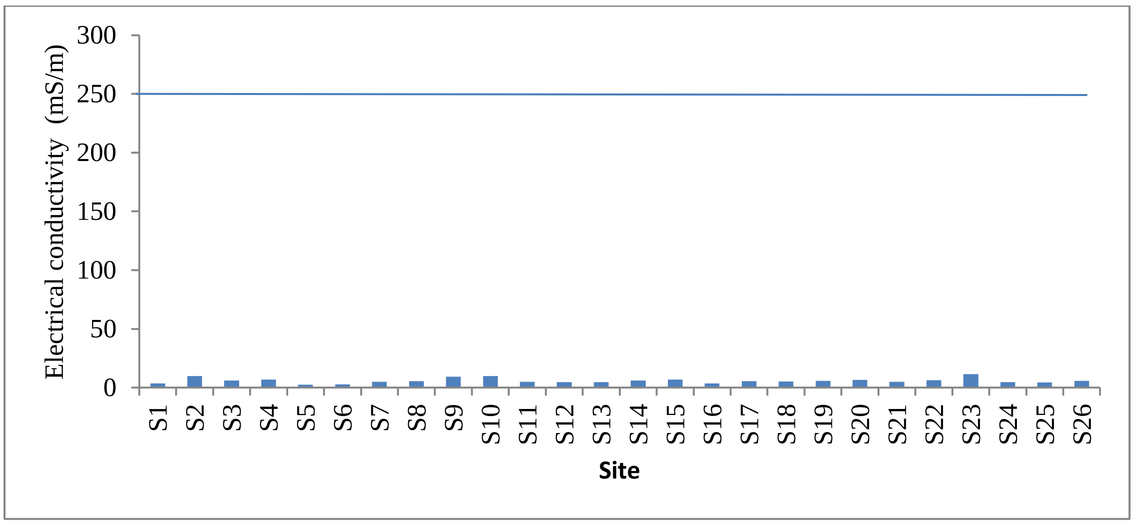

Figure 24: Electrical conductivity of water

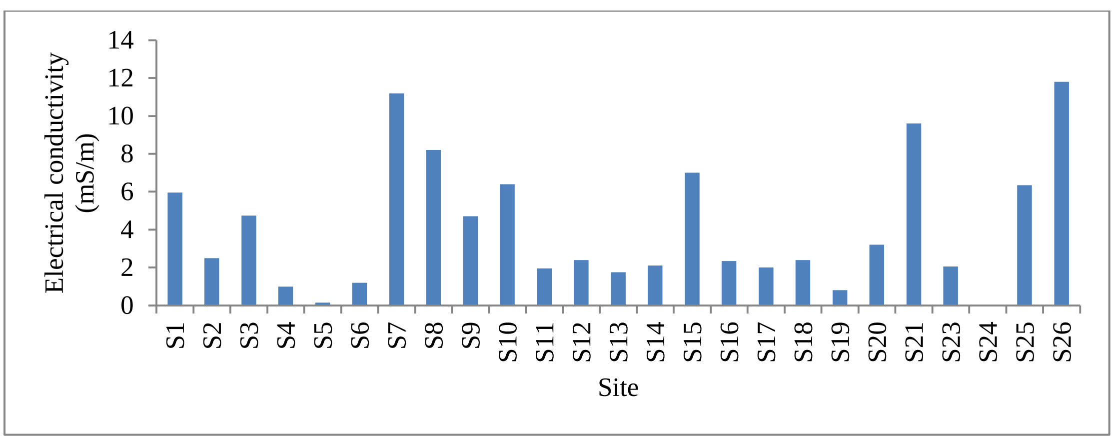

Figure 25: Electrical conductivity for sediments

3.7 Total Dissolved Solids (TDS)

The total dissolved solid is a measure of the total amount of natural and anthropogenic all the materials dissolved in water. In Kenya, the total dissolved solids (TDS) concentrations in drinking water should not exceed 1200 mg/L (KEBS, 2014) while water quality standards for domestic water sources should not exceed 1500 mg/L (NEMA, 2006). All the recorded concentrations of total dissolved solids (33 – 352 mg/L) were below the maximum allowed limits implying that the river water do not have high concentration of dissolved solids (Figure 26 and 27).

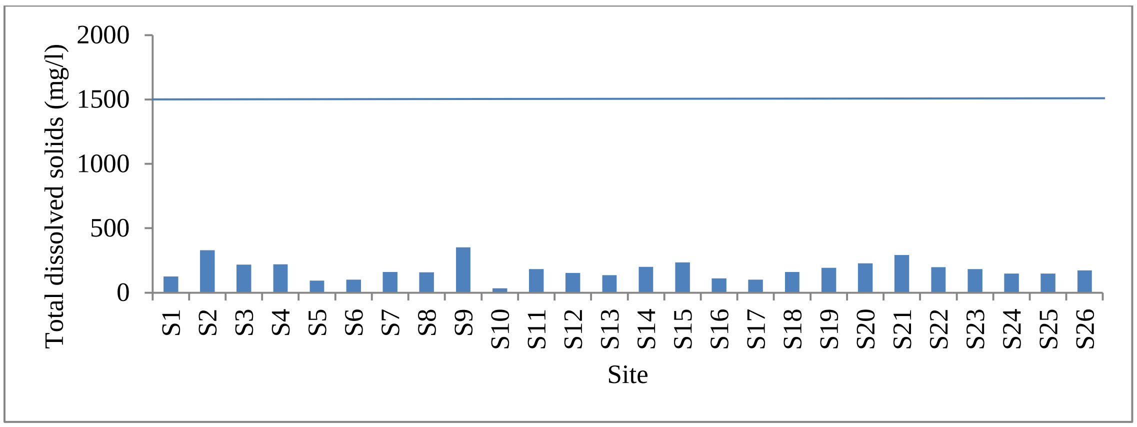

Figure 26: Total Dissolved solids in water

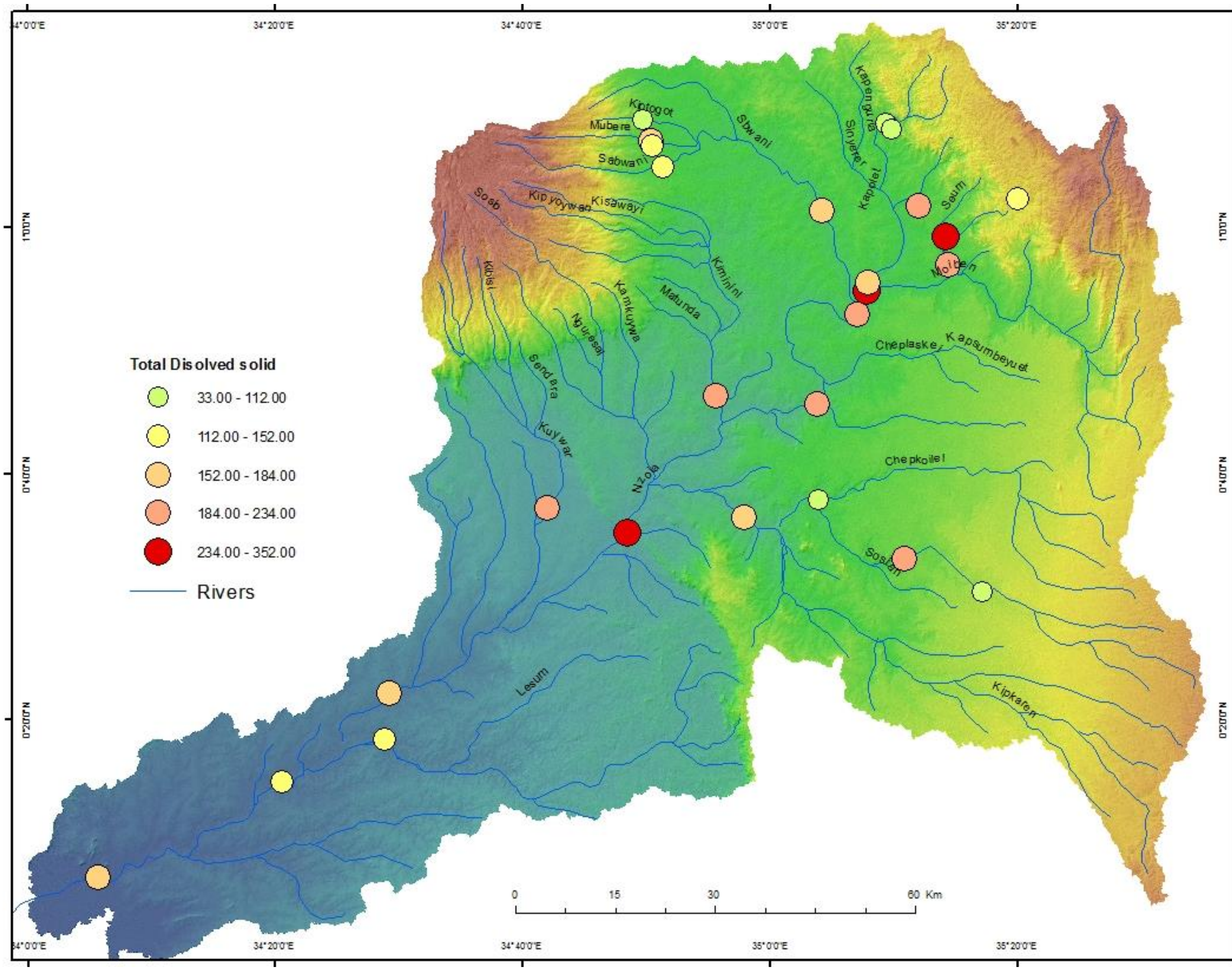

Figure 27: Pollution map for the Total Dissolved solids in water

3.8 Total Suspended Solids (TSS)

The total suspended solids measures floating particles in water. TSS has an inverse relationship with water transparency. In this study, the volume of the suspended solids in water in all the sub-catchments were within the NEMA water quality regulations acceptable limits of 30 mg/l for domestic and commercial water in Kenya (NEMA, 2006) in Figures 28 and 29. The low levels of TSS in water were attributed to the sampling period whereby, it was done during the rainy season and river discharge rates were high hence the suspended solids were washed away downstream. However, for drinking water, the TSS levels should not be detected as per KEBS portable water standards (KEBS, 2014).

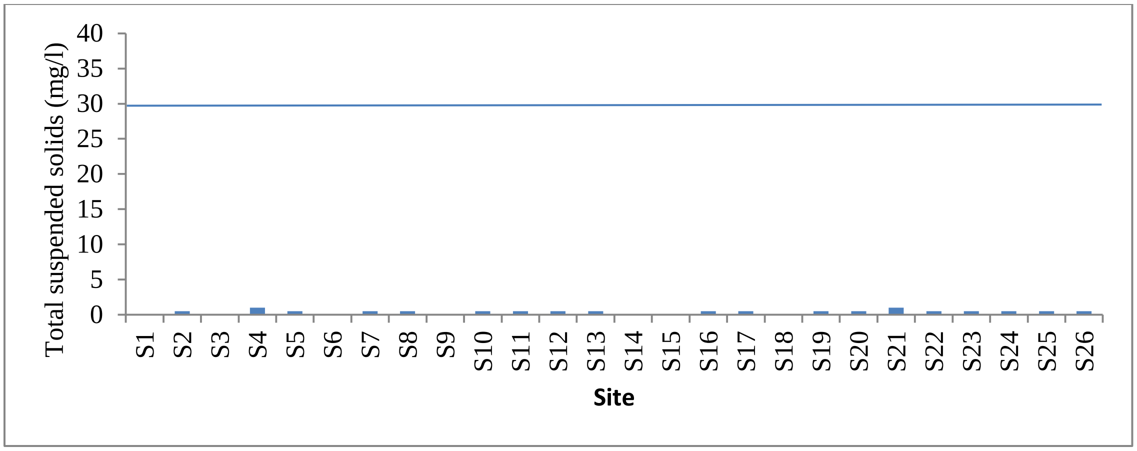

Figure 28: Total Suspended Solids in water

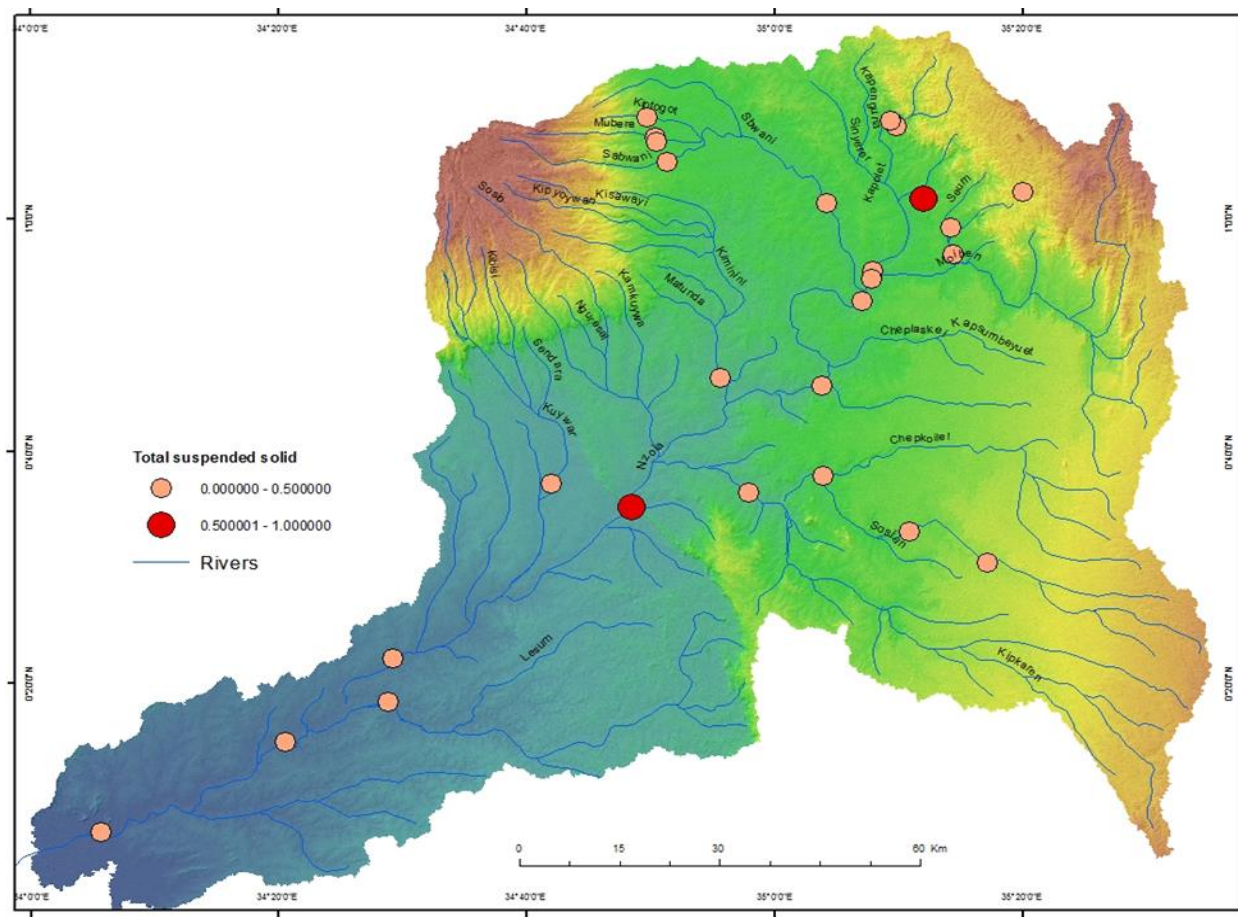

Figure 29: Pollution map for the Total Suspended Solids in water

3.9 Water Temperature

Temperatures ranged from 16°C along River Chepkaitit in Kapcherop (2353m absl) to 22.9°C (1180m absl) on River Nzoia at Rwambwa bridge (Figure 30). These water temperatures variations were majorly attributed to altitude and prevailing weather conditions. In addition, other factors known to influence water temperatures include; shading and ground water influx.

Many of the physical, biological and chemical characteristics of surface water are dependent on temperature. The temperature of the water also affects the volume of dissolved oxygen it can hold, the rate of photosynthesis by aquatic plants, metabolic rates of aquatic organisms and the sensitivity of organisms to pollution.

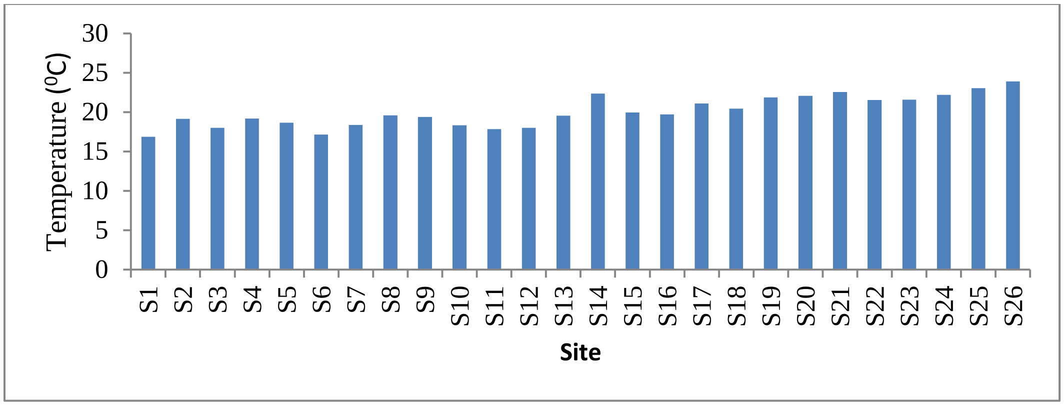

Figure 30: Temperatures of water

3.10 Hardness

The total hardness concentrations of the sampled rivers ranged from 0.1 mg/L to 5.96 mg/L, implying that the river waters are soft hence suitable for domestic, agricultural and industrial use (Figure 31). The hardness levels were below the acceptable limits in Kenya set by KEBS of 600 mg/L (KEBS, 2014). Total water hardness is a measure of dissolved minerals mostly calcium and magnesium in water and is expressed as milligrams per liter (mg/L) of calcium carbonate ($CaCO_3$). Water containing calcium carbonate at concentrations below 60 mg/L is generally considered as soft; 60–120 mg/L, moderately hard; 120–180 mg/L, hard; and more than 180 mg/L, very hard (USGS, 2016).

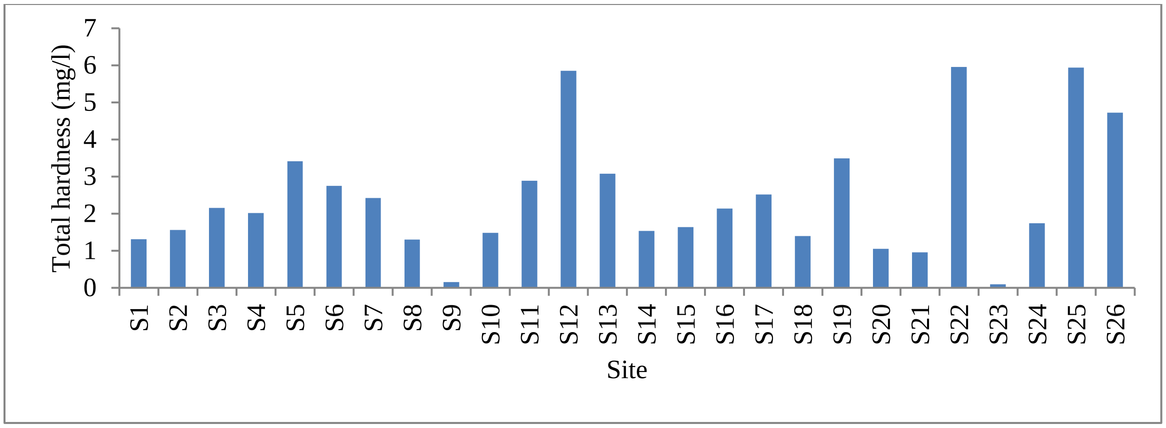

Figure 31: Total hardness in water

3.11 Heavy Metals: Mercury, Cadmium, Arsenic, Chromium and Lead

In this study, the concentrations of mercury, cadmium and arsenic recorded from the sampled sites (concentrations of < 0.001 mg/L) were within acceptable limits set by KEBS of 0.01 mg/L for arsenic and cadmium, and by NEMA for mercury levels of 0.001 mg/L (Table 5). These negligible concentrations can be attributed to the fact that there were few activities within the sampled sites that release these heavy metals in rivers. High levels of chromium were recorded in the River Nzoia near Webuye town (0.29 mg/L) and at Kipkaren town Bridge (0.073 mg/L) on River Kipkaren against maximum acceptable limits of 0.05 mg/L (KEBS, 2014) as shown in figure 32. This was attributed to point pollution by industries around Webuye town. At Kipkaren bridge, the river runs in the middle of township where all kinds of wastes are dumped into the river. The chromium in water could end up being consumed by fish and enter the food chain. When consumed by humans, chromium poses health risks including carcinogenic effects and kidney damage. The lead concentrations recorded for almost all the rivers (0.001 – 0.009 mg/L) were within the acceptable limits of 0.05 mg/L (NEMA, 2006) as shown in figure 33. Human exposure to lead causes brain damage, mental retardation lung cancer and could lead to death of unborn babies. These negligible concentrations can be attributed to the fact that there were no or few activities within the catchment that release lead in river waters.

Mercury, among other heavy metals is a global pollutant originating from industrial waste discharge, atmospheric deposition and mining wastes. Mercury as a transitional element exists in three forms i.e. elemental, inorganic, and organic with each having its own toxicity profile.

Arsenic is abundant in the atmosphere, soils and rocks, natural waters and organisms. Arsenic sources to the environment include natural processes such as weathering reactions, biological activity and volcanic emissions as well as through a range of anthropogenic activities such as mining activity, the use of arsenical pesticides and herbicides and combustion of fossil fuels.

Table 5: Heavy metals (Cadmium, Mercury, Arsenic) in water

Site	Cadmium	Mercury	Arsenic	Site	Cadmium	Mercury	Arsenic
S1	<0.001	<0.001	<0.001	S14	<0.001	<0.001	<0.001
S2	<0.001	<0.001	<0.001	S15	<0.001	<0.001	<0.001
S3	<0.001	<0.001	<0.001	S16	<0.001	<0.001	<0.001
S4	<0.001	<0.001	<0.001	S17	0.001	<0.001	<0.001
S5	<0.001	<0.001	<0.001	S18	<0.001	<0.001	<0.001
S6	<0.001	<0.001	<0.001	S19	<0.001	<0.001	<0.001
S7	0.002	<0.001	<0.001	S20	<0.001	<0.001	<0.001
S8	<0.001	<0.001	<0.001	S21	<0.001	<0.001	<0.001
S9	<0.001	<0.001	<0.001	S22	<0.001	<0.001	<0.001
S10	<0.001	<0.001	<0.001	S23	<0.001	<0.001	<0.001
S11	<0.001	<0.001	<0.001	S24	<0.001	<0.001	<0.001
S12	<0.001	<0.001	<0.001	S25	<0.001	<0.001	<0.001
S13	<0.001	<0.001	<0.001	S26	0.002	<0.001	<0.001

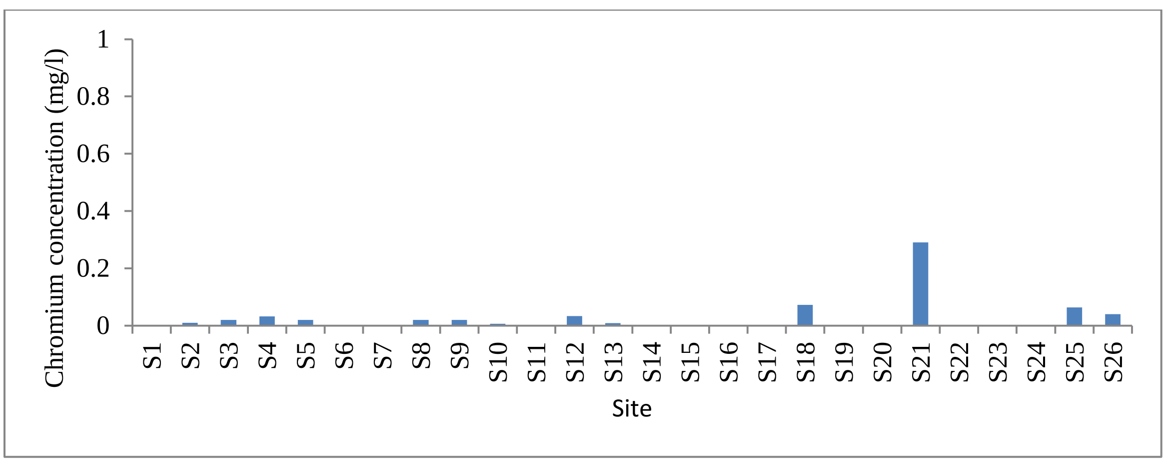

Figure 32: Chromium concentrations in water

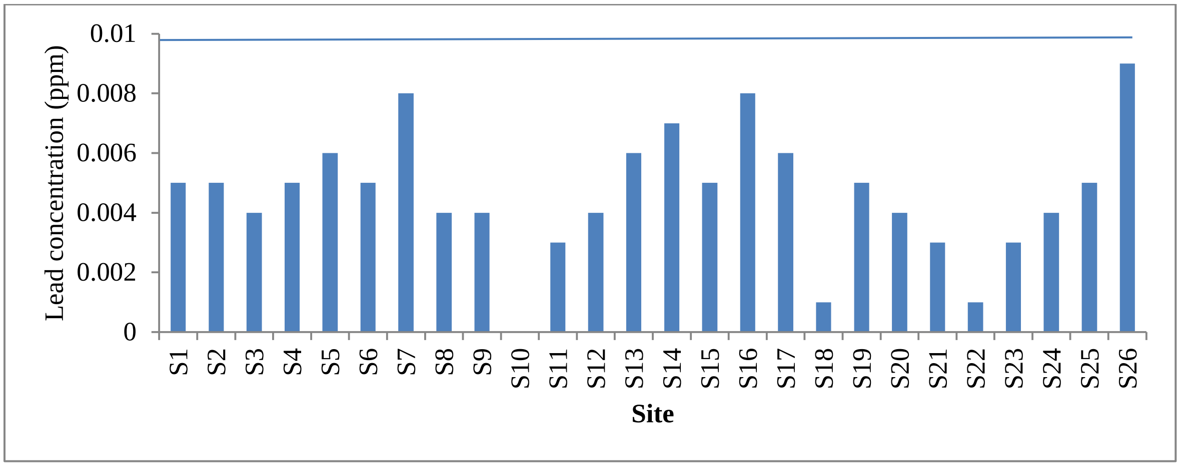

Figure 33: Lead concentrations in water

3.12 Zinc

Zinc sources in the environment are mostly from rock minerals and fertilization in agricultural activities. In this study, zinc was recorded from all the rivers sampled (0.12 – 0.9 mg/L) with its values being within the acceptable limits of 1.5 mg/L (NEMA, 2006) as shown in figure 34 and 35. Exposure of zinc to plants may lead to bio-accumulation thus posing health risks along the food chain.

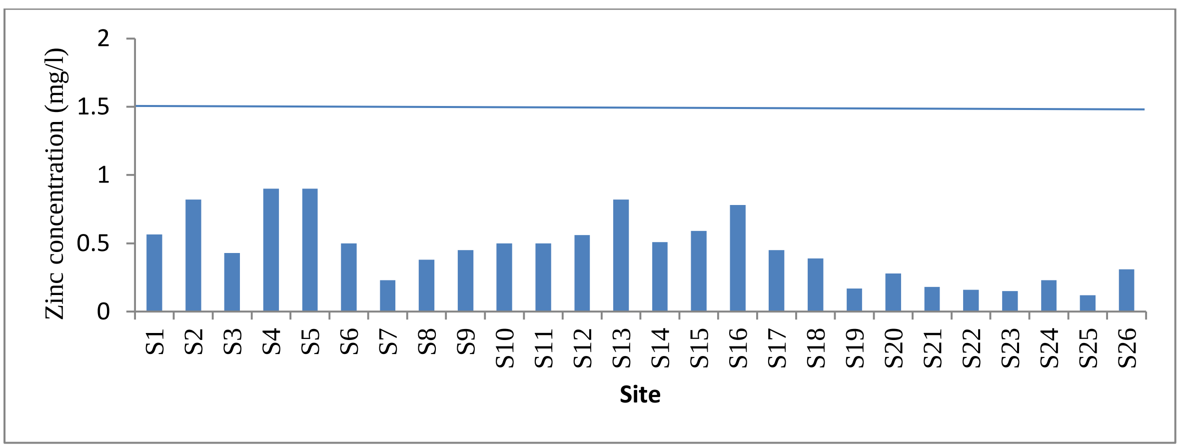

Figure 34: Zinc concentration in water

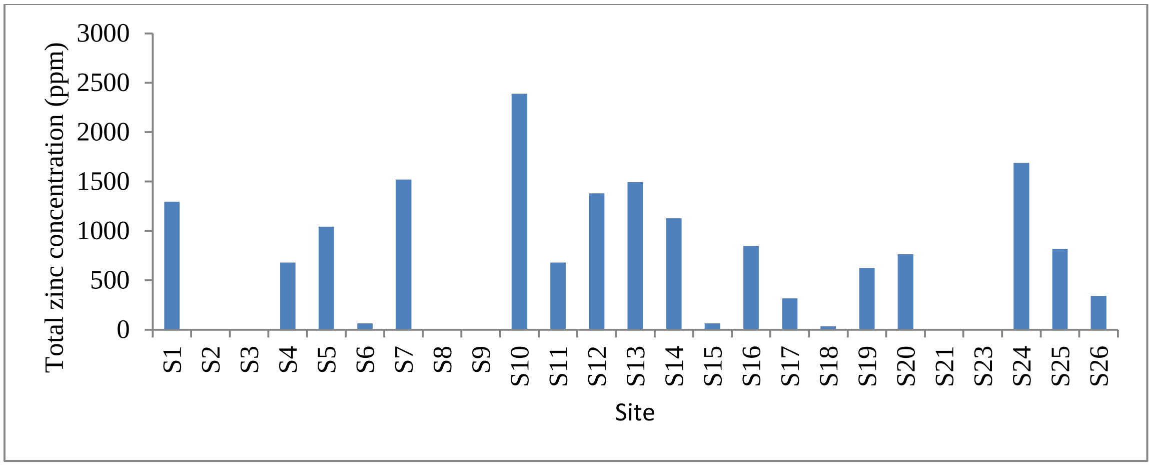

Figure 35: Total zinc concentration in sediments

3.13 Iron

Iron occurs naturally in soil, sediments and ground water and can be found in many types of rocks. Iron can be present in water in two forms; the soluble ferrous iron or the insoluble ferric iron. Water containing ferrous iron is clear and colourless, and when exposed to air the water turns cloudy causing a reddish brown precipitate of ferric iron appears. Iron exists naturally in rivers, lakes, and underground water.

In this study, majority of the rivers sampled had iron levels exceeding the allowable limits of 0.3mg/l (KEBS, 2014). River Kuywa water treatment site near Bungoma town (12mg/l) and River Nzoia at Sigomre bridge (11.6 mg/l) recorded the highest iron levels, followed by River Nzoia at Brigadier bridge in Soysambu (5.9 mg/l). The high levels of iron were largely attributed to soil erosion carrying iron minerals to river waters. Intervention measures should include control of soil erosion to reduce the amounts swept in the rivers. For drinking water; filtration, ozonation, chlorination and use of water softeners should be taken in consideration to reduce potential health risks associated with consumption of such water.

For sediments, all the sampled rivers had iron content ranging between 3000-4000 ppm except at the main source of river Nzoia (Kapolet North water treatment site) which had very little sediment mainly white sands. This was consistent with the iron content in water.

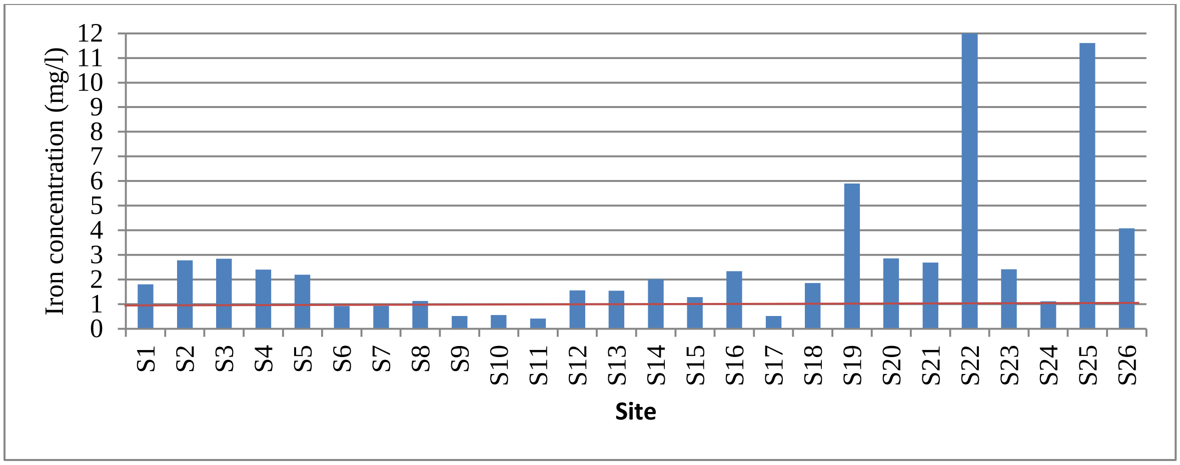

Figure 36: Iron concentration in water

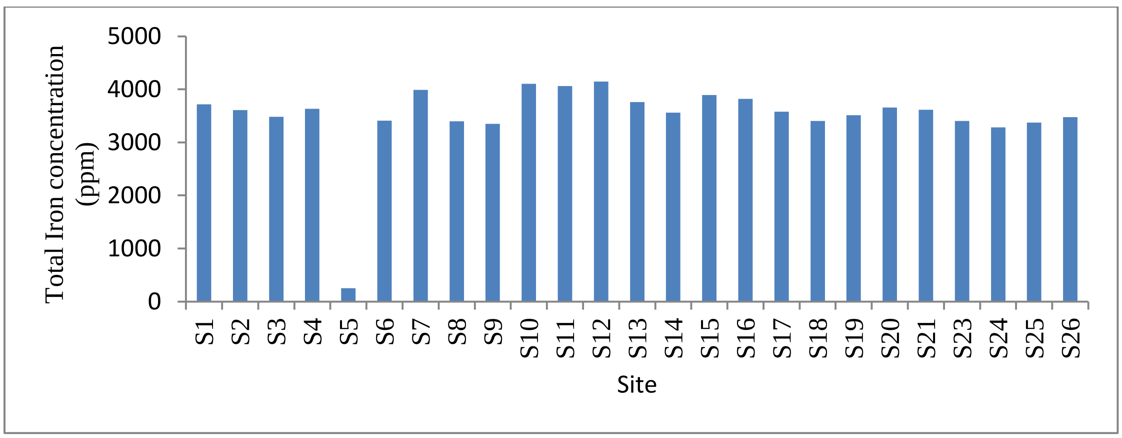

Figure 37: Total iron concentration in sediments

3.14 Copper

Sources of copper found in aquatic environments originate from natural or anthropogenic sources. Natural sources are weathering of soils or rocks whereas anthropogenic sources include sewage or industrial discharges and atmospheric deposition. Copper is considered as a heavy metal pollutant even though it is a vital micronutrient for both plants and humans.

The 26 sampled sites recorded high concentrations of copper in water against the acceptable limit of 1.0mg/L (KEBS, 2014), with the highest concentrations of 2.78mg/L and 2.4mg/L recorded at River Nzoia at Webuye Bridge and River Nzoia at Sigomre Bridge respectively.

The high levels of copper were attributed to high volume of water at the sites and therefore increased carrying capacities mainly erosion. In addition, point-source pollution from industries near Webuye town discharged into the river and farming activities in the surrounding areas in the surrounding areas are other possible sources. Copper is an essential trace nutrient required in small amounts by humans, plants and animals and therefore mitigating measures are necessary to reduce the high concentrations in the affected areas.

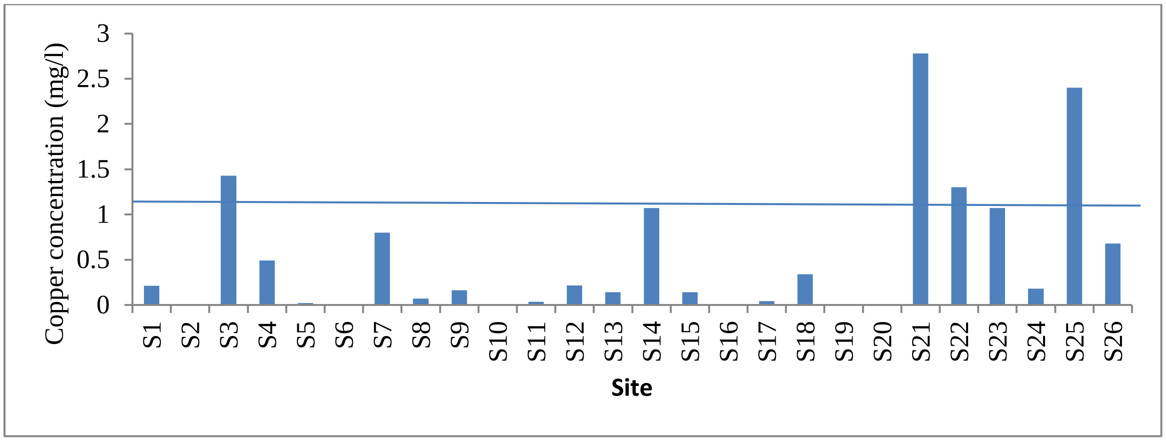

Figure 38: Copper levels in water

For sediments, Rivers Kiptogot, Mubere, Kaibey / Koitobos and Sabwani recorded high concentrations of copper i.e. 178.52 ppm, 189.59 ppm, 147.84 ppm and 92.47 ppm respectively. This could be attributed to non-point pollution especially from highly intensified agricultural activities in this region majorly large scale flower and maize production. Copper is moderately soluble in water and binds easily to soil particles and organic matter. The levels of copper in sediments can provide an indication of the level of pollution of the river as the sediments act as permanent or temporary traps for materials present in the river. The effects of copper on aquatic life include fraying of fish gills and reduced olfaction function in fish.

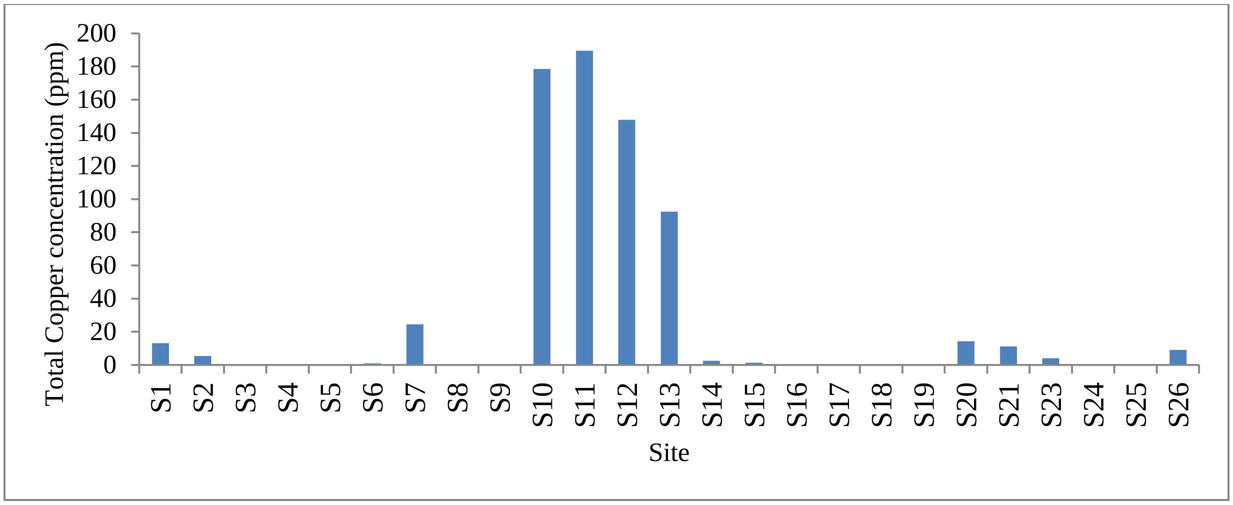

Figure 39: Total copper levels in sediments

3.15 Total Organic Carbon (TOC)

Total organic carbon (TOC) is the amount of carbon found in an organic compound and is often used as a non-specific indicator of water quality. The TOC provides an estimate of the amount of natural organic matter in the water source. The total organic carbon in source waters comes from decaying natural organic matter such as humic acids, fulvic acids, amines, and urea or from synthetic sources such as detergents, pesticides, fertilizers, herbicides, industrial chemicals, and chlorinated organics. Total organic carbon itself is not regulated but is an important consideration for the operators of water treatment plants when they consider disinfection practices.

In this study, TOC was measured in sediments and River Chepkaitit at Chepkaitit bridge, Sosian at Kamagut bridge, Mubere (Mubere bridge), and Sabwani (Endebess bridge) recorded the highest TOC levels. The high levels of TOC in sediments in these sites might have been contributed by mostly agricultural activities. The other reasons could be due to runoff from the surrounding farmlands hence bringing along excess pesticides and chemicals from inorganic fertilizers.

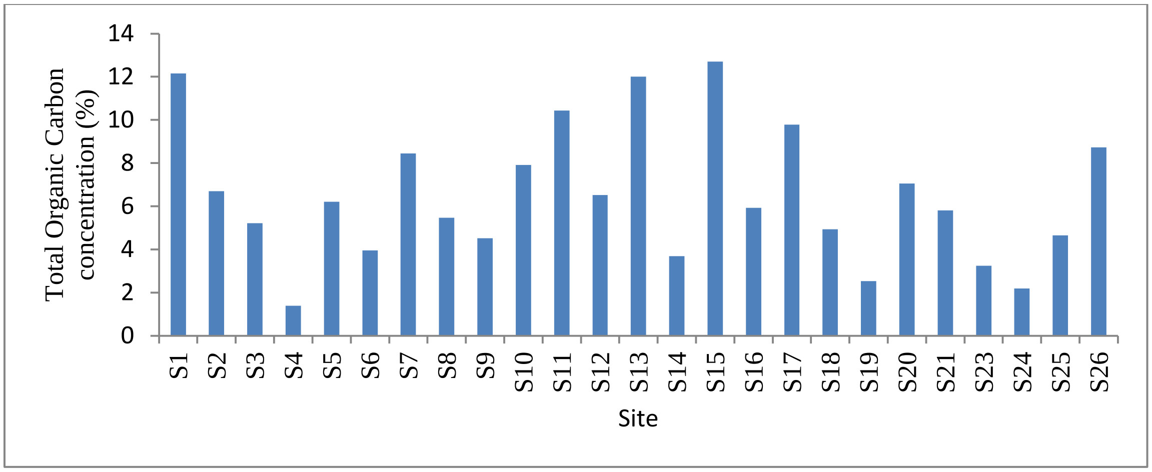

Figure 40: Total Organic Carbon (TOC) in sediments

3.16 Fecal and Total Coliforms

Fecal bacteria are used to test contamination of water from sewage. The fecal bacteria indicate the presence of disease causing micro-organisms in water which is harmful to human health. The fecal bacteria live in the intestinal tracks of humans and animals. Very high levels of fecal bacteria can give water a cloudy appearance, cause unpleasant odors and increase oxygen demand. Sources of fecal contamination to surface waters include wastewater treatment plants, on-site septic systems, domestic and wild animal manure, and overland flow. In this study, all the sampled sites had no fecal bacteria detected except in R. Kipkaren at Kipkaren Town Bridge (47 Cfu/100ml). This could have been caused by the high urban population in Kipkaren town and poor sewage drainage systems leading to the human and animal waste finding its way to the water.

CHAPTER FOUR
CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

From the baseline study, all the rivers in the watersheds forming the River Nzoia catchment contained high levels of iron in water and sediment which exceeded permitted levels for drinking standards set in Kenya by the regulating bodies KEBS and NEMA. In addition, the turbidity or clarity levels of water were beyond accepted limits set for drinking water and acceptable environmental water standards. There was no pollution of water from heavy metals (mercury, cadmium and lead). River Nzoia near Webuye town and Sigomre bridge were the most polluted waters with levels of nitrates, iron, copper, chromium, BOD and COD being above the accepted limits in the environment in Kenya. For sediments, the contents of copper, magnesium and iron were high in the upper catchment of river Nzoia (foot slopes of Mt Elgon) due to highly intensive agricultural activities of Kptogot, Chepchoina and Endebess regions. The levels of nitrates and phosphates in the sediments were high in the lower parts of the river Nzoia catchments. A wide range of interventions were proposed to manage point or non-point pollution sources which included land and soil conservation measures to reduce erosion and sedimentation, precise fertilization, proper sewage treatment and disposal, proper industrial effluent treatment, agro-forestry and forest rehabilitation technologies among others.

4.2 Recommended Interventions

The mitigation measures should mainly be at the sub-catchment or sub-watersheds within the larger river Nzoia catchment especially for non-point sources of pollution. For point source pollution, the interventions especially for high BOD and COD levels in water should be aimed at looking for possible pollution sources in the area i.e. from nearby industrial effluent discharge sites sewage treatment systems and horticultural farms. To reduce or manage high BOD/COD values, proper design of waste water and sewage treatment plants should be done especially aeration. Therefore, it was recommended that waste water effluent and sewage discharges should be monitored in the affected areas as a way of reducing point source pollution in the rivers.

The mitigation measures to reduce turbidity in river water should be geared towards land and soil conservation to control soil erosion at the sub-catchment levels.

The technologies for soil and water conservation will include but not limited to;

- Afforestation on bare lands i.e. agro-forestry and rehabilitation technologies
- Putting up of structures to control overland flow on farms and roadsides
- Stop cultivation activities on the river banks and
- Constructing silt/sediment traps mostly on roads to reduce sedimentation in rivers.

In addition, organic farming should be encouraged in the region to reduce use of pesticides which pollute rivers and conservation agriculture practices like minimum/zero tillage, crop rotation etc. will help conserve the soil and the environment.

4.3 Monitoring Sites and Rivers which require immediate Interventions

4.3.1 River Chepkaitet at chepkaitet bridge (GPS coordinates: E 749216 N 105057)

This site had levels of iron, copper, BOD and COD levels above the accepted environmental limits in Kenya and therefore need timely interventions to manage or reduce pollution

Possible causes of pollution

- Untreated waste water effluent from horticultural farms or industries and sewage discharges in the river
- Use of pesticides containing high levels of copper and iron

Suggested Interventions

- Monitor the quality of waste water effluent and sewage discharges in the affected areas as a way of reducing point source pollution in the river.
- Limit the use of pesticides or use alternatives like organic farming, conservation agriculture

4.3.2 River Nzoia, Kapolet North water treatment site (GPS coordinates: E 740840 N 125332)

This site had levels of iron, BOD and COD levels near or above the accepted environmental limits in Kenya and therefore need timely interventions to manage or reduce pollution

Possible causes of pollution

- Untreated waste water effluent from horticultural farms or industries and sewage discharges in the river
- Soil erosion which leads to increased iron content in water (soils in the area contain high content of iron)

Suggested Interventions

- Monitor the quality of waste water effluent and sewage discharges in the affected areas as a way of reducing point source pollution in the river.
- Control soil erosion in the area to reduce sedimentation in rivers

4.3.3 River Nzoia at Kapolet bridge (GPS coordinates: E 739806 N 126279)

This site had levels of iron, BOD and COD levels near or above the accepted environmental limits in Kenya and therefore need timely interventions to manage or reduce pollution

Possible causes of pollution

- Untreated waste water effluent from horticultural farms or industries and sewage discharges in the river
- Soil erosion which leads to increased iron content in water (soils in the area contain high content of iron)

Suggested Interventions

- Monitor the quality of waste water effluent and sewage discharges in the affected areas as a way of reducing point source pollution in the river.
- Control soil erosion in the area to reduce sedimentation in rivers

4.3.4 River Koitobos at Koitobos bridge (GPS coordinates: E 73048 N 113274)

This site had levels of iron, BOD and COD levels near or above the accepted environmental limits in Kenya and therefore need timely interventions to manage or reduce pollution

Possible causes of pollution

- Untreated waste water effluent from horticultural farms or industries and sewage discharges in the river
- Soil erosion which leads to increased iron content in water (soils in the area contain high content of iron)

Suggested Interventions

- Monitor the quality of waste water effluent and sewage discharges in the affected areas as a way of reducing point source pollution in the river.
- Control soil erosion in the area to reduce sedimentation in rivers

4.3.5 River Nzoia near Webuye bridge (GPS coordinates: E 701083.88 N 64808.78)

This site was the most polluted from all of the sampled waters with the levels of nitrates, BOD and COD levels exceeding the recommended set limits by regulating agencies in Kenya. In addition, the concentrations of iron, copper and chromium in water were above the threshold levels according to Kenyan regulations especially water for human consumption

Possible causes of pollution

- Excessive use of nitrogenous fertilizers on farms (mostly maize, sugarcane and potatoes) which though soil erosion contaminates water to increase levels of nitrates and iron
- Untreated waste water effluent from industries/factories and sewage discharges in the river (Webuye town) for high COD and BOD levels
- Discharge of solid industrial wastes in the river from the town are suggested causes of high levels of chromium and copper

Suggested Interventions

- Control soil erosion from farms at the sub-watershed level in the area to reduce sedimentation and nutrients being eroded in rivers
- Management of the fertilizer use on farms in the sub-watershed especially reduction in nitrogen based fertilizers or proper application to avoid nutrients being transported to rivers
- Monitor the quality of waste water effluent and sewage discharges from the nearby industries in Webuye town as a way of reducing point source pollution in the river.

4.3.6 River Nzoia at Sogomre/Sigomere bridge (GPS coordinates: E 649271.31 N 27541.15)

This site had levels of iron, copper, chromium and COD levels near or above the accepted environmental limits in Kenya and therefore need timely interventions to manage or reduce pollution

Possible causes of pollution

- Improperly treated waste water effluents from industries/factories and sewage discharges in the river for causing high COD, copper and chromium levels. These pollutants were suggested to come from upstream as there was no urban center or industry in the immediate vicinity of the sampled site

- Soil erosion (very turbid waters) which leads to increased iron content in water (soils in the area contain high content of iron).

Suggested Interventions

- Monitor the quality of waste water effluent and sewage discharges from the nearby industries in Webuye town as a way of reducing point source pollution in the river.
- Control soil erosion from farms at the sub-watershed level in the area to reduce sedimentation and nutrients being eroded in rivers.

4.4 Way forward

It was suggested that additional monitoring sites to be included in this activity especially the sub-watersheds on the western sides of Mt Elgon areas covering Kimilili and Kapsokwony. In addition, the following additional parameters for both water and sediments were suggested to be measured during water quality monitoring;

- Heavy metals for sediments (Cadmium, Lead, Mercury)
- Organic pollutants as pesticide residuals in water
- Dissolved organic carbon and inorganic carbon (DOC)
- Carbon-13 isotopes in (C3 and C4) plants for hydrophitic plants
- Map and model hydrology of the rivers in the catchments and link it with water pollution levels.
- Analyze and map soil characteristics for different land uses in the catchments

4.5 Limitations/Challenges encountered during the study

During this baseline study, the following challenges were encountered;

- Lack of capacity (Equipment) to carry out some tests like pesticide analysis
- Bad weather conditions mostly rainfall which hampered sampling of some sites
- In accessibility of sites due to impassable or lack of roads to sampling sites
- Unresponsive correspondents due to the prevailing political conditions in the country during the sampling period

APPENDIX

Appendix 1a: Critical/Acceptable limits of selected physical and chemical Water quality parameters (KEBS, 2014; NEMA, 2006; WHO, 2011)

Parameters	**Units**	**KEBS Standards KS EAS 12:2014 Portable water specifications (Natural portable water)**	**NEMA Water Quality Regulations 2006 Acceptable limits (First Schedule)**	**WHO Standards4th edition (2011)**
Nitrate	Mg/L	45	10	50
Nitrite	Mg/L	0.003	3	3
Phosphate	Mg/L	2.2	-	-
Lead	PPM	0.01	0.05	0.01
Zinc	Mg/L	5	1.5	-
Iron	Mg/L	0.3	-	-
Copper	Mg/L	1.00	0.05	2
Chromium	Mg/L	0.05	-	0.05
Total Hardness	Mg/L	600	-	-
Alkalinity	Mg/L	-	-	-
Total Dissolved Solids	Mg/L	1500	1200	-
Total Suspended Solids	Mg/L	Not detectable	30	-
Turbidity	NTU	25	-	-
Electrical conductivity	µS/cm	2500	-	-
pH		5.5-9.5	6.5-8.5	-
COD	Mg/L	-	50	-
BOD	Mg/L	-	30	-
Cadmium	PPM	0.003	0.01	0.003
Mercury	PPM	0.001	-	0.006
Arsenic	PPM	0.01	0.01	0.01
Faecal Coliforms	Cfu/100ml	Not detectable	-	-
Total Coliforms	Cfu/100ml	Not detectable	-	-

Appendix 1b: Standards for Irrigation waters and recreational Waters (Environmental Management and Coordination, (Water Quality) Regulations 2006 - Ninth schedule

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

Appendix 1c: Quality Standards For Recreational Waters- Environmental Management and Coordination, (Water Quality) Regulations 2006- 10th Schedule

Parameter	**Maximum permissible level**
Arsenic (mg/l)	0.05
Fecal coliform (Counts/100 ml)	Nil
Total coliform (Counts/100 ml)	500
Cadmium	0.01
Chromium	0.1
Colour (True Colour Units)	100
Light Penetration (meters)	1.2
Mercury (mg/L)	0.001
Odour (Threshold Odour Number, TON)	16
Oil and Grease (mg/L)	5
pH	6 – 9
Radiation, Total (Bq/L)	0.37
Surfactant, MBAs (mg/L)	2
Temperature (0C)	30
Turbidity (NTU)	50

Appendix 2: Farming around the forest in Cherangany hills.

Appendix 3: Water sampling in River Kiptogot near Chepchoina centre, Mt. Elgon Ecosystem (very turbid waters)

Appendix 4: Sediment sampling in River Moiben, Cherangany forest Ecosystem

Appendix 5: On-site Water and Sediment sampling and analysis in River Kiminin in Bungoma County, Mt. Elgon Ecosystem

Appendix 6: Water sampling on River Mbere (Mubere) in Endebess, Trans-Nzoia County Mt. Elgon Ecosystem

Appendix 7: River Mubere (Mt. Elgon Forest Ecosystem) (High turbidity or murkiness caused by livestock watering)

Appendix 8: Sand harvesting on River Nzoia in Ruambwa, Siaya County

Appendix 9: Grazing in Cherangany hills forests.

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