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Impact of Human Activities on Water Quality in River Kibos-Nyamasaria, Kisumu County: An Inlet River to Lake Victoria in Winam Gulf, Kenya.

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ABSTRACT

Human activities, Industrial, and poor agricultural practices have resulted to the contamination of rivers and lakes all over the world. Many rivers and streams in Kenya lose water quality after passing through towns and cities which causes health risks. This study used ten sampling points to determine physicochemical parameters in water and sediments from river Kibos-Nyamasaria. A pH meter was used to measure water and soil sediment pH, a inolab conductivity meter was used to measure water and soil sediment conductivity; a muffle furnace was used to measure the soil's sediment organic carbon and organic matter; a hot air oven was used to measure soil sediment moisture. Microsoft Excel was used for the data analysis. In the water sample, pH ranged from 6.93±0.06 to 7.90±0.02 while turbidity ranges from 84.23±0.41 NTU (dry season) to 188.50±1.08 NTU (wet season). During the rainy season, conductivity ranged from 106.93±0.25 µs/cm to 139.26±0.86 µs/cm, and total dissolved solids (TDS) ranged from 101.23±1.15 mg/L to 120.10±0.45 mg/L while total suspended solids (TSS) ranged from 65.40±0.80 mg/L to 123.73±0.60 mg/L. In soil sediment, pH ranged from 6.20±0.05 to 7.26±0.06, conductivity ranged from 44.43±0.31 to 142.23±0.35 µs/cm, sediment moisture ranged from 13.14±0.03 to 26.34±0.03%, organic matter ranged from 2.95±0.06 to 9.43±0.11%, organic carbon ranged from 1.71±0.04 to 5.47±0.07% respectively in both seasons. Increase in the concentrations of physicochemical parameters downstream indicates increased pollution to Lake Victoria. It is necessary to establish measures to reduce pollution and find potential sources of the pollutants.

Keywords: Physicochemical parameters, water, sediment, river Kibos-Nyamasaria, Lake Victoria.

1.0 Introduction

Globally, water pollution is one of the most crucial environmental problems due to population increase, rapid industrialization, poor agricultural activities, pollution, soil and sediment contamination by pesticides and other contaminants generated by human activities (Zhou *et al*., 2020; James & Achieng, 2019; UNESCO, 2015). The concentration and persistence of these wastes is a serious problems worldwide and are more acute in developing countries that do not have proper waste treatment methods before discharging them into the water bodies (Kelle *et al*., 2022; Chowdhury *et al*., 2016; UNESCO, 2015; Yabe *et al*., 2010). According to Paul *et al*. 2022; Kosgei *et al*., 2019; Anyanwu *et al*., 2018; UNESCO, 2015, the main causes of water pollution are industrial discharge, pesticide use, seepage from waste sites, fertilizers, sewage, agricultural waste, decomposing plant, road, rail, and sea accidents involving large oil carriers. Water is one of the essentials for humans as it is needed in bodies' biochemical processes, therefore, resulting water pollution is a serious health threat to all lives on Earth (Kelle *et al*., 2022; Paul *et al.*, 2022; European Parliament, 2021; UNESCO, 2015; UNESCO, 2003; World Water Council, 2000).

Over 70% of the surface of the world is covered by water, only 3% of which is fresh water, and the remainder is salty water (FAO, 2017; UNESCO, 2015; World Water Council, 2000). Only 0.3% of the world's fresh water may be found in lakes and rivers because the majority is frozen due to the extreme cold in some regions (FAO, 2017; UNESCO, 2015; World Water Council, 2000). Sadly, the amount of fresh water available to man for development and life support has been degraded by human activities and rapid industrialization, making the amount of water available to be less than 0.3% (Kelle *et al*., 2022; James & Achieng, 2019; Igiri *et al*., 2018; Rehman *et al*., 2018; Ongulu *et al*., 2015; UNESCO, 2015; World Water Council, 2000). According to the United Nations Educational, Scientific, and Cultural Organization (UNESCO 2015), approximately 2 million tons of industrial wastes, chemicals, human waste, and agricultural wastes such as fertilizers, pesticides, and pesticide residues are disposed in water bodies every day. Therefore, many rivers and streams lose their water quality after passing through large agricultural fields and major towns and cities due to downstream pollution (James & Achieng, 2019). Rehman *et al*. (2018) state untreated sewage, and municipally generated industrial wastes can seriously pollute rivers and cause health issues in towns downstream. By reducing the amount of waste and pollutants discharged into the water bodies, water management must be urgently improved at the local, regional, national, and international levels (Paul *et al*., 2022; Kelle *et al*., 2022; European Parliament, 2021; UNESCO, 2015; Mulei, 2012; Yabe *et al*., 2010). As industrial effluents, agricultural and municipal wastes get their way into the water bodies (rivers and Lakes), chemical and biological contaminants, including pesticides residues, enter into water bodies, particularly surface waters (Kelle *et al*., 2022; Huang *et al*. 2020; Wei *et al*., 2019).

Communities that live near rivers and rely on water for household purposes are compelled to hunt for more expensive tap water alternatives, which most people, especially urban poor, cannot afford (Abong'o *et al*., 2018; UNESCO, 2015). Toxic chemicals and pathogen concentration in river water pose health risks to people using river water for drinking, irrigation of fruits, vegetables, and crops eaten raw, fishing, bathing, and recreational activities (Kelle *et al.*, 2022; European Parliament, 2021; Alengebawy *et al*., 2021; Rai *et al*., 2019; UNESCO, 2015; Ali *et al*., 2013).

Lake Victoria water catchment areas are not exceptional from pollution. Large sugarcane plantations and smallholder farms are found in the Kibos and Miwani areas in Kisumu City, where farmers frequently use pesticides to increase crop yield and eliminate or control various agricultural pests. Toxic wastes from run-offs enter the Kibos-Nyamasaria river, which drains its constituents into Lake Victoria which is the world's largest tropical lake and the world's second-largest freshwater Lake after lake superior in North America (FAO, 2017; UNESCO, 2015; UNESCO, 2003; World Water Council, 2000).The communities in lake Victoria catchment areas that depend on stream water for their domestic activities are forced to look for alternative expensive tap waters that most cannot afford, especially the urban poor (Abong'o *et al*., 2018; UNESCO, 2015). Sediment analyses are important in this study because they may act as reservoirs rather than ultimate sinks, allowing absorbed chemicals to remain in the aquatic biota for extended periods (Paul et al., 2022; Ochoa & Maestroni, 2018).

The justifiable and comprehensive study has not been conducted thoroughly in this area of study to determine the levels of physicochemical parameters in the environment and agricultural land near river Kibos-Nyamasaria. Since waste are always being generated every time, it is not amazing that the aquatic system has become polluted to a certain extent due to their long-term usage. Therefore, the study aimed to determines the level of physicochemical parameters in water and sediments of river Kibos-Nyamasaria during two seasons: wet (April-May) and dry (February-March) and their effect in Winam gulf at entry of river to swamps and eventually to Lake Victoria.

2.0 Materials and Methods

2.1 Study Area

The study was conducted along river Kibos-Nyamasaria, Nyalenda and Dunga swamps in Kisumu east district, county of Kisumu (Figure 1), with altitudes ranging from 1100 to 1160 meters above sea level and situated between a latitude of 0° 40' 0" south and 34° 49' 0" east, (Kanoti et al., 2019; County Government of Kisumu, 2019; Onyango, 2018; Onyango et al., 2013; Masimbe, 2018). The sources of river Kibos-Nyamasaria are the Nandi escarpment and South Nandi Forest. Kibos-Nyamasaria river drains its waters at the southern shores of the Winam gulf of Lake Victoria through Nyalenda and Dunga swamps (Onyango, 2018; Masimbe, 2018). The river flows through several kilometers (about 25 km) before draining into Lake Victoria. Kibos-Nyamasaria river flows within the Lake Victoria drainage basin from the high plateau of South Nandi Forest to the downstream end at Nyanza gulf or Winam gulf. The river flows through industrial area in Kibos, several informal settlements and agricultural farms along Kasule and Nyalunya sub-locations in Central Kolwa location (Kisumu east sub-county) before draining into Lake Victoria (Masimbe, 2018).

2.2 Description of sampling points

Samples of river water and sediments were collected from ten sampling sites purposely selected along the river Kibos-Nyamasaria during the dry season (February - March) and the wet or rainy season (April – May). The first sampling point (S1) was from where the river Kibos and Awach merged to form River Kibos-Nyamasaria, while the rest were distributed along the river, as shown on the map of the sampling sites (Figure 1). The final sampling point (S10) was where the river enters or drains into Lake Victoria. Table 1 describes the human activities around the sampling points along the river Kibos-Nyamasaria and various abbreviations used during the sampling and analysis.

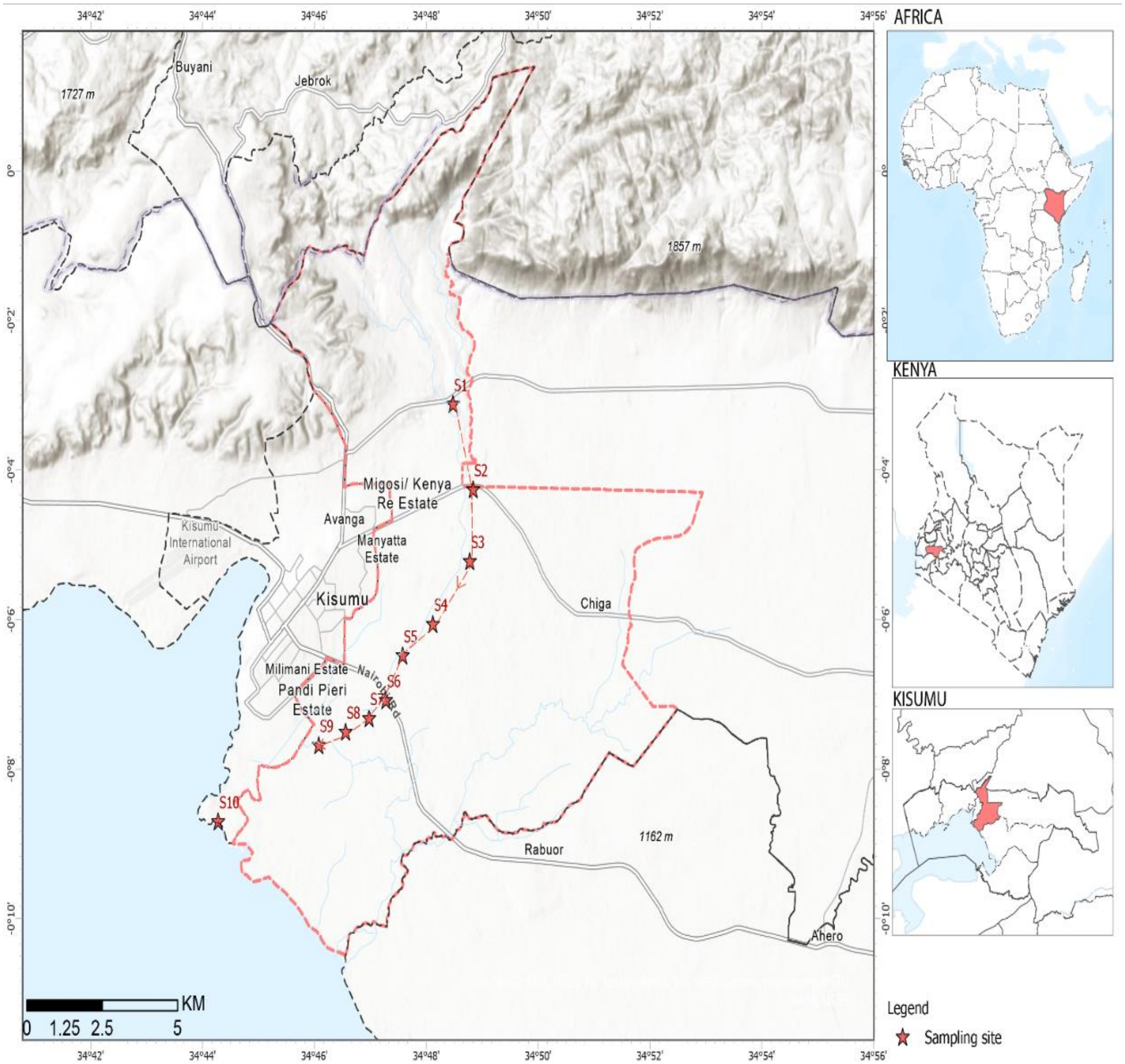

Figure 1: Map of Kisumu City showing rivers and sampling points along river Kibos-Nyamasaria

Table 1: Characteristics of sampling points for Water and Soil sediment analysis along river Kibos-Nyamasaria

Sampling Site	Site intervals (approx.Kms)	Sampling Site descriptions	GPS Coordinates		Human activities around the sampling points
			N(+) /S(-)	E	
S1	S1=0	At convergent of River Kibos & Awach near Guba Bridge Kibos	-0.052^0	34.808^0	Large-scale sugarcane farming, Bushes, Human settlement, maize, tomatoes, cassava farms on river banks, effluent discharge from factories, KALRO farms, cattle, and human watering points
S2	(S1-S2)= 3	Kibo's bridge near Kibos market	-0.071^0	34.814^0	Human settlement, maize, tomatoes, cassava farms on river banks, effluent discharge from Kibo's market, cattle watering, and human watering points
S3	(S2-S3)=2.5	Foot bridge near Kunya Market or Adasa school	-0.087^0	34.813^0	Human settlement, maize, tomatoes, cassava farms on river banks, domestic effluent discharge from the market, cattle watering, Human watering, and bathing point
S4	(S3-S4)=2	Olad Ouko bridge	-0.101^0	34.802^0	Human settlement, maize, tomatoes, cassava farms on river banks, domestic animals and cattle watering points, Human bathing and watering point, river sand harvesting
S5	(S4-S5)=1.5	Foot Bridge near Jamilo academy	-0.108^0	34.793^0	Human settlement, maize, tomatoes, cassava farms on river banks, domestic animals and cattle watering points, Human bathing and watering point, river sand harvesting
S6	(S5-S6)=2	Nyamasaria bridge	-0.118^0	34.788^0	Human settlement, maize, tomatoes, cassava farms on river banks, domestic animals and cattle watering point, sand harvesting, wood selling and treatment point, domestic effluent discharge from Nyamasaria market and estates
S7	(S6-S7)=2	Behind Nyamasaria Estate	-0.122^0	34.783^0	Human settlement, maize, tomatoes, cassava farms on river banks, domestic animals and cattle watering points, Human water and bathing point, river sand harvesting.
S8	(S7-S8)=2	Near KIWASCO Nyalenda wastewater treatment plant	-0.125^0	34.776^0	Human settlement, maize, tomatoes, cassava farms on river banks, domestic animals and cattle watering point, Human watering and bathing point, KIWASCO waste discharge point
S9	(S8-S9)=2	Nyalenda farms	-0.128^0	34.768^0	Human settlement, maize, tomatoes, cassava, etc. farms on river banks, human, domestic animals, and cattle watering points, part of Nyalenda swamp
S10	(S9-10)=4	Point of entry to Lake Victoria	-0.145^0	34.738^0	Nyalenda swamp, Dunga wetland, fishing activities, Human settlement at Nyalenda, Nanga, and Dunga Estates

2.3 Sampling and Sample Collection procedure

Water and sediment samples from the river were collected at different sampling points (Figure 1). The sample for water physicochemical analysis were collected using sterile, 2.5 L ambered bottles fitted with screw-cap (Nyaundi et al., 2021; Ndunda et al., 2018; Abongo, 2009; APHA, 1998). Distilled water and soap were used to clean thoroughly screw-cap amber glass bottles for collecting samples then rinsed with respective water samples before collection using the grab sampling method (Abongo, 2009; APHA, 2002). Sampling bottles were dipped at 20 cm below the water surface, aiming midstream positions, and projecting the container mouth against the flow direction of the river water (APHA, 2002; APHA, 1998). (Nyaundi *et al.*, 2021; Ndunda et al., 2018; Abongo, 2009; APHA, 2002; APHA, 1998).

Sediments samples were scooped within a length of 50 m from the left river bank, midstream and right river bank using an auger at a depth of 20 cm in triplicate from the same points where water samples were collected along the river bank and swamps. Sediment samples collected from each sampling point were mixed thoroughly on a clean piece of aluminum foil then approximately 200g representative sample were taken from the composite selection (Nyaundi *et al.*, 2021; Nyaundi *et al.*, 2020; Alex *et al.*, 2019; Abong'o *et al.*, 2018; Fang *et al.*, 2017; Abdel-Rasheed, 2011; Abongo, 2009; APHA, 1998). The samples were then enfolded or wrapped using aluminum foil well labelled, and placed in a black plastic bag before placing enclosed samples in a labelled self-sealing zip lock polythene bag (APHA, 2002). Samples collected were stored temporarily in polyurethane cooler boxes before transportation to the laboratory for further storage, preparation and analysis. The glassware used during sample collection, preparation, and analysis was soaked in 5% nitric acid, rinsed thoroughly with double-distilled de-ionized water after each use then dried overnight in an oven at 105^0 C (APHA, 2002; APHA, 1998).

Both samples were treated using recommended methods for river water and sediment sample treatment before analysis in the laboratory (Ndunda et al., 2018; APHA, 2002; APHA, 1998). Water samples were stored at 4^0 C while sediments were stored in aluminum containers at -20^0 C in the laboratory deep-freezer before further sample preparation, and analysis within seven days from collection (Abong'o *et al.*, 2018; Rehman et al., 2015; Achakzai & Masood, 2015; APHA, 2002).

2.4 Chemicals and Reagents

Buffer 4,7and 10, standards for the conductivity of 84, 1413, and 12880 µS were used for calibration. The detergents used for cleaning purposes during analysis were bought locally and glassware used were soaked in 5 % chromic or nitric acid for two hours, washed with tap water and rinsed in double distilled water. The apparatus or glassware were then dried in a hot air oven for four hours or overnight at 105^0 C before use (Abong'o *et al*., 2018; Nthusi, 2017; Osoro *et al*., 2016; Abong'o *et al.*, 2015).

2.5 Analytical Methods

The physicochemical examination of water and soil samples, as well as sample preparation and analysis of selected physicochemical parameters from river water and sediment samples, used the analytical methodologies and techniques listed below.

2.5.1 Physicochemical analytical methods of river water and soil samples

A 930 precision pH meter (Biobase) measured water and soil samples pH. Conductivity, TSS, and TDS were measured using the WTW in-lab 720 conductivity meter, while turbidity of the waters was measured using Hanna LP 2000 Turbidity meter. Moisture tests of soil were done using the Memmert hot air oven method set at 105^0C overnight. Soil organic matter (OM) and soil organic carbon (OC) in the soil were determined using a muffle furnace. In contrast, the soil structure test was determined using the Mason Jar test method as per APHA (2002) and APHA (1998) methods.

2.5.2 pH determination method for water and soil samples

A 930-precision pH meter (Biobase) measured water and soil pH. The meter was calibrated using buffer solutions with 4, 7, and 10 pH values. The pH of a water sample was measured by dipping the electrode into a 50 ml solution of water sample in a 100 ml beaker, spinning, and waiting a minute to get a steady reading. For soil samples, 20 g of soil was weighed using an analytical balance, then transferred into a 50 ml beaker, and 40 ml distilled water was added in the ratio of 1:2. The suspension was stirred for 30 minutes, and then pH readings were recorded. The same suspensions prepared and used for pH readings were kept and used for measuring soil conductivity (Rehman et al., 2015; Achakzai & Masood, 2015: APHA, 2002; APHA, 1998).

2.5.3 Conductivity determination

Conductivity measurements in water samples were carried out using a calibrated WTW in-lab 720 conductivity meter using solutions and water samples, which were used to measure pH. Before measuring the samples' conductivity, standards for the conductivity of 84, 1413, and 12880 µS were used for calibration. By dipping the electrode into a sample solution, spinning it around, and waiting up to a minute for a stable reading, before taking the readings. The electrodes were thoroughly cleaned with tissue and distilled water before switching the samples (Rehman et al., 2015; Achakzai & Masood, 2015; APHA, 2002; APHA, 1998).

2.5.4 Total Dissolved Solids (TDS)

By placing the filter paper in the filtration assembly and filtering three separate 20 ml volumes of distilled water, the filter paper used for TDS measurement was cleaned. The suction eventually eliminated all traces of water. Dishes were dried at 105^0C in an oven, cooled in desiccators, and weighed right before use. With a wide bore pipette, measured volumes of the water samples were pipetted onto the filters as they were agitated with a magnetic stirrer. The sample volume (about 50 ml) was chosen to give between 10 and 200 mg of dried residue, after which it was rinsed three times with 10 mL of distilled water. After the filtrations were finished, the suctions lasted for another three minutes. Total filtrates were placed on weighed evaporation plates with washings, where they were then evaporated to dryness in an oven at 105^0 C. After evaporation, the consecutive portions were applied to the same dishes to produce between 10 and 200 mg of dried residue. The oven temperature was initially set at 20^0 C below boiling point to prevent splattering and then increased to 105^0 C after one hour of evaporation. The leftovers were chilled in a desiccator before being weighed and recorded for calculations (Meride & Ayenew, 2016; APHA, 2002; APHA, 1998).

Calculate

$$\text{mg Dissolved Solids/L} = \frac{(A - B) \times 1000}{\text{mL sample}}$$

where:

A = weight of dried residue + dish, mg

B = weight of dish, mg.

2.5.5 Total Suspended Solids (TSS)

The filter papers were cleaned in this procedure by placing the filter papers on the filtration assembly and filtering three separate 20 mL volumes of distilled water. The filters were put on metal dishes and dried for one hour in an oven set to 105°C. Dry filter and crucible combined if a Gooch crucible utilized. The leftovers were weighed after being chilled in a desiccator to maintain an even temperature. The cleaned, dried, and weighed filter paper was used to assemble the filtration system. To fix it, filter sheets were moistened with a small amount of distilled water. A measured amount of water was pipetted using a large bore pipette onto the filter after the samples were stirred with a magnetic stirrer thoroughly. The sample volume (about 50 ml) was chosen to produce between 10 and 200 mg of dry solids, depending on the sample type. Three separate 10 mL amounts of distilled water were used for washing. After the filtrations were finished, the suction ran for roughly three minutes. Next, the filters were carefully removed and put on the aluminum weighing dishes. As mentioned, the drying, cooling, and weighing processes were carried out until a steady weight was attained and recorded for computations (APHA, 2002; APHA, 1998).

Calculation

$$\text{mg Total Suspended Solids / L} = \frac{(A - B)\,1000}{\text{mL sample}}$$

Where:

A = weight of filter + dried residue, mg, and
B = weight of the filter, mg

2.5.6 Turbidity Determination in water samples

After calibrating the instrument as per the manufacturer's operating instructions with the standards that were run on the instrument range to be utilized, the turbidity of all the water samples was measured using a Hanna LP 2000 Turbidity meter. When the air bubbles were gone after shaking the sample, the samples were gently stirred before being poured into a sample cell or cuvette (10 mls) for measurement. The sample cells or cuvettes were thoroughly cleaned with distilled water and gently wiped with a tissue before measurement. The instrument display was used to obtain the turbidity in Nephelometric Turbidity Units (NTU) (Meride & Ayenew, 2016; Rehman et al., 2015; Achakzai & Masood, 2015; APHA, 2002; APHA, 1998).

2.5.7 Moisture Content Determination

Soil moisture tests were done using the Memmert hot air oven method set at 105^0C overnight or for 24 hours by heating 10 g of soil samples in triplicates placed in moisture dishes in a Memmert oven. Each moisture dish's weight was measured both empty and full before and after heating. The weight difference between the dry soil sample and the original sample weight before drying was used to calculate the moisture content of the soil samples. The moisture content % was then calculated by multiplying the result by 100 after dividing the difference in weight by original weight of the sample (Ministry of Agriculture, Government of India, 2011).

2.5.8 Total organic matter and total organic carbon determination

Total organic matter and total organic carbon analyses were conducted utilizing a muffle furnace, employing a thermo gravimetric analytical technique. 10 g of sieved soil sediment (2 mm) was placed into crucibles, weighed, recorded weight, and then put in an MRC muffled furnace set at 105^0 C for 4 hours to remove the moisture from the sediment samples. The crucibles with the dried samples were removed, cooled, weighed to the nearest 0.01 g, and recorded as the initial sample weight (W_1).

The dried sediment samples were placed into the muffle furnace at 400^0 C for 4 hours, cooled in a desiccator, and weighed to the nearest 0.01 g (W_2). The percentage of organic matter (OM) was calculated by subtracting weight (W_2) from (W_1) and dividing the loss in weight by initial weight (W_1), and multiplying by 100 to get the % organic matter (OM) in the soil sediment samples. The Percent Organic Carbon (OC) was calculated by multiplying the percentage of organic matter (OM) by a factor of 0.58 (Ministry of Agriculture, Government of India, 2011).

2.5.9 Soil structure test

Soil structure tests were done using the Mason Jar Test method. Finely sifted soil samples were used to fill the Manson Jar to 1/3 full. Then, added one tablespoon of granular dishwashing detergent. The water was then poured into the glass jar almost to the top, allowing space for a good shake. After vigorously shaking the mixes until they were homogeneous and slimy, the glass jars' lids were snugly fastened. The glass jars were then placed on a flat surface to rest. The glass jars' sides were marked with a black marker pen to indicate the sand component after the mixes had settled for one minute. Two hours after settling, the glass jars' sides were marked with a marker pen to mimic the silt layer. The final clay layer was identified after letting the mixture sit for a few days until the top water layer became clear. As the soil/water mixtures settled for 48–72 hours, sand, silt, and clay broke into horizons, and their proportions were then clearly displayed. The percentages or proportions of sand, silt, and clay were calculated for the exact height of each layer and assessed using a ruler and the computations (Jeffers, 2019).

% Sand = (height of sand) / (total height of mixture) × 100

% Silt = [(height of silt) – (height of sand)] / (total height of mixture) ×100

% Clay = 100 – % Sand – % Silt

2.5.10 Data Analysis

The data for river water and sediment physicochemical parameters were analyzed using Microsoft excel software. The data analyzed were presented as figures with three replicates used for average and two replicates for Standard Deviation.

3.0 Results and Discussion

3.1 Physicochemical properties of water and soil sediments samples from the study area

The physicochemical properties of water and soil sediment samples from the study sites are summarized in Table 2. The pH of water samples ranged from 6.96±0.02 at Kibos Bridge near Kibos market (S2) to 7.90±0.02 at Nyalenda farms (S9) in wet months. During the dry season, the pH of water samples ranged from 6.93±0.06 at the Kibos Bridge near Kibos market (S2) to 7.86±0.05 at the point of entry to Lake Victoria (S10). Conductivity during the rainy season in river water ranged from 106.93±0.25 µs/cm (S1) to 139.26±0.86 µs/cm (S10), while total suspended solids (TSS) ranged from 65.40±0.80 mg/L (S3) to 123.73±0.60 mg/L (S9) in water samples (wet season). Total Dissolved Solids (TDS) in rainy season ranged from 101.23±1.15 mg/L (S1) to 120.10±0.45 mg/L (S10) and in drier months ranged from 93.63±1.30 mg/L (S1) to 118.10±0.33 mg/L (S10). Turbidity ranged from 147.23±0.96 NTU (S1) to 201.46±1.12 NTU (S9) in rainy months and from 84.23±0.41 NTU (S1) to 184.30±1.19 NTU (S10) in drier months. The soils' sediment pH ranged from 6.55±0.15 at the convergent of River Kibos and Awach near Guba Bridge Kibos (S1) to 7.23±0.05 at the point of entry to Lake Victoria (S10) in the drier months. Although during the wet season, the pH of sediment ranged from 6.20±0.05 at the Nyalenda wastewater treatment plant (S8) to 7.25±0.02 at the point of entry to Lake Victoria (S10), indicating that the soils sediment was generally weakly acid to basic. Soil sediment conductivity during dry season ranged from 56.57±0.60 µs/cm (S1) to 230.1±0.31 µs/cm (S10), while the dry season's clay and silt composition varied from 43.83±0.14 % (S1) to

45.99±0.19 % (S10) and 23.61±0.07 % (S1) to 31.82±0.12% (S10) respectively (Table 2). During wet season, sediment moisture ranged from 17.27±0.11% (S2) to 26.34±0.03% (S10), and in dry season it ranged from 13.14±0.03% (S2) to 19.14±0.03% (S10). The organic matter in wet season ranged from 3.21±0.04% (S1) to 9.43±0.11% (S10) and in dry season it ranged from 2.95±0.06% (S1) to 8.75±0.02% (S10). Organic carbon ranged from 1.86±0.03% (S1) to 5.47±0.07% (S10) in wet season and in drier month it's ranged from 1.71±0.04% (S1) to 5.07±0.01% (S10). pH maximum allowable limit (WHO) is between 6.5 – 8.5, conductivity 400 µS/cm, TDS desirable limit 500 mg/L, TSS 30 mg/L, Turbidity 5 NTU respectively (Meride & Ayenew, 2016). This means most of the parameters are within the WHO acceptable limit except turbidity and TSS but the gradual increase downstream (pollution) is worrying.

The study's findings revealed a consistent pattern of escalating soil and water physicochemical parameters downstream towards Lake Victoria, indicating heightened human, industrial, and agricultural engagements along the river. This trend was notably more pronounced during the wet season, possibly due to runoff from settlements, industries, and agricultural practices both upstream and downstream, culminating where the river enters Lake Victoria. To assess pollution levels in water and sediment samples, a suite of water, soil sediment physicochemical tests, and soil structure assessments were conducted. The outcomes of the physicochemical analysis were employed to gauge pollution levels and establish connections resulting from human, industrial, and agricultural activities.

Table 2: Physicochemical characteristics of water and sediments along river Kibos-Nyamasaria

Site	S1		S2		S3		S4		S5		S6		S7		S8		S9		S10	
Parameter	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**
Water samples																				
pH	7.10±0.05	7.05±0.04	6.96±0.02	6.93±0.06	7.34±0.08	7.10±0.10	7.42±0.10	7.18±0.04	7.50±0.10	7.33±0.12	7.50±0.17	7.26±0.16	7.61±0.12	7.40±0.21	7.61 ±0.09	7.45 ±0.18	7.90 ±0.02	7.88 ±0.01	7.89 ±0.09	7.86±0.05
Conductivity µs/cm	106.93 ±0.25	123.13 ±0.35	139.26 ±1.05	147±0.85	127.43 ±0.15	135.43 ±0.15	124.16 ±1.10	129.00 ±0.95	121.40 ±0.20	120.26 ±0.56	123.56 ±0.75	120.53 ±0.70	126.81 ±0.81	130.53 ±0.87	132.66 ±0.85	128.53 ±1.01	137.56 ±0.97	133 ±0.75	139.26 ±0.86	137.26 ±0.36
TDS Mg/L	101.23 ±1.15	93.63±1.30	110.50 ±0.80	118.56 ±1.13	108.30 ±0.81	113.46 ±0.70	113.46 ±0.77	106.16 ±0.75	103.53 ±1.02	99.46±1.25	105.36 ±0.50	101.33 ±0.25	111.40 ±1.35	107.53 ±0.86	117.26 ±1.10	115.46 ±1.12	115.60 ±0.88	113.40 ±0.79	120.10 ±0.45	118.10 ±0.33
TSS Mg/L	86.46±0.73	71.43±0.15	102.70 ±0.60	94.96±0.90	65.40±0.80	71.60±0.10	71.10±0.10	79.70±0.20	94.40±0.05	88.50±0.50	89.70±0.10	83.20±0.90	97.60 ±0.90	111.40 ±0.03	113.20 ±0.20	120.30 ±0.60	123.73 ±0.60	126.90 ±0.70	111.50 ±0.90	110.50 ±0.41
Turbidity NTU	147.23 ±0.96	84.23±0.41	155.33 ±0.85	98.43±1.06	154.30 ±0.81	129.43 ±0.75	158.20 ±0.95	132.30 ±1.05	163.93 ±0.61	144.33 ±0.65	159.10 ±0.80	139.36 ±1.15	181.46 ±1.05	156.13 ±0.80	173.30 ±0.91	152.40 ±0.88	201.46 ±1.12	177.06 ±0.61	188.50 ±1.08	184.30 ±1.19
Sediments																				
pH	6.73±0.09	6.55±0.15	6.20±0.05	6.21±0.01	6.39±0.15	6.27±0.04	6.57±0.10	6.33±0.14	6.57±0.13	6.50±0.17	6.90±0.08	6.73±0.07	7.03±0.07	6.92±0.07	6.20±0.15	6.83±0.10	7.26±0.06	7.16±0.15	7.25±0.02	7.23±0.05
Conductivity (µs/cm)	58.13±0.35	56.57±0.60	44.43±0.31	46.50±0.36	90.60±0.36	91.40±0.20	83.50±0.30	87.67±0.25	90.80±0.45	89.43±0.70	112.10 ±0.20	109.50 ±0.61	123.80 ±0.36	120.50 ±0.36	142.23 ±0.35	138.43 ±0.35	231.2±0.36	226.47 ±0.40	233.63 ±0.25	230.1±0.31
Moisture (%)	18.15±0.03	16.81±0.06	17.27±0.11	13.14±0.03	17.58±0.14	15.75±0.03	18.38±0.03	15.23±0.07	18.78±0.02	13.32±0.11	19.00±0.02	16.82±0.09	19.86±0.10	16.98±0.03	22.10±0.03	17.43±0.02	24.04±0.03	17.70±0.02	26.34±0.03	19.14±0.03
Organic Matter (%)	3.21±0.04	2.95±0.06	4.62±0.10	4.02±0.01	4.65±0.17	4.52±0.11	4.38±0.15	4.41±0.30	3.87±0.09	3.64±0.07	3.93±0.22	3.69±0.17	4.13±0.02	3.89±0.08	8.23±0.03	6.82±0.16	8.03±0.02	6.89±0.10	9.43±0.11	8.75±0.02
Organic carbon (%)	1.86±0.03	1.71±0.04	2.67±0.05	2.33±0.01	2.69±0.11	2.60±0.07	2.54±0.08	2.46±0.06	2.24±0.05	2.11±0.04	2.28±0.12	2.14±0.09	2.4±0.01	2.25±0.04	4.77±0.02	3.95±0.09	4.66±0.01	4.00±0.06	5.47±0.07	5.07±0.01
Clay (%)	44.05±0.03	43.83±0.14	44.44±0.04	44.05±0.08	43.27±0.03	43.15±0.02	39.73±0.02	39.55±0.13	39.87±0.05	39.64±0.11	40.35±0.03	40.74±0.66	44.05±0.09	42.94±0.14	43.28±0.06	42.93±0.21	44.32±0.02	44.77±0.15	45.51±0.07	45.99±0.19
Silt (%)	23.99±0.61	23.61±0.07	25.92±0.12	23.07±0.04	26.06±0.05	25.64±0.04	27.92±0.17	26.88±0.03	28.13±0.04	27.11±0.05	26.66±0.03	25.80±0.06	28.15±0.15	25.85±0.07	28.8±0.12	31.04±0.02	29.73±0.04	30.11±0.03	30.05±0.03	31.82±0.12
Sand (%)	31.63±0.02	32.54±0.04	6.2±0.05	6.21±0.01	6.39±0.15	6.27±0.04	6.57±0.10	33.53±0.11	31.97±0.07	33.23±0.11	32.96±0.02	33.14±0.03	30.87±0.06	31.14±0.12	27.57±0.68	26.03±0.02	25.92±0.03	25.10±0.06	22.45±0.22	22.23±0.03

Sampling Sites (S1-S10)

1

3.3 The graphical presentation of results of physicochemical parameters of river water

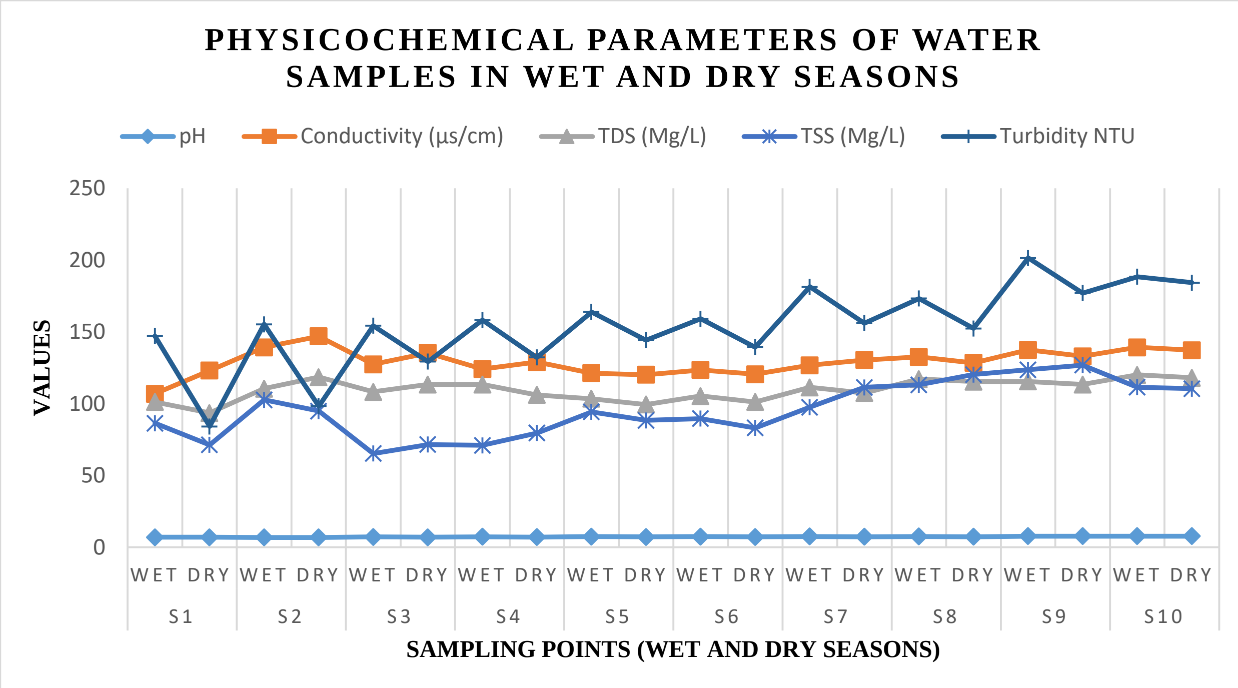

Figure 2: Graph showing increase in water physicochemical parameters downstream

Figure 2 demonstrates a consistent pattern of rising water physicochemical parameters downstream, evident in both wet and dry seasons at ten designated sampling sites spanning from the river's origin to Lake Victoria. This suggests escalated human, industrial, and agricultural involvements downstream along the river Kibos-Nyamasaria, potentially resulting in downstream river pollution. Notably, this trend was more prominent during the wet season, likely due to runoff from human settlements, industries, and agricultural practices both upstream and downstream, ultimately converging where the river discharges into Lake Victoria.

PH is an important parameter in evaluating the potential of hydrogen ion concentration or acid–base balance of water. It is also the indicator of acidic or alkaline condition of water status. WHO has recommended maximum permissible limit of pH from 6.5 to 8.5 (Meride & Ayenew, 2016). In the current investigation pH in water samples ranged from 6.93±0.06 to 7.90±0.02 which are in the range of WHO standards. In soil sediment, pH ranged from 6.20±0.05 to 7.26±0.06 and slightly acidic in some sampling points (figure 3 and table 2).

Turbidity, which refers to the cloudiness of water and depends on the quantity of solid matter present in the suspended state. It is a measure of light emitting properties of water and the test is used to indicate the quality of waste discharge with respect to colloidal matter. Elevated turbidity levels can disrupt disinfection processes and create a conducive environment for microbial proliferation. Additionally, increased turbidity may serve as an indicator of the potential presence of microorganisms, including bacteria, viruses, and parasites. The mean turbidity value obtained from this study is above the WHO recommended value of 5.00 Nephelometric Turbidity Units (NTU) (Meride & Ayenew, 2016).

Total dissolved solids (TDS) signifies water's capacity to dissolve an array of inorganic and certain organic minerals or salts, encompassing elements like potassium, calcium, sodium, bicarbonates, chlorides, magnesium, and sulfates. The presence of these minerals imparts an undesirable taste and a diluted color to the water. TDS holds significance as a water parameter, wherein high values indicate heightened mineral content. The recommended TDS threshold according to WHO for water designated for drinking is 500 mg/l, with a maximum limit of 1000 mg/l. Exceeding this value can lead to issues such as water hardness, excessive mineral accumulation, discoloration, staining, a perceptible salty taste and is harmful to aquatic and human health**.** (Meride & Ayenew, 2016). The concentration of TDS in present study was observed in the range 101.23±1.15 mg/L (S1) to 120.10±0.45 mg/L (S10) in wet season and in drier months ranged from 93.63±1.30 mg/L (S1) to 118.10±0.33 mg/L (S10). This means that the total dissolved solids concentration in river Kibos-Nyamasaria was found to be within the limit of WHO standards. High values of TDS may affect persons who are suffering from kidney and heart diseases. Water containing high solid may cause laxative or constipation effects according to Meride & Ayenew, (2016).

TSS is a measure of the amount of solid particles in water that are large enough to be trapped by a filter. The particulates, organic or inorganic can find their way into water bodies from diverse origins such as soil and agricultural drainage, industrial activities, sewage and urban runoff. Elevated concentrations of suspended particles can result in heightened cloudiness, diminished sunlight penetration, and lowered oxygen levels, all of which can pose adverse consequences for aquatic ecosystems. High levels of TSS also make water cloudy and murky, and they can interfere with the growth of plants and algae. TSS can also be harmful to human health, as it can carry bacteria, microganisms and other pollutants. In this study TSS ranged from 65.40±0.80 mg/L to 123.73±0.60 mg/L which is above 30 mg/L WHO maximum limit for drinking water.

3.4 The graphical presentation of results of physicochemical parameters of sediments

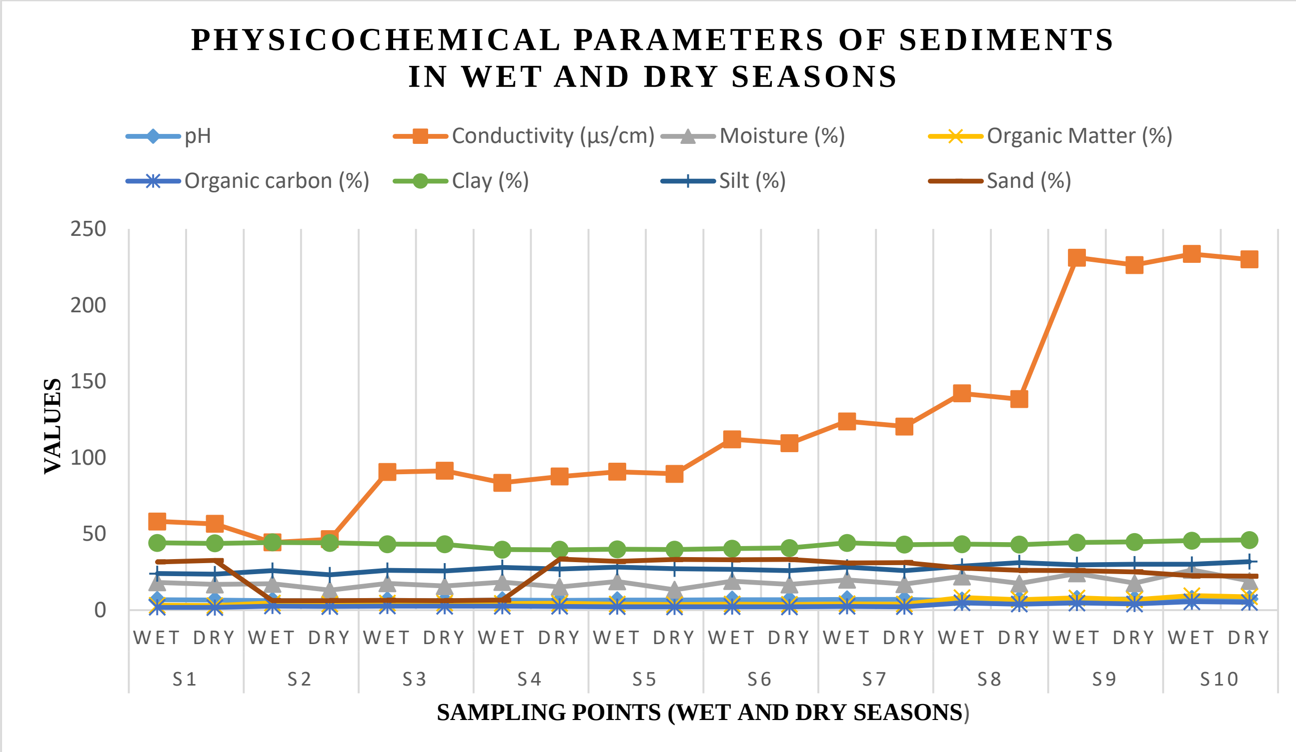

Figure 3: Graph showing increase in sediment physicochemical parameters downstream

Figure 3 show a general trend in the increase of the sediment physicochemical parameters downstream both in the wet and dry seasons in ten sampling points along the river to Lake Victoria. Electrical conductivity (EC) assesses a solution's ability to conduct an electric current, a process primarily reliant on its ionic content. Higher levels of dissolved ionic solids correspond to elevated conductivity, often referred to as "soluble salts." Dissolved inorganic substances generally exhibit strong conductivity, whereas dissolved organic substances exhibit limited conductivity. As per World Health Organization (WHO) guidelines, the EC value for safe drinking water should remain below 400 µS/cm (Meride & Ayenew, 2016). In this study, conductivity in sediments ranged from 44.43±0.31 to 142.23±0.35 µs/cm and was the highest in sediment (figure 3) indicating presence of dissolve ions which can conduct electric current but still within the limits of WHO.

Conductivity in water samples ranged from 106.93±0.25 µs/cm to 139.26±0.86 µs/cm and were below WHO standards of maximum limit of 400 µS/cm for drinking water (Meride & Ayenew, 2016). The progressive rise in the physicochemical parameter values downstream signifies increase human, industrial, and agricultural engagements along the river Kibos-Nyamasaria, potentially contributing to river and sediment pollution downstream. This pattern was notably more pronounced in the wet season compared to the dry season, likely due to surface runoff originating from human settlements, industries, and agricultural activities both upstream and downstream, eventually converging where the river empties into Lake Victoria.

Possible effect of increased pollution to the community downstream

In the analyzed water and sediment samples (illustrated in figures 2 and 3), there was an evident upward trend in the levels of selected physicochemical parameters as one progresses downstream towards Lake Victoria. This pattern could be attributed to the consistent input and accumulation of these physicochemical characteristics stemming from human, industrial, and agricultural activities occurring downstream along the river. With industrial discharges, agricultural runoff, and municipal waste finding their way into water bodies like rivers and lakes, there's a concurrent introduction of chemical and biological pollutants, encompassing pesticide residues, into these water sources. This phenomenon is particularly noticeable at various points along the river, resulting in an amplified state of pollution. The communities residing adjacent to these rivers, heavily reliant on water for daily use, could find themselves compelled to seek costlier alternatives like tap water—an option often financially out of reach, especially for urban populations with limited means. The absence of timely intervention could potentially lead to elevated risks posed by the presence of harmful chemicals and pathogens in river water, thereby endangering the health of those who rely on it for drinking, crop irrigation, fishing, bathing, and recreation. In light of this, the importance of curbing water and sediment pollution is underscored to avoid potential crises impacting aquatic ecosystems, animals, and human inhabitants within the study region. Therefore, it's imperative to institute a regimen of consistent monitoring for downstream physicochemical parameters in this geographic locale. This proactive approach is vital for managing, mitigating, and ultimately reducing the extent of environmental contamination and the correlated health hazards.

3.3 Effect and variations of some physicochemical characteristics in river water and Sediments

Several studies indicates that, the gradual increase of pH of rivers water and sediment downstream influences the bioavailability and transport of many toxic chemicals such as pesticides in water and sediments (Aiyesanmi *et al*., 2008; Drevenkar *et al*., 1996).Therefore, gradual increase of these physicochemical parameters downstream of river Kibos-Nyamasaria due to increase human activities should be monitored urgently with relevant government agencies to avoid health calamity which might occur. According to Ahmad *et al*., 2000 studies, toxic chemicals such as heavy metals and pesticides respond variably in water and soil, depending on their specific properties and the water-soil physicochemical parameters. Hydrolysis, which is a chemical reaction in which water reacts with a compound to produce other compounds, increased level of toxic chemicals adsorption and desorption due to pH increase downstream (Ahmad *et al*., 2000). When the pH of the water is greater (above 7) or alkaline, hydrolysis in water might happen very quickly. The rate of hydrolysis increases ten times for every unit increase in pH due to pollution of river downstream (Ahmad *et al*., 2000). The pH and speciation of dissolved ions also affect some toxic chemicals in water such as pesticides capacity to coagulate or sorb ions (Ahmad *et al*., 2000). The tread also leads to gradual increase of the conductivity and other water and sediments physicochemical parameters due to pollution of river as a result of anthropogenic activities downstream. In this study of water and sediment, the pH were within the range of most natural rivers, streams, or lakes between 6.5 and 7.5. This might increase tremendously if not monitored urgently due to the increase anthropogenic activities downstream. The WHO allowable pH range for water and sediment is 6.5-8.5 (Rehman et al., 2015; Achakzai & Masood, 2015).

The sorption, transport, and transformation of chemicals such as pesticides are significantly influenced by the organic matter composition of the soil sediments (Tariq *et al*., 2016). The organic matter in this study varied from 2.95 ± 0.06 % at the convergent of River Kibos & Awach near Guba Bridge Kibos (S1) to 9.43 ± 0.11 % downstream at the point of entry to Lake Victoria (S10). Depending on the type of dissolved toxic chemical and the organic matter, soil with an organic carbon concentration of greater than 5% facilitates the sorption and accumulation of toxic chemicals in water and sediments (Rehman et al., 2015). In this study some point recorded organic carbon greater than 5% which might be facilitating the sorption and accumulation of toxic chemicals in water and sediments of river Kibos-Nyamasaria.

As explained by Fosu-Mensah *et al*. 2016 organochlorine pesticide residue levels and other toxic chemicals in the soils are associated with high conductivity, organic matter, and organic carbon of the soil sediments. This might be explained by the fact that, like the fats, oils, or lipids found in plants and animals, pesticide molecules and other chemical which are present in river Kibos-Nyamasaria water and sediments have a high propensity to attach to organic matter and carbon in soil sediment (Fosu-Mensah *et al*. 2016). Fosu-Mensah *et al*. (2016) and Aiyesanmi

& Idowu (2012), revealed the trend of significant ($p>0.05$) associations between total organochlorine pesticides assessed in soil sediment samples and organic carbon, organic matter, and the two variables.

The texture of the soil sediment affects how toxic chemicals such as organochlorine pesticides and heavy metals behave in the soil, according to Fosu-Mensah *et al*. (2016). Sandy soils promote the leaching of toxic chemical, whereas clay soils aid in accumulating toxic chemicals found in water through colloid formation. Several studies shows that when the amount of sand increased, the number of toxic chemicals such as organochlorine pesticides decreased quantity (Fosu-Mensah *et al*. 2016; Tariq *et al*., 2016; Aiyesanmi and Idowu; 2012). Fosu-Mensah *et al*. (2016) in their study states that, toxic chemicals such as organochlorine pesticides have a high positive and significant connection ($p > 0.05$) with the percentage of silt, indicating that as the percentage of silt increased, so did the concentrations of these toxic chemicals in water and sediments.

4.0 Conclusion

Gradual increase of levels of selected physicochemical parameters downstream were linked to human, industrial, and agricultural activity along the Kibos-Nyamasaria River. The pollutants may have entered the water and soils through a variety of methods, including spray drift, wash-off from sprayed agricultural land, accidental spills on the ground, improper disposal of leftover spray solution or dumping of untreated domestic and industrial wastes into rivers or nearby, misuse or overuse of the chemicals which eventually drains into the river and nearby water bodies through leaching and surface runoff endangering soil organisms, animals, human and aquatic community.

According to WHO and NEMA guidelines, some of these selected physicochemical parameters in this study were in levels not advised for use in drinking water. The steady increase of these selected physicochemical parameters downstream in soil and water samples from the research area suggests that some human activities gradually continue to pollute river Kibos- Nyamasaria illegally. Controlling water and sediment pollution is necessary to prevent potential tragedies for aquatic, animal, and human health. Regularly monitoring of physicochemical parameters downstream in this study region is required to prevent, regulate, and reduce environmental contamination and health hazards.

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Competing interests

The authors declare that there is no competing interest concerning this work.

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