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Levels of chemical parameters in the up-stream and downstream of Nyakomisaro tributary of River Kuja within Kisii town, Kisii County Kenya

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Abstract

Rapid population growth, urbanization, and increased consumption have exerted pressure on freshwater resources, particularly in urban areas. This study evaluated the chemical quality of water in the Nyakomisaro tributary of River Kuja, comparing upstream and downstream sections in Kisii town, Kenya, between February and May 2016. Water samples were analyzed for total alkalinity, copper, lead, zinc, phosphorus, total suspended solids (TSS), and nitrates using standard laboratory techniques and Atomic Absorption Spectrophotometry. Data analysis employed SPSS, with means compared using a T-test at a 95% confidence level ($p \leq 0.05$). Results showed mean concentrations of 3.04 mg/L (TSS), 71.06 mg/L (total alkalinity), 3.79 mg/L (nitrates), 8.66 mg/L (phosphates), 0.24 mg/L (copper), and 0.15 mg/L (zinc), while lead was undetectable. All parameters were higher downstream, with significant differences observed between upstream and downstream values. Despite these variations, levels remained within the permissible limits set by the National Environmental Management Authority (NEMA) and the World Health Organization (WHO), indicating water suitability for consumption. The study recommends expanding piped water supply and enforcing wastewater treatment before disposal. These findings will support policy formulation and sustainable water resource management in Kisii County.

Keywords: Chemical parameters, Downstream, Tributary, Upstream, Nyakomisaro

1.0 INTRODUCTION

Water is a scarce resource that requires utmost protection. It is estimated that 40% of the world population will live in water scarce regions by the year 2025 [59]. Rapid population growth, urbanization, consumption and the desire for better living has placed great strain on fresh drinking water supply, especially in urban centers, with attendant health and environmental issues [2, 40, 47].

Water resources comprising of surface water (river and lakes), ground water, and coastal waters support living things including human beings [34, 37]. Supply of potable water is important to the development of any country [12, 17, 13]. Clean water sustains a healthy population and it contributes to the quality of life of households. Potable water supports public health and ensures economic growth [5, 29, 30]. Water is also a vital resource for agriculture, manufacturing and other human activities [6, 8]. While the supply of fresh water is limited, both the world's population and demand for fresh water resource continues to expand rapidly Though available in huge quantities only less than 3% is reliable and accessible, the meager percentage is under pressure from anthropogenic pollutants, making fresh water the most critical resource issue facing humanity [5, 58].

Globally it is estimated that 450 billion cubic meters of wastewater currently enter world water bodies each year through point sources pollution [10]. Nonpoint source pollution which is pollutants of different forms from diverse sources has over the years provided a challenge to researchers and planners [3, 13, 17].

Water as a resource is becoming a scarce and costly commodity in most parts of the world [15, 18]. Intensive human and animal sewage leakage is associated with numerous environmental and human health effects, but nitrogen, phosphorus, and microbial organisms that get into water are of particular concern [16].

Significant threats to water quality are attributed to spills, leakage from constructed pit latrines near water bodies and illegal dumping of solid wastes directly or into dumpsites near water bodies [1, 3]. Precipitation, erosion, and flooding aggravate contaminant escape from these sites into rivers [14, 19, 20]. Location of human structures and livestock facilities beside streams and watering them in the water bodie make water to be most vulnerable to contamination from pathogenic microbes found in their excreta [16, 41]. It is reported that 80% of all illness in developing countries is related to water and sanitation. In urban areas, disposal of untreated industrial and municipal effluent and other wastes into rivers and lakes may contribute greatly, to the poor quality of river water [17, 14].

Developed countries have historically experienced a succession of water quality problems relating to pathogens, eutrophication, acidification, organic compounds, heavy metals and micro-pollutants and sediments from municipal, industrial and agricultural waste sources [19, 20, 21, 49]. In rapidly developing countries – such as Brazil, China and India – similar sequences of water problems have emerged over the last few decades. In other developing countries, water pollution still remains problematic and is one of the single leading causes of poor livelihood and bad health [49].

In Kenya water resources are increasingly becoming polluted from both point and nonpoint sources; the major pollutants are: agricultural activities which produce sediments and agrochemical residues; Industrial processing of agricultural and forestry products which produce liquid effluents, gaseous emissions and solid wastes and domestic effluents of all forms [24, 35, 38, 44].

2.0 MATERIALS AND METHODS

2.1 Study Area

The study area is Nyakomisaro tributary of river kuja flowing through Kisii Town. The town is located at an altitude of 1850 meters above sea level and lies between longitude 34o45’0”E and 34o47’0”E and latitude 0o40’0”S and 0o42’0”S in South Western Kenya (Figure 1). It is situated approximately 309 km North West of Nairobi on the highway to Mwanza [39].

2.1.1 Climate

The study area experiences equatorial climate and receives rain almost throughout the year. This type of rainfall is bimodal, with short rain received between September and November while long rains come from April to June (wet season), the rest of the year is dry, average rainfall being over 1500mm. The average temperature is 20ºC. Winds blow at an average speed of between 5 and 15km/hr. The average humidity is 40% [39].

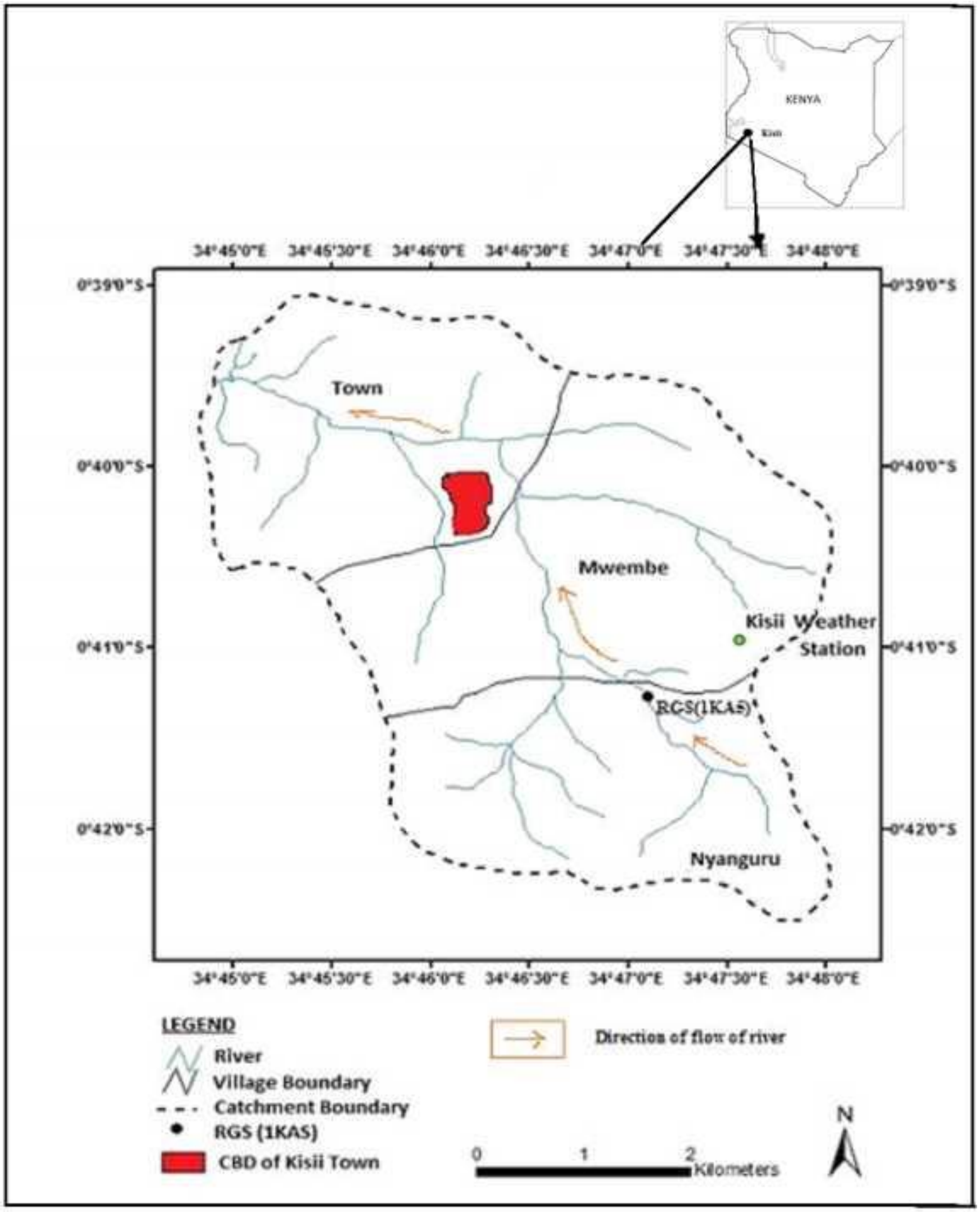

Figure 1: Map of Kenya showing Kisii County and location of Nyakomisaro tributary-the study area. Source: Google map

2.1.2 Geology and Soils

The geology of the area is divided into six major distinct geological systems namely, The Nyanzan systems, Kavirondian system, Bukoban systems, Tertiary volcanic systems,

Pleistocene systems and Major intrusive systems. The study area falls within the Bukoban systems composed essentially of andesite rocks, quartzite and basalts, while the stratigraphy sequence is the basalt which are overlaid by quartzite and the subsurface and surface is covered by the andesite estimated to be of the Precambrian age [39].

The stratigraphic sequence is the base under laid by the basalts which are overlaid by the semi consolidated; these are in turn overlaid by the semi-solid lateritic ferrous rocks, while the surface is basically quartzite disseminated in the loose, unconsolidated red volcanic rocks, with great amount of iron in its chemical composition [39].

2.1.3 Flora and Fauna

The main economic activity is small scale agriculture, the main cash crops are Camellia sinensis, Coffea Arabica / Coffea canephora, Musa acuminata and Saccharum officinarum while livestock production is both dairy and beef production though they are also engaged in small scale trade commercial businesses and soapstone carvings [26].

2.1.4 Hydrology

The region is dissected throughout by rivers which form a dendritic pattern. Many permanent streams drain the county, the main one being Kuja river in the south west and its tributaries being Rivers Iyabe and Riana that drain the north west of the county [26]. The tributaries mouth is Lake Victoria. The catchment of the rivers is Kisii highlands which also forms a watershed [26].

2.1.5 Socio-economic activities

The human population of Kisii municipality is 112417 people with a density of 874.7persons per square km according to the Kenya national census of 2019 [26]. Kisii town serves as the main urban and commercial centre in the Gusii highlands and south Nyanza region. The sex ratio is approximately 1:1, Education level is average, though the poverty level stands at 51% [26].

2.2 Research Design

2.2.1 Selection of the Study Area

River Kuja has got many tributaries but Nyakomisaro one of the tributaries was chosen as it passes through Kisii town, it is also a source of water for domestic, commercial, and agricultural activities around the town unlike the other tributaries which do not cross the town, and hence it is important to monitor the level of pollution of the tributary. Three stations were selected upstream before Kisii town and seven stations downstream after the tributary is within Kisii town so as to find out where there are higher levels of contamination.

2.2.2 Data collection

Water was sampled following the standard methods for examination of water and wastewater [10]. Water was collected in 500ml polythene bottles which were washed with one molar concentrated nitric acid and then rinsed with the sample water before collection. Water samples were collected along the 3km stretch of the tributary. Water was collected at the selected sites (Table 1). The ten sampling stations were equidistant from each other. Water was collected at a distance of 1.5m into the river from either side and at a depth of about 30cm. The samples were collected once a month between February and May 2016. February and March as dry months, April and May as rainy months.

Table 1: Sampling stations and their corresponding grid references

SAMPLING STATIONS	GRID REFERENCES
A	34.1E, 0.9N
B	34.2E, 0.8N
C	34.3E, 0.7N
K	34.4E, 0.7N
L	34.4N, 0.6N
M	34.5E, 0.6N
N	34.5E, 0.5N
O	34.6E, 0.5N
P	34.6E, 0.4N
Q	34.6E, 0.4N

2.2.3 Sample processing and storage

The water samples collected were labeled as per the sampling station and since the analysis was to commence within six hours no preservatives were used to stop microbial activity.

The samples were packed in an icebox and transported to Kenyatta university laboratory for analysis. Rainfall data during the study period was obtained from Kenya Metrological department.

2.3 Chemical parameters Analysis

2.3.1 Alkalinity

This was determined by titrating the sample with 0.02M Sulphuric acid using methyl orange as indicator and recorded as milligrams per liter of calcium carbonate [10].

2.3.2 Total suspended solids

The amount of Total suspended solids in the water sample was determined gravimetrically. A pre- weighed filter paper was used to filter 100ml of the water sample. The combined filter paper and filtered solids was dried at 1050C and reweighed. This was done until a constant value was reached. The weight of suspended solids was computed using the formulae below:

TSS (mg/l) = ((Wc - Wt) X 106) V-1

Where TSS = Total suspended solids,

Wt = Weight of pre-combusted filter in grams;

Wc= Constant weight of filter + residue; V = volume of water sample used [67].

2.3.3 Metals (Copper, Lead and Zinc)

Samples for analyses of metals were first pretreated and digested (metals were dissolved by acidifying with hydrochloric acid 1ml per 100ml of sample then boiled gently for five minutes and made to a known level with distilled water) and analyzed using atomic absorption spectrophotometer [58].

2.3.4 Nitrate-Nitrogen (NO3-N)

The Nitrate-nitrogen concentration was determined using filtered water samples following modified sodium salicylate procedure. Nitrate-nitrogen was reacted with sodium salicylate and sulphuric acid to produce a yellow compound (nitro salicylic acid). Color intensity was then measured calorimetrically using a digital spectrophotometer (HACH Model) at a wavelength of 420nm. Standard of known NO3-N concentration was subjected to the same treatment as water sample and readings used to determine the actual concentration of nitrate in the sample [10].

2.3.5 Total phosphorus

Total phosphate concentration was determined using filtered water by ascorbic acid reduction method. Unfiltered water sample was oxidized to PO4-P by autoclaving the samples at 1200C for 40 minutes using Ammonium persulfate oxidizing agent. Phosphate ions combine with ammonium molybdate to form a molybdophosphate complex. The complex is readily reduced by ascorbic acid to an intensely blue molybdophosphate complex. Colour intensity was measured calorimetrically at a wavelength of 690nm using a digital spectrophotometer (HACH Model), [10, 34].

2.4 Data Analyses

The results were analyzed using SPSS which applied the t-test to compare the means between the upstream and downstream levels and between the wet and dry seasons.
The results were presented in form of tables and graphs. The results were compared with the WHO and NEMA limits for chemical parameters for portability.

3.0 RESULTS

Table 2: Mean Values of the Physico- chemical and Microbial Parameters of water of Nyakomisaro Tributary of River Kuja

Parameter	Upstream	Downstream	Sig.	Stream
Suspended Solids (mg/l)	0.92	5.16	-	3.04
Alkalinity (mg/l)	66.53	75.59	0.00	71.06
Nitrate Nitrogen (mg/l)	2.99	4.59	0.00	3.79
Phosphorus (mg/l)	8.46	8.87	0.00	8.66
Copper (mg/l)	0.17	0.31	-	0.24
Zinc (mg/l)	0.12	0.18	0.00	0.15

3.1 Total Suspended Solids

The study showed that the total suspended solids along the tributary varied (Table 2). The suspended solids ranged from 0.92mg/l in station B to 5.19mg/l in station L (Figure 2). The mean value of TSS at the downstream was $\bar{X}$ = 5.16 mg/l and the upstream was $\bar{X}$ = 0.92 mg/l, (Table 2 and Figure 3). Using t-test the results showed no significant difference between the stations at p = 0.05. Therefore, the null hypothesis is not rejected.
The total suspended solid content in water bodies is influenced by amount of soil, silt human activities and amount of run off which drain into them [2]. The higher downstream values could be attributed to run off, human activities and municipal wastes from the town.

The mean TSS of Nyakomisaro tributary was 3.04mg/l which was lower than that of Nyanchwa-Riana River Kisii, Kenya which was 52.33mg/l [41, 42]. It was also lower than that of River Kaveri in India whose mean was 78.87mg/l [48], and river Jakara in Nigeria with a mean of 219.39mg/l [2].

Figure 2: Mean Suspended Solids recorded at stations A-Q during study period

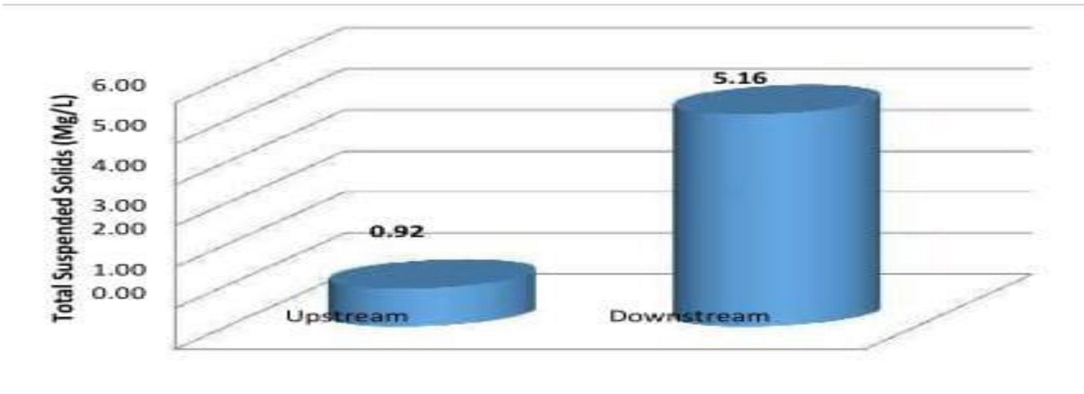

Figure 3: Mean up and downstream Total Suspended Solids during the study period

3.2 Alkalinity

The study showed that alkalinity along the tributary varied, Table 2. It ranged from 66.41mg/l in station A to 75.85mg/l in station N (Figure 4).

The lowest mean for alkalinity was recorded in the upstream and the highest at the downstream (66.41mg/l and 75.85mg/l) respectively Figure 4. According to Table 2 and Figure 4, the mean value of alkalinity in the upstream was $\bar{X}$ = 66.53 mg/l and ($\bar{X}$ = 75.59 mg/l in the downstream. Using t- test there was significant difference between the stations at p = 0.05. Therefore, the null hypothesis is rejected

According to [36] alkalinity of rivers is mainly influenced by carbonates and bicarbonates due to weathering of rocks, waste discharge and microbial decomposition of organic matter in the water body. In the downstream the higher levels could be attributed to increased microbial decomposition of agricultural products and animal wastes and municipal effluents.

The mean alkalinity of Nyakomisaro tributary was 71.06 mg/l**,** was lower than that of Elala River which was 149.50mg/l [27]. A higher value still of 153.20mg/l was reported by [4] at Ogun River. A similar higher value was recorded in Narmada River in India whose mean value was 125mg/l in a study carried by [28].

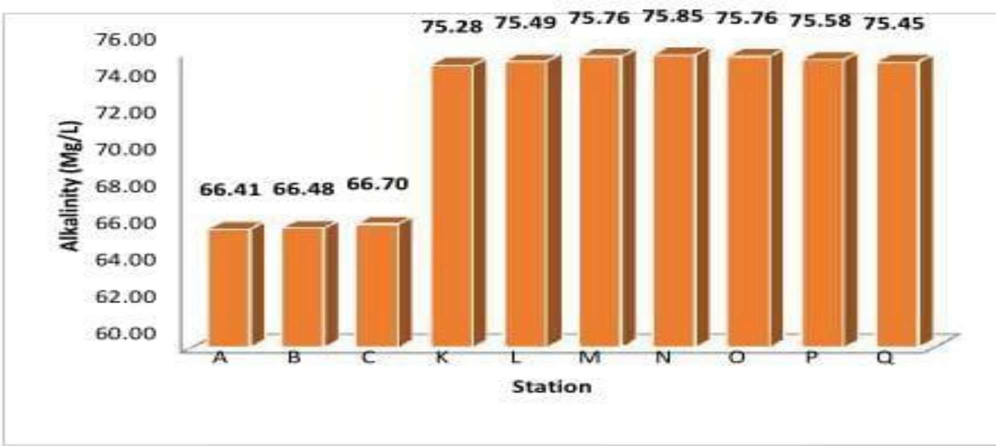

Figure 4: Mean Alkalinity recorded at stations A-Q during the study period

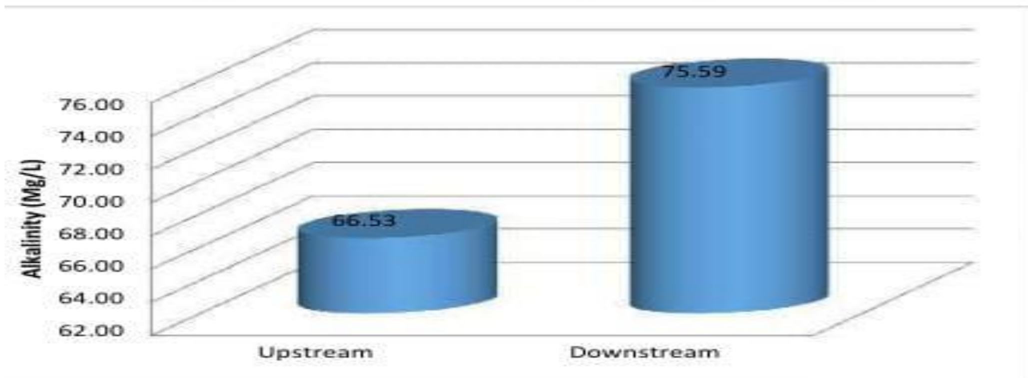

Figure 5: Mean up and downstream total alkalinity during the study period

3.3 Nitrate- Nitrogen

The study showed that the Nitrate-Nitrogen along the tributary varied, Table 2. The Nitrate- Nitrogen ranged from 2.80 mg/l in station A to 4.61 mg/l in station K. The lowest mean Nitrate- Nitrogen was recorded in the upstream and the highest at the downstream (2.80 mg/l and 4.61 mg/l) respectively, (Figure 6). The mean values were $\bar{X}$ = 2.99 mg/l, upstream and $\bar{X}$ = 4.59 mg/l downstream, (Table 2 and Figure 7). Using t-test the results showed significant difference between the stations at p = 0.05. Therefore, the null hypothesis is rejected.

Nitrate-Nitrogen in the water is attributed to agricultural land use practices, anthropogenic activities [31, 34, 37]. It is also influenced by run-off from municipal wastes and decay of vegetation [31]. The almost equal levels in the entire stream of the tributary were due to the slow rate of flow of the river. Since the upstream neighborhood is more agricultural than downstream this might be one of the influencing factors behind the slightly higher nitrogen values in the upstream and as the river flow some nitrate is used up by plants and deposited in sediments.

The mean Nitrate-Nitrogen levels of Nyakomisaro tributary was 3.79mg/l which is lower than that of Nyanchwa-Riana-river, Kisii, Kenya which is 44.89 mg/l [41, 42] and Elala river water whose mean value was 34.60 mg/l [57]. Higher results still were observed by [2] who recorded a mean of 19.39mg/l from Jakara River in Nigeria

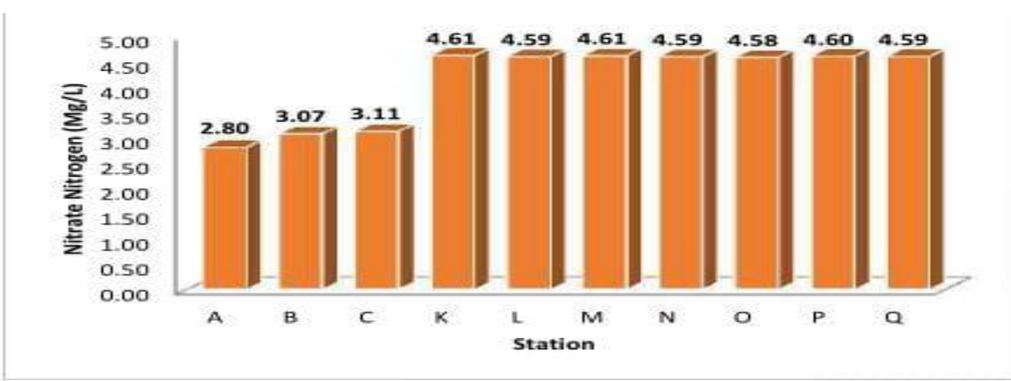

Figure 6: Mean Nitrate-Nitrogen recorded at stations A-Q during the study period

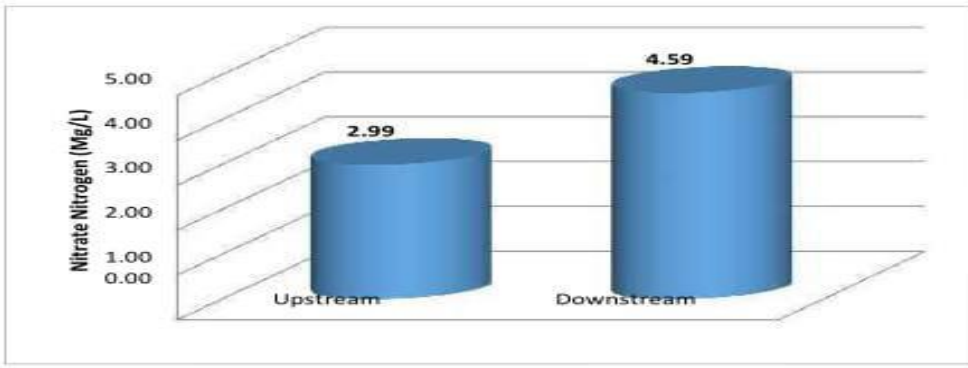

Figure 7: Mean up and downstream Nitrate-Nitrogen during the study period

3.4 Total phosphorus

The study showed that the total phosphorus along the tributary varied, (Table 2). It ranged from 8.43mg/l in station C to 8.88mg/l in station K.

The lowest mean for total phosphorus was recorded in the upstream and the highest at the downstream (8.43mg/l and 8.88mg/l) respectively, (Table 2 and Figures 8 and 9). Phosphorous concentration in water had a mean value of $\bar{X}$ = 8.87 mg/l, at Downstream and $\bar{X}$ = 8.46 mg/l at the Upstream. Using t-test there was a significant difference between the stations at p = 0.05. Therefore, the null hypothesis is rejected.

According to [9, 43, 45] phosphorus is naturally derived from the weathering of rocks and the decomposition of organic material, but it can also enter water bodies in runoff or discharges of soil and fertilizer , sewage, municipal and domestic effluents is also rich in phosphorus. The slightly higher values recorded in the downstream could be attributed to decomposition of organic materials from runoff from agricultural farms and municipal effluents which end up in the river [46, 65, 66, 68]. The other sources of phosphorus are through detergents as people bath and wash directly at the river. There are also many watering points for livestock along the river. The mean value of phosphorus recorded along the tributary was 8.66 mg/l is lower than that of Nyanchwa-Riana River Kisii, Kenya which was 55mg/l, [41, 42]. However, the value is higher than that recorded by [23] of 0.08 mg/l for Angawa river and 0.11mg/l for Elala river [27].

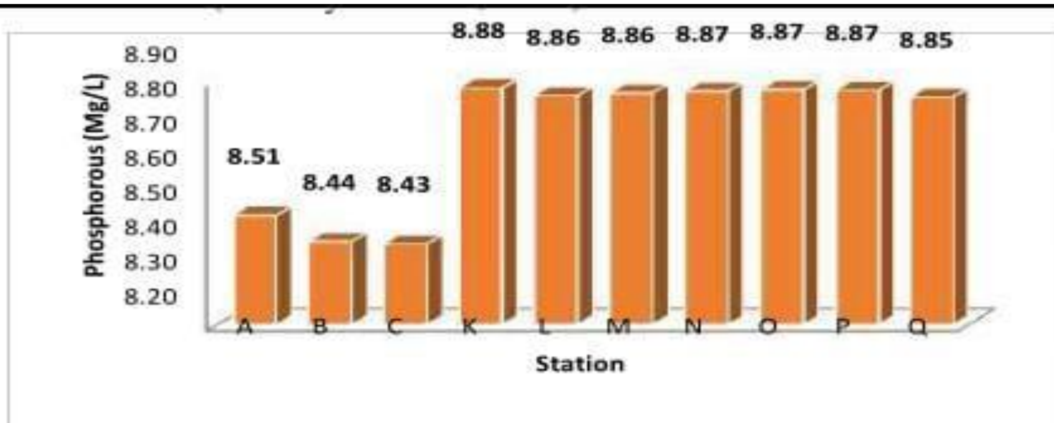

Figure 8: Mean Phosphorus recorded at stations A-Q during the study period

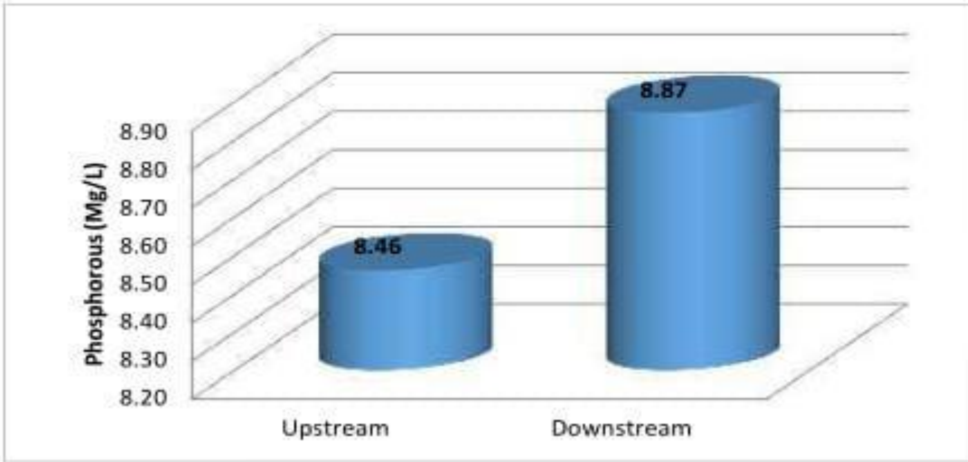

Figure 9: Mean up and downstream Phosphorus during the study period

3.5 Copper

The study revealed that the concentration of copper along the tributary varied, Table 2. It ranged from 0.17mg/l in station A- C to 0.32mg/l in station O (Figure 10). The lowest mean was recorded in the upstream and the highest at the downstream (0.17mg/l and 0.32mg/l) respectively (Figure 11).

Copper concentration in water had a mean value of $\bar{X}$ = 0.17 mg/l, at the upstream and $\bar{X}$ = 0.31 mg/l in the downstream. Using t-test there is no significance difference between the stations at p = 0.05. Therefore, the null hypothesis is not rejected.

According to [28, 50, 53] Agricultural chemicals contain traces of copper. The rate of flow and water characteristics such as pH, hardness influence the levels of copper in water [11, 51, 56]. The observed Copper levels could be attributed to the agricultural activities along the tributary. Farmers, with their activity in agro-production, use different chemical preparations, which contain trace amounts of copper which together with raw waters from agricultural surfaces, are washed to Nyakomisaro tributary. The higher downstream levels could be due to low rate of flow where some copper are deposited as sediments. The mean levels of Copper of Nyakomisaro tributary were 0.24 mg/l, while [7, 55] recorded a higher mean value of 0.27 mg/l in Stnca River.

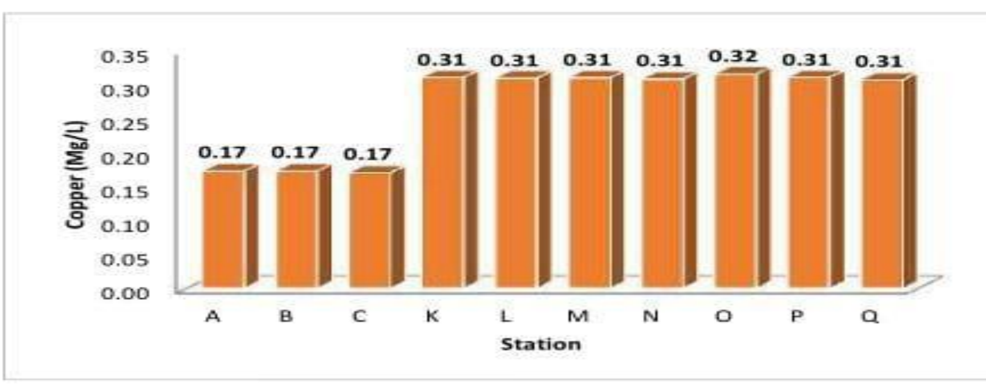

Figure 10: Mean Copper recorded at stations A-Q during the study period

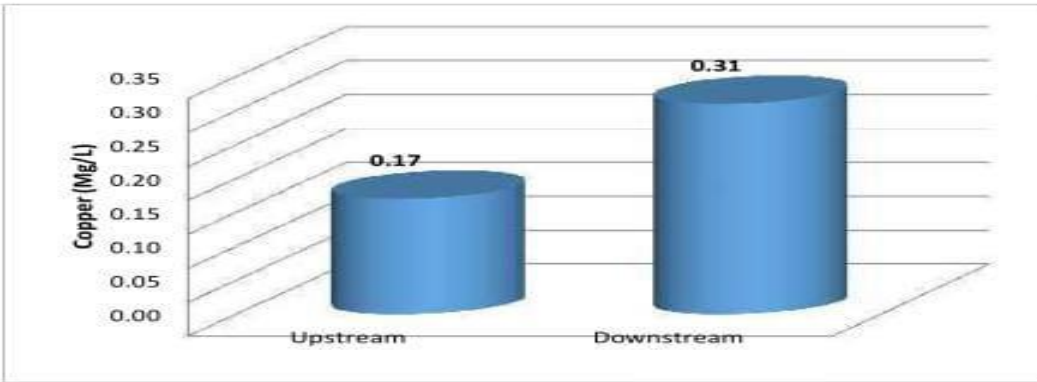

Figure 11: Mean up and downstream Copper recorded during the study period

3.6 Zinc

The study showed that the Zinc along the tributary varied, Table 2. It ranged from 0.12mg/l in station A- C to 0.19 mg/l in station M. The lowest means were recorded in the upstream and the highest at the downstream (0.12mg/l and 0.19mg/l) respectively, (Figure 12). The mean levels of zinc were $\bar{X}$ = 0.12 mg/l at the upstream and $\bar{X}$ = 0.18 mg/l at the downstream (Figure 13). Using t- test there was a significant difference between the stations at p = 0.05. Therefore, the null hypothesis is rejected, the mean level of zinc for the entire tributary was 0.15 mg/l Table 2).

According to [52, 54, 61] Agricultural chemicals contain traces of Zinc. The rate of flow and water characteristics such as pH, hardness influence the levels of Zinc in water [11, 51, 54]. The observed Zinc levels at Nyakomisaro tributary can be attributed to the agricultural activities along the tributary. Farmers in the study area use different chemical preparations, in agro production which contain traces of zinc. The higher downstream levels could be due to slow flow rate and runoffs from municipal effluents which are deposited as the river flow. The highest permitted value for zinc in water tentatively is set at 300 mg/l [57].

The mean levels of zinc when compared with other studies of Nyakomisaro tributary is 0.15 mg/l, a similar study carried out by [49] in Diyala River in India on heavy metal contamination found higher Zinc levels of 75mg/l. A study by [22] in river Ganga in west Bengal recorded zinc mean value of 0.19mg/l which was also higher than that of Nyakomisaro tributary.

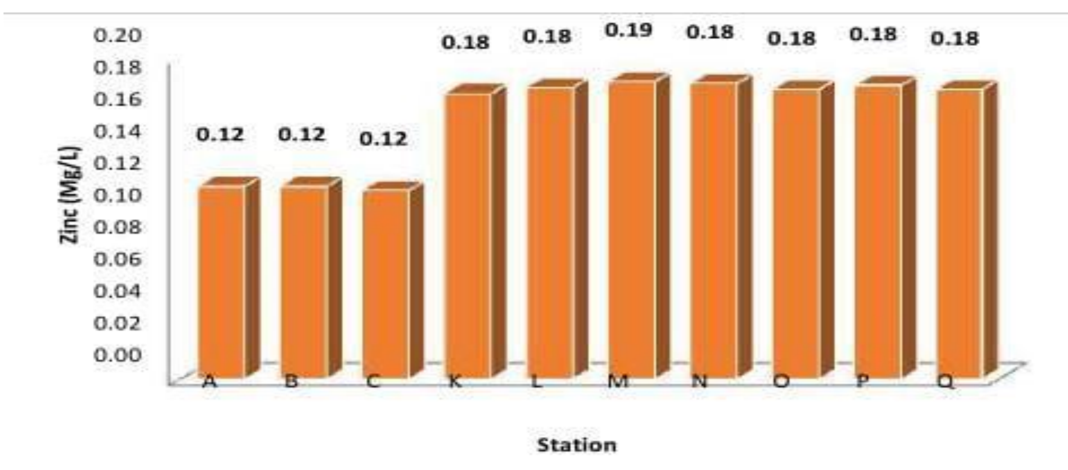

Figure 12: Mean Zinc recorded at stations A-Q during the study period

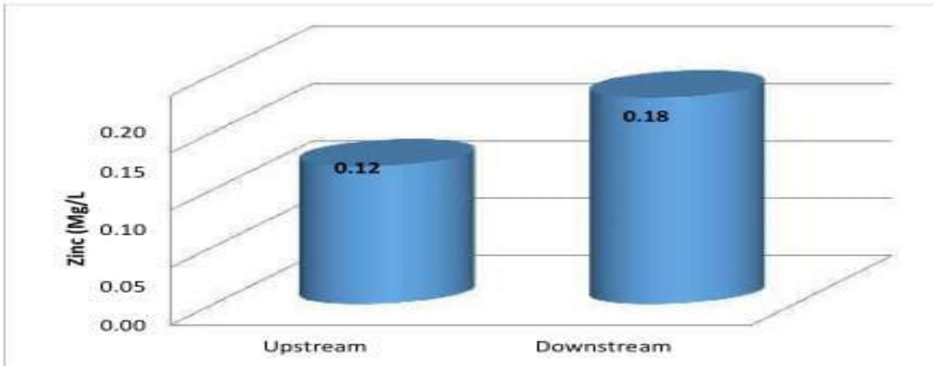

Figure 13: Mean up and downstream Zinc recorded during the study period

CONCLUSION

The chemical parameters of Nyakomisaro tributary varied, all the chemical parameters recorded were higher at the downstream of the tributary.

There were significant difference total alkalinity, nitrate, phosphorus and zinc between up and downstream, therefore the null hypothesis for the parameters is rejected but no significant differences in suspended solids and copper, while the null hypothesis is not rejected for such parameters.

RECOMMENDATIONS

Installation of piped water to all households within the Kisii municipality Treatment of effluents before disposal to avoid effluents into the river.

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