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Pollution

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Physico-Chemical Properties of River Kisat, Lake Victoria Catchment, Kisumu County, Kenya

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Abstract

Physico-chemical parameters were studied in five stations along River Kisat from March, 2016 to August, 2016. The aim of the study was to establish whether the river water meets the set quality standards for surface water. It was established that the river water is negatively impacted by wastewater from various human activities along the stretch of the river. The averages of the physico-chemical parameters were; electrical conductivity 657.27 ± 208.78 µ cm-1, temperature 24.84 ± 0.65°C, pH 7.87, dissolved oxygen 4.19 ± 0.7 mg l-1, turbidity 89.90 ± 9.76 NTU, flow rate 0.14 ± 0.05 ms-1, total alkalinity 150.85 ± 28.23 mg l-1, total nitrogen 885.39 ± 227.56 µg l-1, total phosphorus 677.18 ± 20.87 µg l-1, Silicates 4.11 ± 0.52 mg l-1 and chlorophyll a 130.54 ± 40.15 mg l-1 respectively. The study revealed that DO, pH, alkalinity and silicate showed significant difference along the river (P 0.05). The results indicate that the water of River Kisat is polluted with pollutants from domestic wastewater, agricultural and/ or surface run off. Therefore there is need for measures to be put in place to reduce water pollution along the river in order to improve the water quality.

Keywords: Water quality; Pollution; Physico-chemical parameters; River Kisat

Introduction

Water is essential for the survival of all forms of life and the availability of good quality water is an indispensable feature for preventing diseases and improving the quality of human life [1]. Rivers play a major role in integrating and shaping the landscape, and moulding the ecological setting of a basin. They are key in controlling the global water cycle and are the most dynamic agents of transport in the hydrological cycle [2]. Water resources are of high importance for human life and economy and are the main source to fulfill drinking water needs, irrigation of lands and for industry. Therefore lack of water is considered as socioeconomic obstructive factor of a country [3].

Industrial development and modern urbanization have resulted in the formation of large urban zones [4], industrial zones [5] and intensive development of agriculture [6]. This has not only increased the need for water, but also growth of urban and industrial waste discharges to the rivers with no prior treatment at the same time, decrease the ability of water to self-cleanse/auto purify. Pollution of a river first affects its chemical quality and then systematically destroys the community disrupting the delicate food web [7,8] and many rivers become short-lived and end up drying.

Today, the need for clean water is considered as one of the biggest environmental global problems. Currently, more than 1.2 billion people in the world have no access to drinking water and 3 billion people have inappropriate sanitary services and more than 200 diseases have been linked to contaminated water [9]. About 6,000 people die daily from diarrhea diseases. According to WHO (2011), it is estimated that every year around 5 million people die due to consumption of contaminated water and based on current trend of urbanism in the world until 2025, around 3 billion people will need water supply and more than 4 billion people will need access to sewerage services.

Water quality can be monitored either by direct measurement of both the physical and chemical parameters of water or by analyzing the inhabiting biota thus quality of an aquatic ecosystem is dependent on the physico-chemical qualities of water and the biological diversity of the system [10]. The physico-chemical monitoring approach includes the analysis of different parameters such as pH, turbidity, conductivity, total suspended solids, total dissolved solids, total organic carbon, nutrients and heavy metals [11]. These parameters affect the drinking water quality, if their values are in higher concentrations than the safe limits set by the regulatory bodies [12]. Therefore, there is need to investigate the quality of drinking water to ensure adequate access to clean and safe water by the growing human population.

Materials and Methods

Study area

The study area is River Kisat, located in Kisumu County of Kenya which drains into the eastern part of the Nyanza Gulf of Lake Victoria. The study catchment area is within Latitudes 0°18'S to 0°04'N and Longitudes 34°43'E to 35°30'E (Figure 1).

Data collection and analysis

Measurements of physical parameters were done in situ at each sampling site using respective meters [13]. Dissolved oxygen concentration (mgl-1) and temperature (°C) were measured using an oxygen meter model YSI 15B; pH was measured using a Digital Mini Model 49 pH meter; conductivity (µS cm-1) was measured using a conductivity meter model LF 96. The three meters all had automatic temperature compensations at 25°C. Turbidity (NTU) was measured using a turbidimeter model Hach 2100P. All the meter probes were immersed 30 cm below the water surface and the measurements taken after the readings were allowed to stabilize. The flow/velocity of the river was determined by use of a current meter.

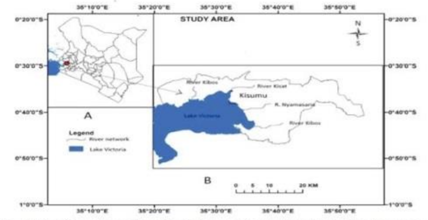

Figure 1: Map of Kenya (A) shows Kisumu County (B) with River Kisat that drains in Lake Victoria, the study area.

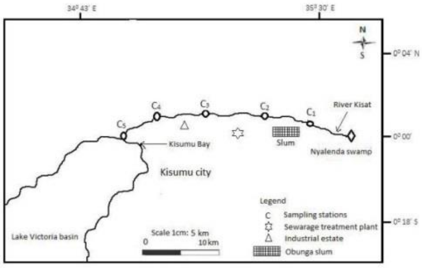

Figure 2: River Kisat showing the sampling sites (C1 to C5) and drains into Kisumu Bay, of Lake Victoria, Kenya.

Water samples for chemical analysis were collected from five different sampling sites of the river. Sampling site C1 was located at the river source, site C2 was 3 km from the source, site C3 was after the industrial and municipal sewerage treatment works, site C4 was located under a bridge, 1.5 km away from the river mouth and site C5 was at the river mouth (Figure 2). Sampling was done monthly for six months at each site. The samples were taken at a depth of 30 cm and water transferred into clean bottles and transported to Kenya Marine and Fisheries Research Institute (KEMFRI) laboratory in Kisumu for analysis. Total alkalinity was determined titrametically using 0.02 N standard HCl and Bromocresol green-methyl red indicator [13]. Total nitrogen, total phosphorus and silicates were determined colometrically using UV/VIS spectroscopy machine T80+ [13]. Chlorophyll a was extracted from the sample using ethanol. The absorbance was measured using a spectrophotometer at a wavelength of 750 nm and 665 nm [13]. The chlorophyll-a concentration was calculated using the formula: Chl-a, µg l-1=(11.40 (E665 - E750) * V1)/(V2 *L)

Where: 11.40 is the absorption coefficient for chl-a; V1=volume of extract in ml; V2=volume of the filtered water sample in litres; L=light path length of cuvette in cm; E665, E750=optical densities of the sample.

Results and Discussion

Mean values of temperature were 25.07 ± 0.78°C, 24.78 ± 0.67°C, 24.95 ± 0.71°C, 24.75 ± 0.54°C and 24.63 ± 0.42°C at sampling sites C1, C2, C3, C4 and C5, respectively with an average of 24.84 (Table1). ANOVA test revealed that the recorded temperature values at the sampling sites along the river were not significantly different (P=0.447>0.05). Water temperature changes with seasonal variations, exposure to solar radiation, flow rate, depth of water, humidity and cloud cover in the area. Although mean temperatures recorded at all sites were high, site C5 recorded a slightly low temperature and this could be attributed to the shading by the Eichhornia crassipes that cover the river as it enters into the lake.

Physico-chemical	Sampling stations					Average	P-value (P 0.05)
Parameters	C1	C2	C3	C4	C5	24.84 ± 0.65	P=0.441
Temperature (°C)	25.07 ± 0.78	24.78 ± 0.67	24.95 ± 0.71	24.75 ± 0.54	24.63 ± 0.42		
Flow rate (Km/h)	1.4 ± 0.05	1.5 ± 0.05	1.3 ± 0.01	1.7 ± 0.08	1.00 ± 0.02	1.38 ± 0.05	P=0.358
pH	6.85 ± 0.16	6.29 ± 0.17	6.17 ± 0.22	5.49 ± 0.24	5.72 ± 0.24	6.1 ± 0.24	p=0.001
Dissolved oxygen (mg/l)	5.92 ± 0.75	4.11 ± 0.71	3.8 ± 0.69	3.69 ± 0.42	3.42 ± 0.40	4.19 ± 0.7	P=0.001
Conductivity (µS/cm)	390.75 ± 118.40	839.65 ± 323.01	796.45 ± 253.32	840.93 ± 330.32	695.43 ± 226.15	657.27 ± 186.78	P=0.267
Turbidity (NTU)	32.37 ± 5.15	97.78 ± 17.11	108.35 ± 21.55	88 ± 8.85	122.98 ± 18.97	89.90 ± 9.76	P=0.126
Alkalinity (mg/l)	107.23 ± 20.37	124.33 ± 26.52	199.67 ± 28.93	173 ± 29.58	150 ± 28.18	150.85 ± 28.23	P=0.001
Total nitrogen (µg/l)	400.77 ± 124.50	629.71 ± 185.14	720.87 ± 289.87	677.14 ± 208.78	857.88 ± 363.96	657.27 ± 227.56	P=0.418
Total phosphorus (µg/l)	342.17 ± 112.48	670.16 ± 122.81	1027.24 ± 346.31	1227.38 ± 424.28	1160.77 ± 361.48	677.18 ± 20.87	P=0.419
Silicate (mg/l)	4.12 ± 0.65	4.14 ± 0.75	4.46 ± 1.02	4.05 ± 0.54	3.8 ± 0.37	4.11 ± 0.52	P=0.004
Chlorophyll-a (mg/l)	95.82 ± 21.15	105.86 ± 24.59	113.98 ± 33.46	123.88 ± 35.15	213.14 ± 74.30	130.54 ± 40.15	P=0.455

Table 1: Mean values ± 1 SD of physico-chemical parameters investigated along River Kisat from March 2016 to August 2016.

Physico-chemical parameters

Electrical conductivity varied between 390.75 ± 118.40 µS cm-1 in C1, 839.65 ± 323.01 µS cm-1 in C2, 796.45 ± 253.32 µS cm-1 in C3, 840.93 ± 330.32 µS cm-1 in C4 and 659.43 ± 226.15 µS cm-1 in C5 with a mean EC of 657.27 ± 186.78 µS cm-1 (Table 1). One way ANOVA test showed no significant difference (P=0.267>0.05) in conductivity. Conductivity levels in rivers are influenced by total dissolved solids deposited in water. The load of total dissolved solids is determined by the type of soils at the catchments area and human activities. In tropical waters, marked seasonal variation in temperature and rainfall also influence the conductivity of rivers as well as time of residence, evapotranspiration and the flow rate of the river [14]. High conductivity mean value recorded in sampling sites C2 and C3 may be due to the high volume of a combination of partially treated and untreated industrial effluents which contained dissolved solids and are regularly discharged into the river. There are also fish processing industries and together with household products contribute to high amounts of dissolved solids.

The mean pH in the sites were 6.85 ± 0.16 in C1, 6.29 ± 0.17 in C2, 6.17 ± 0.22 in C3, 5.49 ± 0.24 in C4 and 5.72 ± 0.24 in C5 (Table 1). One way ANOVA test showed that mean pH values in the sites along the river were significantly different (P 0.001). pH under natural conditions is dependent on the amount of carbonate and bicarbonate alkalinity and carbon dioxide in solution while in aquatic ecosystems pH is dependent on the balance between photosynthesis and respiration [15]. The acidic pH recorded in the sampling sites could be attributed to the high decomposition rates of organic wastes deposited in the river through run-off from industrial and agricultural activities. Decomposition of these organic wastes makes use of the dissolved oxygen in water and leads to the production of humic acids lowering the pH levels. pH levels were below the set standards by the National Environment Management Authority (NEMA) which ranges between 6.5-8.5.

The highest mean dissolved oxygen was recorded in sampling site C1 (5.92 ± 0.75 mgl-1) while the lowest was at site C5 (3.42 ± 0.4 mgl1) (Table 1). One way ANOVA test showed significant difference (P0.001) in dissolved oxygen between the sampling sites. The amount of dissolved oxygen in the water is a function of various factors that include metabolic activity rates, diffusion, atmospheric pressure, temperature and flow rate [16]. The high dissolved oxygen levels recorded in C1 could be attributed to the area having minimal disturbance from human activities such as waste dumping that deplete oxygen due to decomposition whereas low dissolved oxygen levels in C5 may be due to the high productivity rate that makes use of oxygen noted by the high chlorophyll levels. In addition C5 has a slow flow rate which reduces the solubility of oxygen in water. Mean dissolved oxygen level recorded was 4.19 mg l-1. This value was lower than the NEMA set standard of 8 mg l-1. Mean flow rate recorded in the sampling sites was 1.4 ± 0.05 km h-1 in C1, 1.5 ± 0.05 km h-1 in C2, 1.3 ± 0.01 km h-1 in C3, 1.7 ± 0.07 km h-1 in C4 and 1.00 ± 0.02 km h-1 in C5. (Table 1). ANOVA test showed no significant difference in flow rate of the river's sampling sites (P=0.0.358>0.05). The low flow rate of the river is due to the river having a relatively short distance of about 4 km, a width that range between 0.6 m at the river's upstream to 4.3 m at the river mouth and a depth of between 0.2 m to 0.4 m thus it has a low flow rate. The lowest flow rate at C5 can be attributed to the site being overgrown with water hyacinth that interferes with water flow.

Turbidity along the river showed a wide variation during the sampling period with a low recorded value of 32.37 ± 5.15 NTU and a high value of 195 NTU. Mean turbidity in the sampling sites were 32.37 ± 5.15 NTU in C1, 97.7 ± 17.11 NTU in C2, 108 ± 35 NTU in C3, 88 ± 8.85 NTU in C4 and 122.98 ± 18.97 NTU in C5 (Table 1). One way ANOVA test on turbidity in the river's sampling sites showed no significant difference (P=0.358>0.05). Turbidity in rivers is influenced by presence of phytoplankton, sediments from erosion, re-suspended sediments from the bottom, waste discharge, algae growth, urban runoff, matter from decaying vegetation and industrial waste and sewage [17]. Sampling site C1 recorded the lowest mean turbidity; this could be attributed to the filtering effect of the swamp before the site, which removed most of the sediments before they could be deposited in the river. Sampling site C5 recorded the highest mean turbidity during the study period; this could be as a result of the cumulative effects of sampling sites C2, C3 and C4. Turbidity as per NEMA requirements should be 5 NTU and this was way below the recorded river value that was 89.90 NTU.

The average alkalinity was 150.85 ± 28.23 with a wide variation ranging from 107 mg l-1 $CaCO_3$ in C1 to 199.67 ± 28.93 mg l-1 $CaCO_3$ in C3. One way ANOVA test revealed significant difference (P 0.001) in the sampling sites (Table 1). Alkalinity is influenced by the presence of bicarbonate, carbonate and hydroxyl ions that are formed as a result of the interaction between carbon dioxide in water with basic materials such as calcium carbonate from chalk or limestone [18]. High alkalinity levels in site C3 could be attributed to the low rate of water flow which led to an increased length of time the water was in contact with the parent rock that promoted the weathering process. Alkalinity levels in C3 could also be from effluent discharge from detergent and fish processing industries. Lower levels in site C5 may be as a result of high rates of photosynthesis process by the water hyacinth that have excessively grown and make use of carbon dioxide and also due to the low evaporation rates that increase dilution of the carbonate and bicarbonate ions as limited amount of the sun's rays reach the water body as most of the sun's energy is blocked by the canopy formed by *Eichhornia crassipes*.

Total nitrogen and total phosphorus values increased downstream. TN ranged from 400.77 ± 124.50 µg l-1 to 857.88 ± 363.96 µg l-1 with an average mean 657.274 ± 208.78 µg l-1 whereas TP ranged from 342.17 ± 112.48 µg l-1 to 1227.38 ± 424.28 µg l-1 with an average of 885.39 ± 227.56 µg l-1 (Table 1). One way ANOVA test showed no significant difference for both the nutrients in the sampling sites. Variations in TN and TP concentrations in rivers is attributed to anthropogenic activities, domestic and industrial inputs of phosphorus such as sewage disposal and phosphorus rich detergents [19], agricultural run-off [20], rainfall frequency and vegetation type at the catchments [7]. Low records of the nutrients in sampling site C1 could be due to minimal human activities at C1. High TN and TP downstream may be attributed to the accumulation of the nutrients downstream as well as surface runoff of fertilizers used to maintain the golf course situated before the sites. Means of total nitrogen and total phosphorus recorded were higher than the set standards by NEMA.

Silicates showed moderate variations in all the sampling sites along river Kisat. The values ranged from 2.2 mg l-1 to 5.54 mg l-1 in C1, 2.76mg l-1 to 4.97 mg l-1 in C2, 3.17 mg l-1 to 5.04 mg l-1 in C3, 2.50 mg l-1 to 5.73 mg l-1 in C4 and finally 2.65 mg l-1 to 5.55 mg l-1 in C5. One way ANOVA test, the mean silicate of the river's sampling sites showed that there was a significant difference among the sampling sites (P=0.0040.05) (Table 1). Sampling site C5 recorded the lowest mean silicates and this can be attributed to the high diatom composition that made use of silica, in addition, low silica concentration may be due to the uptake by water hyacinth as the make use of this nutrient for chlorophyll synthesis. Similarly, the low mean silicates at sampling site C1 may be as a result of the high diatom composition in the station which uses the silicates to build up their structures.
Chlorophyll-a levels ranged from 64.76 mg l-1 to 144.11 mg l-1 with means of 95.82 ± 21.15 mg l-1 in C1, 105.86 ± 24.59 mg l-1 in C2, 113.98 ± 33.47 mg l-1 in C3 and 123.88 ± 35.16 mg l -1 in C4 and 213.14 ± 74.30 mg l-1 in C5 (Table 1). ANOVA test showed no significant difference (P=0.455>0.05) in chlorophyll a levels between the sampling sites.

Chlorophyll a levels were observed to increase downstream along the river. The high chlorophyll a recorded in sampling site C5 during the study period could be attributed to the accumulated effects of nutrient flow downstream that causes high productivity hence a rise in chlorophyll level.

Conclusion

Four of the eleven environmental parameters (dissolved oxygen, alkalinity, pH and silicates) showed significant differences along the river ($P<0.05$). These parameters were not within the recommended standards according to NEMA and so not suitable for domestic use. Contaminated water bodies is an indication of their mismanagement and with time may face serious environmental problems which may not support healthy living. There is therefore need for stringent measures to be put in place to curb water pollution along the river in order to improve water quality.

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