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Article

Effect of Human Activities and Seasonal Variation on Water Quality of Nkenye (Chikuu) Stream in Chuka, Kenya

O Ombaka [1,] *, JM Gichumbi [1], ST Mukono [1], D Kibara [2]

[1] *Department of Chemistry, Chuka University College, Kenya*

[2] *Department of Biological Sciences, Chuka University College, Kenya*

* Author to whom correspondence should be addressed; E-Mail: Ombaka2020@yahoo.com.

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Abstract: Composite water and sediment samples were taken from Nkenye stream at five different sampling stations during wet and dry seasons. Water quality parameters were analyzed using standard methods to ascertain the effect of human activities on the water quality. The variations in the physicochemical and biological parameters were observed from station to station both in the dry and wet seasons. These variations were attributed to human activities. Results showed significant seasonal variation in most measured parameters with a few showing significant spatial variation. The characteristics of the water from the stream revealed an acceptable quality for most of measured parameters when compared with drinking water standards. However, high values of turbidity, iron, manganese, chromium and microbial load were recorded compared with drinking water standards, which call for proper treatment of the water before being used by the public. The results of sediment samples revealed that silicate, iron, aluminum are present in major quantities while other minerals are present in trace amounts. Thus the present study concludes that Nkenye stream water is contaminated and needs attention for it to be safe for domestic use.

Keywords: total coliforms; microbial parameters; total dissolved solids; electrical conductivity; alkalinity; hardness.

1. Introduction

Water is important both physiologically and ecologically as it plays an essential role in temperature control and also is the medium in which many organisms live [1-5]. However, most of fresh water bodies all over the world are getting polluted, thus decreasing the portability of water [6,7]. Rivers and streams are used as sites for waste disposal [8]. Wastes from agricultural run off, sewer over flow, discharge of chemicals by communities and industries contributes to significant effects on water quality of a stream [9-11]. These wastes on entering the stream can contribute to pollutants such as sediments, nutrients, pesticides, herbicides, pathogens, organic enrichment, toxicants, oxygen demanding substances, road salts, heavy metals, petroleum products, resulting into levels that are of health threat to the surrounding environment and to also man [12,13]. Toxins within water can harm or even kill aquatic organisms and other animals that may have accidentally fed on the infected organisms [14].

Nutrient enrichment in streams due to anthropogenic activities can result in excessive growth of aquatic plant and algae [15]. This can lead to turbidity, more organic matter falling to the bottom of the system in form of dead plants and animals [16]. Bacteria and other organisms decompose this matter and in the process use a lot of oxygen [17]. In very productive freshwater systems, the oxygen levels can be in such short supply that fish kills occur [18].

The growing problem of degradation and human activities on ecosystem require a regular monitoring of water bodies with required number of parameters with reference to the quality of water. This is not only prevents the outbreak of diseases and occurrence of hazards but also checks the water from further deterioration. Thus, this study examined the water quality characteristics of the Nkenye stream, as a key activity in managing the water sources, restoring if polluted and anticipating the effect activities on the stream.

2. Materials and Methods

2.1. Study Area

The area of study (Chuka) lies at latitude 0˚19’59’’ and longitude 37˚38’45’’. The altitude is approximately 1445 m above sea level. It is on the eastern slopes of Mount Kenya. The cash crops grown are coffee, tea and pyrethrum. For subsistence, food crops grown are maize, beans and bananas albeit inadequately for the residents. The area has favorable soil and climate.

2.2. Sampling Techniques

Water samples were collected from five randomly selected stations located along Nkenye stream (Table 1). The sampling was done on a seasonal pattern. Clear, clean and dry 2 litres polyethylene bottles for physicochemical analysis and 1 litre sterilized glass bottles for bacteriological analysis were first rinsed three times with water to be sampled and then opened at depths of 5 cm below the water surface in order to fill it with water. It was filled in such a way that no air bubbles were left behind in the bottles. Collection was done at fixed time to maintain the consistence in the results. Composite sampling method was adopted, and standard procedures were followed for water samples collection, preservation, transportation and analysis [18-20]. The parameters such as turbidity, pH, total dissolved solids, electrical conductivity and temperature were measured on the field using water and soil analysis kit (Electronics India, model 16E). Rest of the parameters of water samples were measured in the laboratory immediately after transportation to the laboratory. To ensure accuracy, analysis was done in triplicates and mean values was taken into consideration. Double deionised water was used to prepare standard reagents. Similarly sediments were also taken at the same sampling sites as the water from depths of 3 to 5 cm below the stream bed using a plastic trowel and pre-cleaned polyethylene bags. The sampling sites are indicated in Table 1.

Table 1. Sampling sites

Site/village	Name
1	Chuka town (source)
2	Jombas
3	Kathituni
4	Kithigirani/Kathigiriri
5	Mbugi

2.3. Analysis

The collected water and soil samples were analyzed for various physicochemical and microbiological parameters. The procedure for analysis was followed as per the standard methods of analysis of water and waste water [18]. AAS (Varian specr-AA-10 model) and XRF (Minipal QC model) was used for determination of trace metals in sediments. The certified standard reference material from the National Institute of Standards and Technology was used for validation of the atomic absorption spectrophotometric method. The specific methods employed under this investigation have been summarized in Table 2 [18].

Table 2. Water quality test methods

Parameters	Test Methods
Temperature	Thermometric
pH	Potentiometric
Electrical conductivity	Conductometric
Turbidity	Nephelometric
Total dissolved solids	Gravimetric
Total suspended solids	Gravimetric
Total alkalinity	Titrimetric
Total acidity	Titrimetric
Total hardness	EDTA titrimetric
Sulphate	Turbidimetric
Ammonia	Nessierization spectrophotometric
Nitrate	Ultraviolet spectrophotometric
Nitrite	spectrophotometric
Chloride	Argentometric
Fluoride	Ion-selective electrode
Phosphorous	Spcetrophotometric
Metals	Atomic absorption spectrophotometric
MPN of coliforms organisms/100 mL	IDEXX Quanti-Tray/2000
E. coli/100 mL	IDEXX Quanti-Tray/2000

3. Results and Discussion

3.1. Physicochemical Parameters

Seasonal fluctuations in the values of various physicochemical parameters at different sampling sites and their average values for Nkenye water samples have been given in Table 3. The results of physicochemical parameters which were not in compliance with world health organization (WHO) standards for drinking water are depicted in Fig. 1.

Water temperature is a key variable responsible for shaping the ecology of aquatic habitats. Metabolic rates of most stream organisms are controlled by temperature, as most animals are cold blooded; their metabolic rate is faster in warm water. Therefore they need more food and oxygen in warm water and release more wastes. This increase in metabolic rate occurs only up to a point before the upper temperature tolerance is exceeded and the organism dies. Approximate upper limits range from 38 ^oC for fish and 50 ^oC for aquatic insects to 73 ^oC for blue-green algae. However elevated temperatures lower than these maximum limits still are stressful, especially to organisms at sensitive juvenile stages. In the present study the temperature values ranged between 22.00 ^oC - 24.70 ^oC in wet season and 22.50 ^oC - 25.10 ^oC in dry season. Wet minima and dry maxima were observed at all the sites with the marginal variations. The unexpected high temperature recorded during the dry season could be due to the flow rate. The rate of water flow directly impacts water temperature. During dry seasons less water usually exists in a stream. As a result it flows more slowly allowing the water to warm up more quickly and to higher temperatures. The higher temperature recorded at site 5 during wet and dry season might be due to unshading of stream by riparian (river bank) vegetation. At site 5, human activities like clearing of riparian vegetation and overgrazing has contributed to the sun shining directly on Nkenye stream water body, causing the water to warm up very quickly and potentially to very high temperatures. At this site, the banks has slumped and eroded away, causing the channel to become broad and shallow as deep holes were filed in by sedimentation. This implies that site 5 is broad and shallow. As such the water would be easily heated to high temperatures. The results of temperature for both dry and wet seasons are within safe limits.

Table 3. Mean of physicochemical qualities of the water samples in wet season and dry season

Parameters	Site 1		Site 2		Site 3		Site 4		Site 5		WHO
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	(2011)
Temperature (^oC)	22.20	23.10	22.0	22.50	23.71	25.61	21.40	21.80	24.70	25.10	NS
pH	7.16	6.82	7.03	6.54	7.49	6.93	6.99	6.32	7.31	7.05	6.5-7.5
Electrical Conductivity (μΩ/cm)	0.17	0.53	0.32	0.65	0.03	0.07	1.82	5.63	0.19	0.72	1500
Total Dissolved solids (mg/L)	0.29	0.60	0.42	0.67	0.03	0.08	3.38	8.53	0.27	0.96	600-1000
Total Suspended solids (mgL)	0.01	0.01	0.02	0.01	0.02	0.02	0.08	0.03	0.12	0.09	NS
Total Solids (mg/L)	0.30	0.61	0.44	0.68	0.05	0.10	3.46	8.56	0.39	1.05	NS
Turbidity (NTU)	22.39	0.19	23.08	0.24	19.93	0.17	25.17	0.43	25.31	0.57	5
Total alkalinity (mg/L)	3.81	4.28	4.00	5.20	4.83	5.43	6.15	8.03	2.68	3.66	120-600
Total acidity (mg/L)	2.73	0.11	3.00	0.40	2.21	0.08	2.03	0.07	1.88	0.05	NS
Total hardness (mg/L)	0.18	27.38	0.20	36.00	0.06	18.33	0.32	42.60	0.35	47.30	100-500
Sulphate (mg/L)	8.21	11.57	11.20	13.32	7.44	10.97	6.51	9.88	6.42	9.62	250
Ammonia (mg/L)	0.57	0.11	1.29	0.13	0.83	0.18	0.43	0.06	0.40	0.04	NS
Nitrates (mg/L)	7.38	3.86	10.60	6.60	9.23	4.76	10.57	6.67	8.38	5.89	50
Nitrite (mg/L)	0.23	0.18	0.51	0.39	0.61	0.50	0.21	0.16	0.18	0.14	3
Chloride (mg/L)	5.23	0.42	10.00	2.60	2.14	0.33	4.85	0.37	4.80	0.35	250
Fluoride (mg/L)	0.31	0.27	0.60	0.53	0.11	0.07	0.29	0.24	0.28	0.20	1.5
Phosphorous (mg/L)	3.71	2.19	10.11	8.33	2.55	2.01	4.89	4.13	3.20	3.15	NS

Note: NS = not specified, ND = not detected

The pH is affected not only by the reaction of carbon dioxide but also by organic and inorganic solutes present in water. The rocks and minerals in an area (geology) strongly influence the natural pH of surface water. Carbonate rich sedimentary rock and soils contributes to stream water being alkaline. Effluents and discharges from industry, municipalities and agriculture can impact pH. With decreasing pH, metals become increasingly solubilized (mobilized) and available for uptake by aquatic organisms. In dissolved form metals can cause extreme physiological damage to most forms of aquatic life and thus most plants and animals tend to be very sensitive to pH and are intolerant of pH below 5.7. High pH can be toxic and most aquatic organisms are intolerant of environment with pH greater than 9. The observed values of pH ranged from 6.99 to 7.49 in wet season and 6.32 to 6.93 in dry season. The higher values during the wet season as against the dry season might be due to the dilution of alkaline substances and also dissolution of atmospheric carbon dioxide. The pH of water samples from Nkenye stream is within the limits of the WHO guidelines for drinking water.

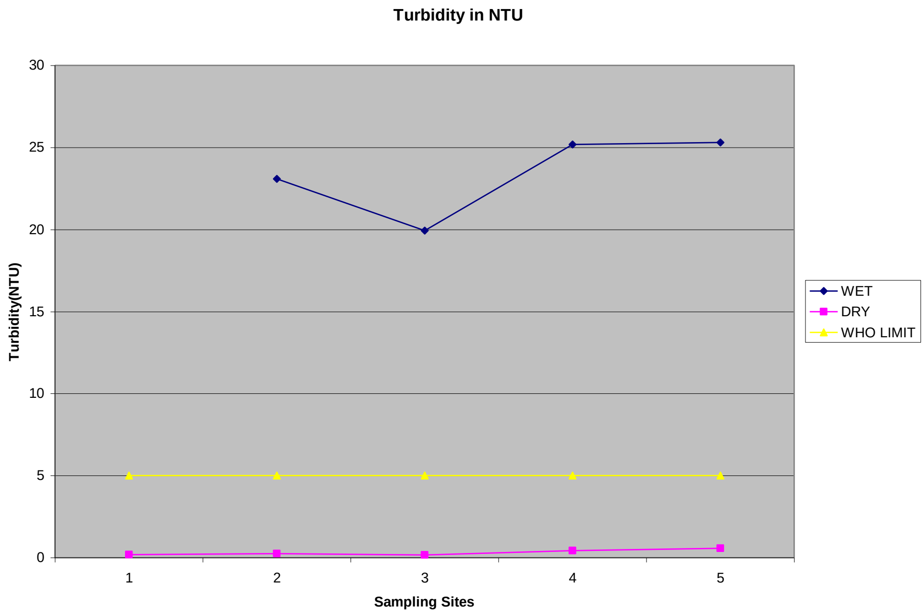

Figure 1. Turbidity in NTU

Electrical conductivity of water is a useful and easy indicator of its salinity or total salt content and the values obtained in present investigation ranged between 0.03 to 1.82 μmho/cm in wet season and 0.07 to 5.63 μmho/cm in dry season. This is well below the WHO guideline value prescribed for drinking water (1500 μmho/cm). Water conductivity values measured for the dry season were higher than for the wet season. This is attributed to excessive evaporation of water from the stream during the dry season, which might have consequently increased the concentration of dissolved salts as reflected in the total dissolved solid values. The temperature could also have contributed to higher conductivity observed during dry season. Site 4 showed higher values of electrical conductivity and total dissolved solids in contrast to other sites. This might be due to enrichment of electrolyte possibly due to the phenomenon of mineralization or weathering of sediments. Human activities at site 4 might have also contributed to high erosion resulting to a large amount of sediments reaching Nkenye stream and this could have affected water quality at the site. The decrease in electrical conductivity and total dissolved solids and total suspended solids recorded at site 3 can be attributed to the presence of marsh at this site which acts as a natural ecosystem service provider in water purification through photo extraction of heavy metals, nutrients and ions by plants (*Cyperus latofolius*) and the physical sieving of solid waste.

Turbidity refers to the amount of light that is scattered or absorbed by a fluid. It is measured in turbidity units based on the comparison of the scattering of light by a water sample with that of a standard suspension of formazin. Turbidity in streams refers to the cloudiness of the water due to the presence of suspended particles of silt, clay, waste effluents and other particulate materials. This can originate from natural sources such as peaty waters from upland areas, as well as from human activities. An increase in stream water turbidity can cause a reduction in the depth of light penetration into the water column. This effectively decreases rates of photosynthetic activity and thus primary productivity in submerged plants. A reduction in the food source at the primary level may then have a knock–on effect upon higher trophic levels. Turbidity also raises water temperature because the suspended particles absorb the suns' heat. Warmer water holds less oxygen, thus increasing the effects of reduced photosynthesis. The mean turbidity values measured in the stream water samples were generally higher during the wet season as compared to the dry season. This can be attributed to heavy rainfall leading to increased surface runoff from adjacent streams and upper land which carry a lot of suspended materials into the stream leading to high turbidity values. During wet season, suspended particles in the water are always in motion due to the high rate of circulation of water. Whereas, in the dry season, the particles tend to settle on submerged logs as there is little turbulence. All the values of turbidity during wet season were not within the limit of the WHO guideline for drinking water, while in dry season they were found to be within the limit.

In the present investigations, the alkalinity values in mg/L $CaCO_3$ ranged from 2.68 to 6.15 in wet season and 3.66 to 8.03 in dry season. High alkalinity recorded during dry season could be attributed to increase in the level of silicates during this season. The total alkalinity values of all water samples were in the range given by WHO. Total acidity ranged from 1.88 to 3.0 in wet season and 0.05 to 0.40 mg/L $CaCO_3$ in dry season. High values of acidity during wet season might be attributed to runoff of a large load of acid to the stream.

Natural water containing a large amount of dissolved salts of calcium or magnesium (carbonates of calcium and magnesium) is called hard water, in contrast to soft water containing only small amount or none of these salts. Hard water is not fit for domestic use. It also interferes with some industrial processes, block pipes and prevent soap from lathering. The results of hardness in the present study indicates low hardness values during wet season and high values during dry season, which might be due to high dilution during wet season. The values of hardness obtained were within the limit given by WHO standards for drinking water.

The sulphate values in the current study were found to be maximum in dry season and minimum in wet season in all the five sites. The minimum in wet season can be attributed to increasing inflow and dilution.

In stream water, common sources of ammonia include commercial and manure based fertilizers, waste water treatment plants and faulty septic system. Ammonia is commonly converted to other forms of nitrogen (such as nitrate) by natural processes involving bacteria and other microorganisms in healthy streams. Ammonia is toxic to fish and other types of aquatic life. Ammonia's toxicity depends on both the temperature and pH of water. Ammonia concentration ranged from 0.40 -1.29 mg/L in wet season and 0.04-0.18 mg/L in dry season. Ammonia concentration values measured for the wet season were higher than for the dry season. This is attributed to the agricultural run off during the season.

Drinking water with high levels of nitrate poses a risk to human health from methemoglobinemia. Nitrates stimulate the growth of plankton and water weeds that provide food for fish. This may increase the fish population. However, algae grow too wildly, oxygen levels will be reduced and fish die. Nitrates can be reduced to toxic nitrites in the human intestine. Nitrate levels ranged from 7.38 to 10.60 mg/L in wet season and 3.86 to 6.67 mg/L in dry season. The high levels of nitrate obtained during wet season could be due to agricultural runoff. Nitrites are relatively short-lived because they are quickly converted to nitrates by bacteria. Nitrites produce a serious illness in fish, even though they don't exist for long in the environment. Nitrites also react directly with hemoglobin in human blood to produce methemoglobinemia. Nitrite levels in the present study ranged from 0.18 to 0.61 mg/L in wet season and 0.14 to 0.50 mg/L in dry season. The levels of nitrate and nitrite are within the limit set by WHO standards for drinking water.

High concentration of chloride is considered to be the indicator of pollution due to organic wastes of animal or industrial origin. Chlorides are troublesome in irrigation water and also harmful to aquatic life. Chloride values ranged from 2.14 to 10.0 mg/L in wet season and 0.33 to 2.60 mg/L in dry season. High level during wet season could be due to increase in the amount of trade wastes, piggery wastes in the receiving stream during the wet season. The levels of chloride obtained were within the recommended limit by WHO standards.

Fluorides are beneficial in water when present in concentration up to 1 mg/L. These induce dental health, this much concentration is necessary to prevent the teeth against dental carries. However, when concentration of fluorides increases to more than 1.5 mg/L a disfigurement involving unsightly staining of the teeth known as mottled tooth enamel is caused. This disease is also termed as flourosis. In the present study, the concentration of fluoride ranged from 0.11 to 0.60 mg/L in wet season and 0.07 to 0.53 mg/L in dry season. High values of fluoride recorded during wet season can be attributed to increase in discharge from fertilizer reaching the stream during this season. The mean values of fluorides are within the safe limit for drinking water set by WHO standards.

Nearly all fertilizers contain phosphates (chemical compounds containing the element phosphorous). When it rains, varying amounts of phosphates wash from farm soils into nearby waterways. Phospahtes stimulate the growth of plankton and water plants that provide food for fish. This may increase the fish population and improve the waterways quality of life. If too much phosphate is present in algae and water weeds grow wildly, choke the water way and use up large amounts of oxygen. Many fish and aquatic organisms may die. Results of the study revealed that the phosphate content during wet season ranged between 2.55 to 10.11 mg/L. While in dry season it ranged between 2.01 to 8.33 mg/L. The high phosphate level during the wet season could be related to the high rate of decomposition of organic matter and from run off surface catchment and interaction between the water and sediments from dead plants and animals remains at the bottom of the stream. The relatively high levels of phosphate observed at site 2 could be due to discharges and farming activities around the site. The recommended maximum level of phosphate for streams had been reported as 0.1 mg/L, while 0.025 mg/L is found to accelerate eutrophication process in streams.

3.2. Trace Metal Concentrations in Water Samples

Table 4 shows the levels of trace metals in the water samples from Nkenye stream. The results of the parameters which were not within the limits set by WHO have also been presented graphically (Figs. 2-4).

A close examination of Table 4 indicates that the levels for all the elements at all the five sampling sites of the stream were below the WHO maximum guideline values for the respective elements in drinking water except for Cr, Mn and Fe.

A high content of iron in the surface waters is indicative of pollution with industrial waste water or with mining spills. Iron concentrations above 0.3 mg/L change the organoleptic properties, prevent the use of the water for technological purposes and cause technical difficulties in using water for household needs by forming precipitates. The concentrations of the iron from water samples ranged from 0.62 to 2.22 mg/L in wet season and 0.33 to 1.13 mg/L in dry season. High levels of iron during wet season could be attributed to iron-rich run off during this period. The levels of iron at all sampling sites were above the recommended limit set by WHO standards.

Manganese (Mn) is a common problem in natural waters. In drinking water, this element may cause unsightly stains and produce a brown/black precipitate. Although it is an essential element, the chronic ingestion of Mn in drinking water is associated with neurological damage. In the present study, the levels of manganese in water samples ranged from 0.55 to 0.92 mg/L in wet season and 0.24 to 0.59 mg/L in dry season. All the values measured in both seasons were higher than the maximum limit set by WHO standard for drinking water.

Chromium(III) and chromium(VI) are present in water from the erosion of chromium deposits found in rocks and soils. Chromium(VI) is more toxic and poses potential health risks. People who use water containing total chromium in excess of the maximum contaminant level over many years could experience allergic dermatitis. The values measured in the present study ranged from 0.30 to 0.43 mg/L in wet season and 0.32 to 0.48 mg/L in dry season. These values are above the maximum guidelines given by WHO. The high values observed in dry season can be attributed to decrease in the volume of the stream water. The high levels of iron, manganese and chromium in the water could lead to serious environmental and health hazard to the consumers.

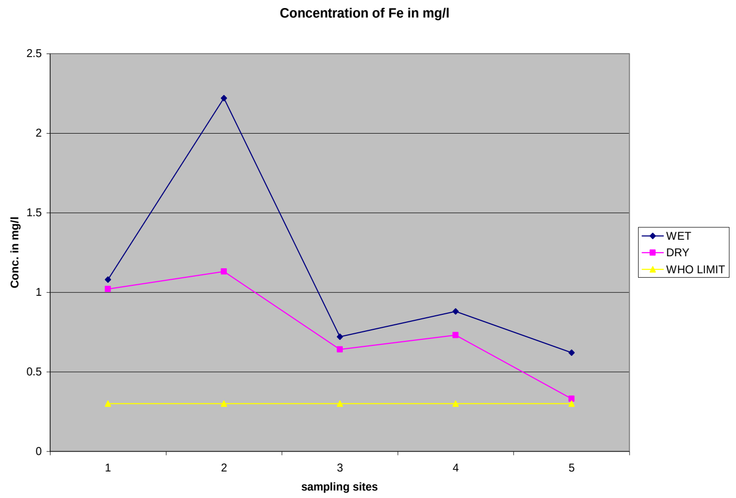

Figure 2. Concentration of Fe in water samples

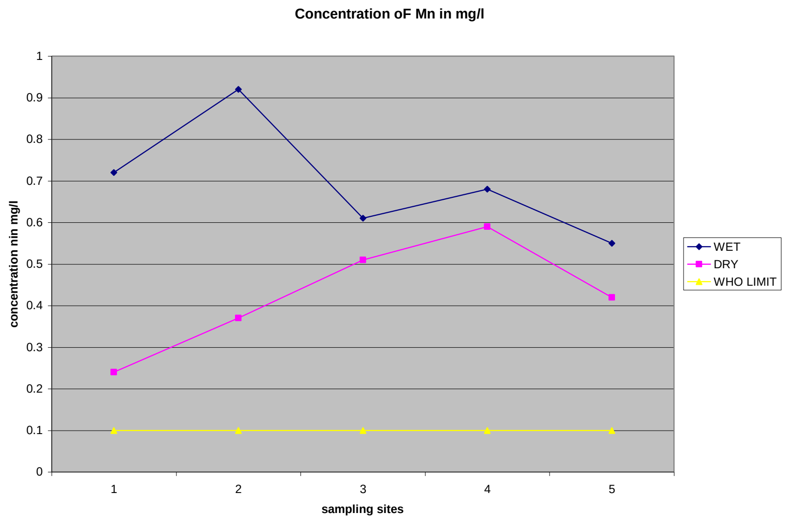

Figure 3. Concentration of Mn in water samples

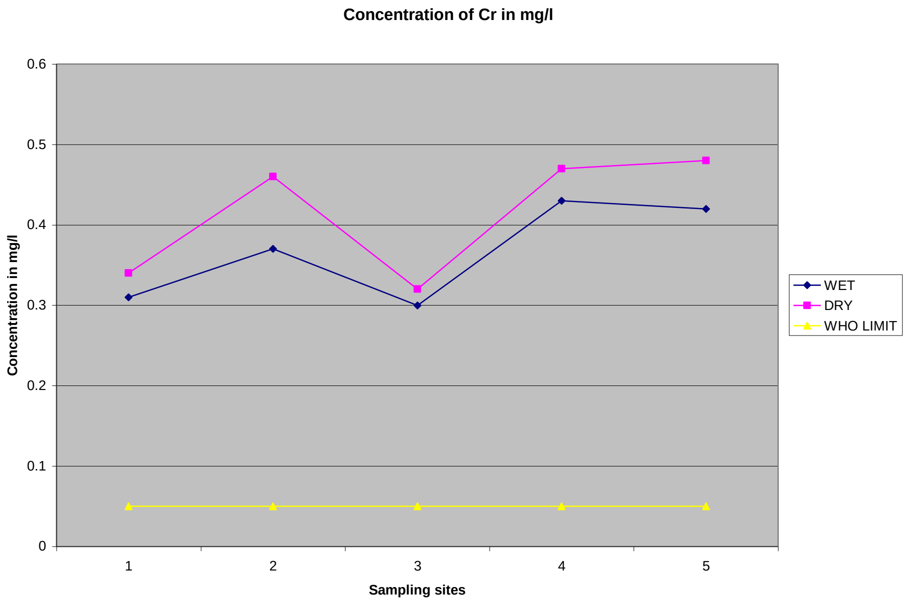

Figure 4. Concentration of Cr in water samples

Table 4. Elemental contents of the water samples in wet season and dry season

Parameters (mg/L)	Site 1		Site 2		Site 3		Site 4		Site 5		WHO (2011)
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	
Na	10.23	6.25	16.85	9.15	4.78	4.32	6.22	5.58	5.41	4.87	200
Ca	4.36	5.57	5.45	7.79	2.97	3.02	3.78	3.81	3.46	3.49	75
Mg	1.61	1.38	1.86	1.70	0.96	0.87	1.02	1.01	0.83	0.79	30
Fe	1.08	1.02	2.22	1.13	0.72	0.64	0.88	0.73	0.62	0.33	0.3
Mn	0.72	0.24	0.92	0.37	0.61	0.51	0.68	0.59	0.55	0.42	0.1
Zn	0.08	0.09	0.10	0.18	0.05	0.08	0.08	1.10	0.07	0.08	5.0
Cu	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.0
K	2.27	2.09	3.67	2.47	1.49	1.25	1.53	1.44	1.40	1.47	NS
Cr	0.31	0.34	0.37	0.46	0.30	0.32	0.43	0.47	0.42	0.48	0.05
Pb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.01
Sb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.02
Co	0.04	0.05	0.06	0.10	0.03	0.04	0.05	0.09	0.03	0.05	NS
Cd	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.03
Mo	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS
B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.4
V	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS
Si	6.60	6.68	6.73	7.16	5.62	5.97	5.55	5.63	5.57	5.81	NS
Sr	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS
Al	1.33	1.74	1.88	2.07	0.99	1.07	1.16	1.23	1.17	1.20	NS

Note: NS = not specified, ND = not detected

3.3. Trace Metal Concentrations in Sediment Samples

Sediments make a stream cloudy and as it settles on top of the stream bed, it covers up and fills in the space between the rocks and cobbles. Pollutants carried along with sediments, such as metals and nutrients, further affect water chemistry of a stream, making survival even tougher on aquatic plants and animals. The results of trace metal levels in the sediments are given in Tables 5 and 6.

Qualitative analysis on sediments was carried out using XRF and the results obtained are given in Fig. 5. The observed data reveals that silicate, iron and aluminum are available in major quantities and the rest exist in trace amount. This result was confirmed by carrying out full assay analysis using AAS. The values of loss on ignition ranged between 4.21-4.69% in wet season and 19.23 to 26.21% in dry season. These values indicate that the sediments from Nkenye stream has high percentage of carbonaceous matter content during dry season.

Boron levels in sediments samples were below its detection limits for the analytical method used. The concentration of the analyzed metals in percentages was in the order Al > Fe > Ca > Na > Mg > Mn > K > Cu > Cr > Pb > Zn > Sb > Mo > Co > Sr > Cd. These levels can be attributed to the types of pollutants which have been carried along with sediments.

The levels of trace metals in sediments were found to be higher than in water samples. Examination of Tables 4 and 6 reveals that there is no relationship between the levels of trace element in sediment and water.

Table 5. Full assay analysis

Parameters	**Site 1**		**Site 2**		**Site 3**		**Site 4**		**Site 5**	
	Wet	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**
Na_2O	1.42	1.39	1.48	1.43	1.40	1.36	1.51	1.49	1.35	1.23
CaO	6.62	7.07	7.32	8.96	6.58	7.08	7.75	7.78	6.53	6.92
MgO	6.84	4.11	7.00	3.35	6.71	4.43	6.85	6.57	6.80	6.71
Fe_2O_3	16.35	18.11	17.20	20.30	16.22	17.34	16.45	16.70	16.21	16.33
MnO	0.41	0.30	0.55	0.21	0.33	0.20	0.55	0.32	0.37	0.32
K_2O	0.76	0.57	0.87	0.65	0.56	0.48	0.78	0.61	0.66	0.51
SiO_2	37.22	12.27	39.89	13.40	35.82	16.14	40.03	21.03	30.78	15.30
Al_2O_3	12.01	11.09	12.91	18.62	11.32	13.99	13.27	16.17	9.84	11.05
TiO_2	2.71	2.69	2.96	2.84	1.53	1.43	2.89	2.80	1.63	1.60
LOI	4.53	19.23	4.68	25.28	4.21	20.78	4.69	26.21	4.42	25.38

Table 6. Levels of trace elements in sediment samples in wet season and dry season

Parameters	Site 1		Site 2		Site 3		Site 4		Site 5	
× 10^{-2} (g/100 g)	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Na	23.27	2.42	25.10	2.46	20.81	2.34	26.03	2.48	20.46	2.33
Ca	36.51	2.87	37.40	2.93	31.79	2.80	38.38	3.06	31.73	2.31
Mg	17.28	8.92	19.80	9.75	15.15	8.72	20.14	9.87	15.02	8.66
Fe	113.20	114.20	115.00	114.25	110.89	113.77	115.25	114.70	110.81	113.67
Mn	12.73	13.46	13.10	13.50	12.71	13.41	13.72	13.97	12.67	13.38
Zn	1.42	1.23	1.46	1.43	1.39	1.20	1.56	1.48	1.29	1.19
Cu	2.09	0.11	2.14	0.12	2.04	0.08	2.20	0.15	2.02	0.06
K	10.41	1.74	10.70	1.77	9.64	1.70	10.87	1.79	9.60	1.67
Cr	1.78	0.12	1.91	0.14	1.73	0.11	2.09	0.18	1.69	0.09
Pb	1.56	0.52	1.76	0.55	1.28	0.49	1.82	0.58	1.17	0.45
Sb	1.42	0.02	1.52	0.03	1.40	0.01	1.63	0.05	1.37	0.01
Co	0.20	1.03	0.23	1.05	0.18	1.00	0.26	1.09	0.13	0.90
Cd	0.03	0.01	0.06	0.02	0.04	0.01	0.10	0.04	0.03	0.01
Mo	0.34	0.27	0.78	0.31	0.31	0.17	0.86	0.32	0.29	0.15
B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
V	0.07	0.06	0.11	0.08	0.05	0.04	0.18	0.10	0.03	0.02
Sr	0.18	0.07	0.26	0.10	0.14	0.05	0.31	0.12	0.12	0.04
Al	114.37	120.16	115.60	122.73	112.73	120.03	115.77	122.78	112.24	120.01

Note: ND = not detected

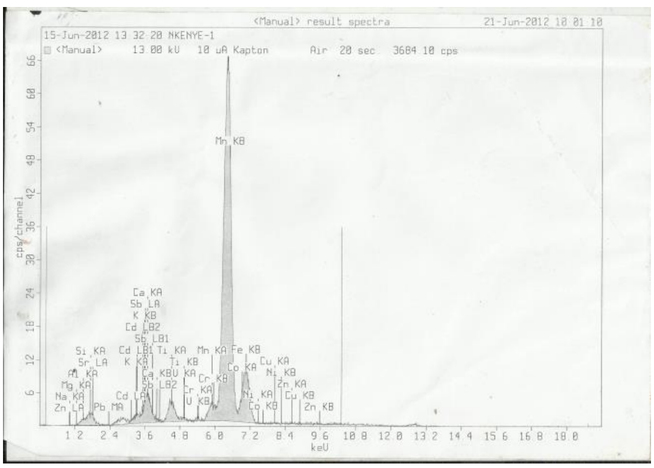

Figure 5. A representative XRF spectra of Nkenye sediments

3.4. The Results from Bacteriological Analysis

The results of the microbiological examination of the Nkenye stream water showing total coliform and *E. Coli* for the wet and dry seasons are presented in Table 7. Higher values of *E. Coli* were recorded during the wet season than in the dry season and this can be attributed to influx through runoff of microorganisms originating from vegetation, decay, municipal sewage, garbage, domestic and faecal waste into the Nkenye stream water body. The microbial values recorded in the stream body represent high bacteria load compared to recommended standards for drinking water. This condition constitutes a threat to end users, thus the need for adequate disinfection process before being used for domestic purposes.

The bacteriological analysis of water is done primarily to determine its portability i.e. it fitness for drinking. As many diseases of the intestinal origin e.g. typhoid fever, dysentery etc have been known to be transmitted to humans through the taking in of water polluted with sewage, the bacteriological analysis which indicates the degree of pollution serves as a useful measuring stick to determine the safety of water .

Table 7. Levels of bacteriological parameters

Sampling Sites	**Wet Season**		**Dry Season**	
	MPN Of Coliform Organisms/100 mL	*E. Coli*/100 mL	MPN Of Coliform Organisms/100 mL	*E. Coli*/100 mL
1	> 2420	1299.7	> 2420	29.6
2	> 2420	> 2420	> 2420	> 2420
3	> 2420	961	> 2420	2.0
4	> 2420	437.1	> 2420	20.2
5	> 2420	315.1	> 2420	12.0

4. Conclusions

The physicochemical characteristics of the Nkenye stream water samples revealed a fresh water environment with low physical and chemical pollutants burden. However, high turbidity, iron, manganese and chromium were recorded. Seasonal variation in a number of the measured water quality parameters was significant. Microbial burden of the Nkenye stream water was high compared to the recommended standards for drinking water, thus constituting a serious hazard to public health, as their presence is indicative of a possible presence of microorganisms associated with water-borne diseases, suggesting the need for adequate disinfection process before being used for domestic purposes. Silicates, iron and aluminium are present in sediments from Nkenye stream as major quantities and others exist in trace amounts. Sediments from Nkenye stream have low carbonaceous matter.

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