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# Sources of Water Pollution and Selected Physicochemical Parameters of the Nyakomisaro River in Kisii County, Kenya

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**Abstract:** Water is the most vital natural resource in existence as all forms of life depend on it. However, this resource is constantly polluted by human activities. Pollution of rivers is a big challenge not only in Kisii County but as a Country at large. Purposive sampling was used to identify the study area and random sampling was used to collect questionnaires. Water samples were also collected from the study site and physicochemical parameters were analysed in the laboratory. Primary data was analysed descriptively while laboratory data was analysed descriptively and statistically using t-test. Dumping of liquid and solid waste (37.2%) and farming along the river banks (34.9%) were some of the causes of pollution in River Nyakomisaro. The two main economic activities affecting the river are sand harvesting (30.6%) and farming along the river banks (26.8%). The mean value of COD, BOD, TDS, Do, pH, Ec and Temp in Nyaguru (upstream) sampling points were 74.58±13.88 mg/l, 8.42±0.4 mg/l, 20.25±0.5 N. T. U, 3.75±0.21mg/l, 6.78±0.02, 0.19±0.00 S/m and 22.28±0.37°C respectively and the mean value of COD, BOD, TDS, Do, pH, Ec and Temp in Daraja (downstream) sampling points were 14.33±1.09 (mg/l), 4.92±0.45 (mg/l), 17.5±0.5 N. T. U., 3.65±0.34 mg/l., 6.84±0.02, 0.18±0.00 S/m and 22.98±0.40°C respectively. The concentrations of these physico-chemical parameters except Do and pH showed significant differences among the points (P>0.05). The values of all the parameters were within standards stipulated by World Health Organization except the values of Chemical Oxygen Demand. This also means that this water is not good for drinking and certain protective measures should be taken to ensure that residents depending on the source are not affected by it use. Therefore, community and town residents should be sensitized on the effects of indiscriminate disposal of waste to environment and River Nyakomisaro. Also, there should be a continuous monitoring of the water quality along the river to ensure that water is safe for consumption.

**Keywords:** Water, Physicochemical Parameters, Pollution and River

## 1. Introduction

Water is made up of over seventy percent of the Earth's surface and it's the most valuable natural resource in existence [1-3]. Water is crucial component of all forms of life [4-6]. Furthermore, it is a habitat [7], commodity consumed by animals and plants [8], acts as a carrier of other substances or properties such vector disease, organic and inorganic chemicals, energy and many others [9-11]. There is no other resource that affects so many areas of the economy or of human and environmental health like water [12]. However, globally 1.1 billion people lack access to safe drinking water due to water pollution [13-15].

In developing countries like Kenya, water sources for domestic use include; lakes, irrigation canals, ponds, dams, rivers, wells, borehole and rain harvested water among others, however, these sources are relentlessly polluted from both point and non-point sources due to agriculture, industrial and domestic wastes, leakages from landfills and pit latrines which contribute to organic, inorganic and aesthetic pollution of water [16-19].

[20] Recorded elevated levels of Diazinon, Fenitrothion, Cyhalothrin, Malathion, bis (2-ethylhexyl) phthalate, Dimethoate while analyzing of organic contaminants and the physico-chemical properties of borehole water of Maili-nne

Estate and Sosiani village, Uasin Gishu County, Kenya. [21] detected the following from Athi and Kauthulini River water sources; total coliforms mean ranged between 10 and 23,830 CFU/100 mL, *Escherichia coli* mean range between 10 and 3480 CFU/100 mL, *Vibrio cholera, Shigella sp., Salmonella sp., Klebsiella sp., Streptococcus faecalis* and *Clostridium perfringens* were also detected. [22] While assessing microbiological water quality of sand dams in southeastern Kenya indicated that the water from test holes and covered wells was microbiologically of better quality than the scoop holes with median TTC levels of 0/100 mL and 159/100 mL respectively. However, the median values of turbidity for both scoop holes (20–30 NTU) and covered wells (5–10 NTU) exceed the World Health Organisation (WHO) guideline values. In addition the conductivity of water from 23% of scoop holes and 26% of covered wells is above the recommended WHO limit.

A river is a natural flowing water course, usually fresh water flowing towards the ocean, sea, lake or other river. River water quality status is generally affected by many physical, chemical and biological parameters introduced by natural forces and human (anthropogenic) activities [23]. United Nation Development Program reported that approximately 1.8 million children die annually due to diarrhea which is attributed to unsafe water while in 2013, it is estimated that of 700,000 children worldwide dies as a results of diarrheal diseases resulting from drinking contaminated water [24].

River Nyakomisaro in Kisii County passes through highly populated Kisii town where many economical activities are carried out [25, 26]. Raw sewage was spotted in River Nyakomisaro, which connects to rivers Riana and Gucha that drain into Lake Victoria and residents expressed their concern over risk of contracting cholera [27]. It was vital to assess sources of water pollution to River Nyakomisaro and determine physicochemical parameters of the water. Findings of the study is hoped to help to fill the gaps by providing information on the effect of pollution of River Nyakomisaro which in return will be used in proper decision making on the effects of pollution.

# 2. Methodology

### *2.1. Study Area*

Nyakomisaro sub catchment is within Kisii County. River Nyakomisaro is a tributary of River Gucha and its water serves Kisii town [28]. Kisii County is one of the 47 counties in the Republic of Kenya. It shares common borders with Nyamira County to the North East, Narok County to the South and Homabay and Migori Counties to the West. The County lies between latitude 0° 40' 38.4" South, and longitude 34º 34' 46º 61" East and covers an area of 1,317.5 km2. Kisii County exhibits bimodal rainfall pattern with average annual rainfall of 1500m and temperatures that range between 21°C – 30°C. Crops grown in the country include tea, coffee, pyrethrum, maize, beans and bananas as well dairy farming. Kisii County has a population of 1,266,860 according to [29].

### *2.2. Data Collection*

#### *2.2.1. Secondary Data Collection*

Secondary data were collected from various documents including, administrative documents including government reports and online documents, some published and unpublished hard and soft information sources.

#### *2.2.2. Primary Data Collection*

Primary data was collected through the use of a structured questionnaire survey.. The study area was divided into two areas Nyanguru (upstream and Daraja (Downstream) of Nyakomisaro River. Purposive sampling was used to identify the section of Nyakomisaro River where there as pollution. The sample size was determined from the formula proposed by Yamane cited by Isreal (2009) as indicated below. Systematic random sampling procedure used to select a total of 104 sample households which were interviewed using a structured questionnaire.

Sample Size Determination

During preliminary study it was approximated that about 140 household lived along the River. Therefore sample size was determined from the formula proposed by Yamane cited by Isreal (2009), which state that:

$$n = \frac{N}{1+N(e)^2}$$

Where: n=sample size
N=target population size
e=level of precision (sample error)
Therefore, N=140 households and e=5%
Thus required sample size;

$$n = \frac{140}{1 + 140(0.05)^2}$$

$$\mathrm{n} = \frac{140}{1.35}$$

N=104
Desired sample size determined and used were 100.

### *2.3. Measurement of Physico-Chemical Parameters in the Field*

A total of 24 water samples were collected from two different sites during the wet season in 2018. Water samples were taken in a well labeled 500 ml sampling glass container and transported to University of Eldoret for analysis. Parameters such as temperature, pH and dissolved oxygen were measured on site. Grab sampling was generally applied during the sampling. The samples were analyzed for following physicochemical parameters of Chemical Oxygen Demand, Biochemical Oxygen Demand, Total Dissolved Solids, Dissolved Oxygen, pH, Electrical Conductivity and Temperature by using standard methods stipulated by [30].

### *2.4. Data Analysis*

Each set of questionnaires response from the farmers were

coded and keyed in the statistical package of social scientist (SPSS version 20) to analyze data. Data was analysed descriptively and presented in tables and figures. The physicochemical parameters were analysed descriptively using SPSS version 20 and significant differences in the physicochemical parameters among sampling points was analysed with t-test.

# 3. Results

### *3.1. Socio-economic Characteristics of Households*

The general information about socio-economic characteristics of household heads such as gender, age and occupation are presented in Tables 1, 2 and 3 respectively.

***Table 1.*** *Sex of household head.*

| Gender | Frequency | Percentage |
|---|---|---|
| Female | 68 | 68 |
| Male | 32 | 32 |
| Total | 72 | 100 |

Slightly more than two thirds (68.0%) of the interviewed household were female compared to close to a third (32.0%) who were male.

***Table 2.*** *The age of the respondents.*

| Age (Years) | Frequency | Percent |
|---|---|---|
| 15-24 | 20 | 20 |
| 25-35 | 53 | 53 |
| 36-50 | 17 | 17 |
| 51 and above | 10 | 10 |
| Total | 100 | 100 |

Among household heads interviewed, 20%, 53%, 17% and 10% fall between 15-24, 25-35, 36-50 and 51 and above years' age bracket. The study shows that majority of the respondent's falls between 25-35 years' age bracket and this is the active group of the society.

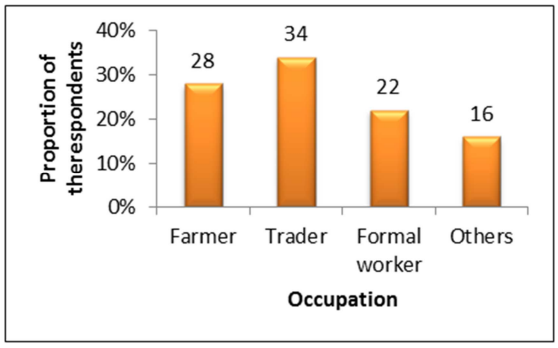


***Figure 1.*** *Proportion of occupation of the respondent.*

Results showed that most of the respondents are traders (34%) and farmers (28%). Some of them are formal workers (22%) and others (16%) have different type of occupation. From the results it's apparent that most of the respondents living along River Nyakomisaro were traders and farmers.

### *3.2. River Nyakomisaro Possible Causes of Pollution*

The study tried to establish the possible causes of pollution to River Nyakomisaro and results are presented in tables 3, 4, 5, 6, 7 and figure 2.

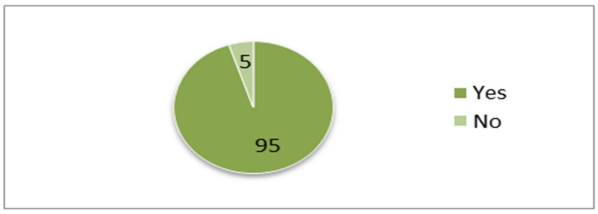


***Figure 2.*** *Possibility of pollution of River Nyakomisaro.*

When the respondents were asked if River Nyakomisaro is polluted, majority of the respondents (95%) believed that there is pollution only (5%) of them didn't agree that there is any kind of pollution in River Nyakomisaro.

***Table 3.*** *Possible causes of pollution of River Nyakomisaro.*

| | Frequency | Percent |
|---|---|---|
| Dumping of solid and liquid waste to the River | 96 | 37.2 |
| Cultivation along the River | 90 | 34.9 |
| Occurrence of floods | 36 | 14.0 |
| Soil erosion carrying waste into the River | 26 | 10.1 |
| Drought | 7 | 2.7 |
| No response | 3 | 1.1 |
| Total | 258 | 100 |

Majority of the respondents (37.2%) believed that one of the possible causes of River Nyakomisaro pollution is dumping of both liquid and solid waste to the River. Farming along the river (34.9%) was also a major cause of river contamination among others.

***Table 4.*** *Distance from the buffer zone.*

| | Frequency | Percent |
|---|---|---|
| 0-30m | 28 | 28 |
| 30-60m | 46 | 46 |
| 60-150m | 16 | 16 |
| 150 and above | 10 | 10 |
| Total | 100 | 100 |

Among household heads interviewed, 28%, 46%, 16% and 10% fall between 0-30m, 30-60m, 60-150m and 150 and above meters. The study shows that majority of the respondent's live 30-60 m far from the river.

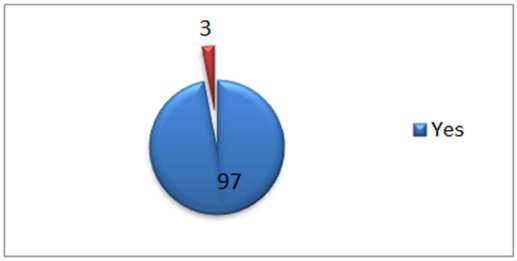


***Figure 3.*** *Possible of economic activities causing pollution of River Nyakomisaro.*

When the respondents were further asked to suggest possible economic activities causing pollution of river Nyakomisaro sources of pollution, majority of the respondents (97%) believed that there are economic activities causing pollution, only (3%) of them didn't agree that there are economic activities causing any kind of pollution in River Nyakomisaro.

***Table 5.*** *Possible economic activities that could lead to pollution of River Nyakomisaro.*

| | Frequency | Percent |
|---|---|---|
| Deforestation | 59 | 19.0 |
| Mining-Sand Harvesting | 94 | 30.3 |
| Farming Along The River | 83 | 26.8 |
| Building Along The River | 51 | 16.5 |
| Oil Spillage From car/Motor Cycle Wash | 23 | 7.4 |
| Total | 310 | 100. |

The two main economic activities affecting River Nyakomisaro are sand harvesting (30.6%) and farming along the river banks (26.8%) while few reported oil spillage from car and motor cycle wash (7.4%).

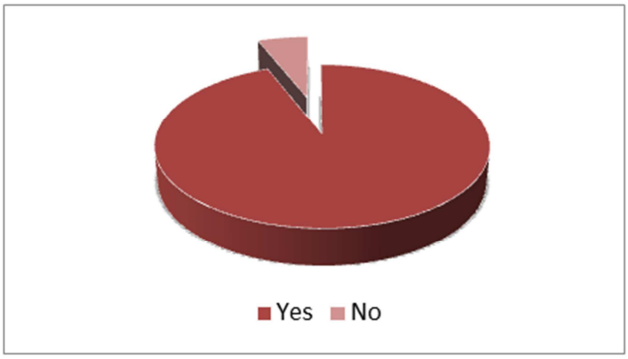


***Figure 4.*** *Environmental factors that could contribute to pollution of River Nyakomisaro.*

When the respondents were asked if there are environmental factors that could contribute to pollution in River Nyakomisaro, majority of the respondents (95%) believed that there are environmental factors that contribute to pollution only (5%) of them didn't agree that there are any kinds of environmental factors that contribute to pollution in River Nyakomisaro.

***Table 6.*** *Current mitigation measeures taken to reduce pollution of River Nyakomisaro.*

| | Frequency | Percent |
|---|---|---|
| Yes | 60 | 16.2 |
| No | 40 | 10.8 |
| Total | 100 | 27.0 |

When the respondents were asked if there is any current mitigation measures taken to reduce pollution in River Nyakomisaro, majority of the respondents (16.2%) believed that there is mitigation measures to reduce pollution, (10.8%) of them didn't agree that there is any kind of mitigation measures taken to reduce pollution in River Nyakomisaro.

***Table 7.*** *Mitigation measures taken to reduce pollution of River Nyakomisaro.*

| | Frequency | Percent |
|---|---|---|
| Creating awareness on the importance of clean water | 78 | 25.2 |
| Implementation of policies to clean environment | 85 | 27.4 |
| Enacting of laws that protect cutting down of trees | 56 | 18.1 |
| Advocating for regular cleaning of River Nyakomisaro | 41 | 13.2 |
| Relocating of people who build along the River | 18 | 5.8 |
| Educating people on the effects of cultivating along the River | 32 | 10.3 |
| | 310 | 100 |

Results indicate that measures that should be taken to protect River Nyakomisaro are implementation of policies to clean environment (25.2%) and creating of awareness on importance of clean water (27.4%) had the highest percentages while a relocating people who build along the River had the lowest percentage of 5.5%.

### *3.3. The Physicochemical Parameters of River Nyakomisaro*

The study also focused on determining the physicochemical parameters of River Nyakomisaro. Results are presented below.

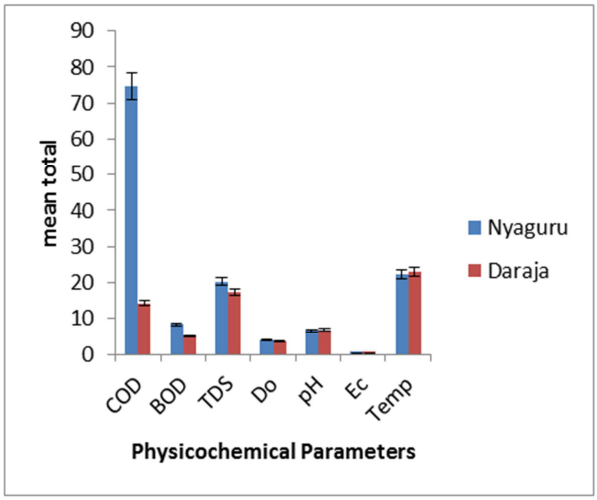


***Figure 5.*** *The mean values of physicochemical parameters of Nyanguru (upstream and Daraja (Downstream) of Nyakomisaro spring.*

The mean value of COD, BOD, TDS, Do, pH, Ec and Temp in Nyaguru (upstream) sampling points were 74.58±13.88 mg/l, 8.42±0.4 mg/l, 20.25±0.5 N. T. U., 3.75±0.21mg/l, 6.78±0.02, 0.19±0.00 S/m and 22.28±0.37°C respectively and the mean value of COD, BOD, TDS, Do, pH, Ec and Temp in Daraja (downstream) sampling points were 14.33±1.09 mg/l, 4.92±0.45mg/l, 17.5±0.5 N. T. U 3.65±0.34mg/l, 6.84±0.02 mg/l, 0.18±0.00 and 22.98±0.40°C respectively.

The study also determine whether there existed significant differences in the physicochemical parameters between Nyaguru (upstream) and Daraja (Downstream) of Nyakomisoro spring. Using t-test, results indicated that there was a significant difference in temperature (t=-3.075; df=11, $p$=0.011), COD (t=4.570; df=11, $p$=0.001) BOD (t=8.042; df=11, $p$=0.000), TDS (t=3.065; df=11, $p$=0.011) and Ec

(t=4.874; df=11, *p*=0.000). However, there no significant difference in Do (t=0.480; df=11, *p*=0.640), and pH (t=-1.981; df=11, *p*=0.073).

# 4. Discussions

### *4.1. Anthropogenic Activities Around River Nyakomisaro*

Nyakomisaro sub catchment is within Kisii County. Kisii town is located south-western Kenya, is the main urban and commercial center. River Nyakomisaro is a tributary of River Gucha and its water serves Kisii town [28]. The major causes of pollution to River Nyakomisaro reported by respondents were; dumping of both liquid (connecting of untreated sewerage channels to the river) and solid waste to the River (37.2%). Farming along the river (34.9%) was also a major cause of river contamination among. [27] Reported raw sewage that was spotted in River Nyakomisaro, which connects to rivers Riana and Gucha that drain into Lake Victoria and residents expressed their concern over risk of contracting cholera. A study done by [31] on water pollution identified dumping of liquid and solid waste as mainly the causes of water pollution in Delhi and recommended proper solid waste disposal system and liquid waste treatment before entering in to river. Educational and awareness programs should be organized to control the pollution. The major economic activities around the river are agriculture, car/ motocycle cleaning and sand harvesting. Improper agriculture practices and deforestation lead to land degradation and alteration of physico-chemical parameters of the River. [32] and [33] reported that population growths and developmental activities along water bodies in many sub Saharan countries have been responsible for negative changes in water quality parameters. In order to protect River Nyakomisaro, respondents suggested measure such as implementation of policies to clean environment and creating of awareness on importance of clean water had the highest percentages.

### *4.2. Physico-chemical Parameters*

The mean levels of temperature recorded were 22.28±0.37°C in Nyaguru (Downstream) and 22.98±0.40°C Daraja (downstream). These levels were low and it could be due to meteorological aspects such as humidity, solar radiation and rainfall. There was a significant deference in temperature between Nyaguru (upstream) and Daraja (Downstream) of Nyakomisoro spring (t=-3.075; df=11, *p*=0.011) could due depth difference in the downstream and upstream. Shallow waters generally warm easier and quicker compared to deeper side of the River. [34] Conducted a study in the Greek lakes and reported that variations in temperature this could be due to morphometric measurements of water bodies. [35] recorded, a slightly difference in temperature between the two sampling sites in Lake Mweru-Wantipa, Zambia. A study done by [36] water quality and plant species composition of selected sites within Chemususu dam, Baringo County, Kenya recorded a significant difference in the mean temperature between upstream Rivers and the dam; and between upstream Rivers and out flowing River with C1 and C3 (P=0.001, T=-7.889); C2 and C3 (P=0.001, T=-7.613); C1 and C4 (P=0.002, T=-5.665), and between C2 and C4 (P=0.004, T=-5.013) and it was attributed to interaction of the calm water with ambient temperature due to solar radiation could also have led to the increase in temperature in the dam.

The mean levels of Chemical Oxygen Demand (COD) recorded were 74.58±13.88 mg/l in Nyaguru (Downstream) and 14.33±1.09 mg/l Daraja (downstream. COD levels in our study exceeded the WHO standards of 50 mg/l. [37] while investigating pollutants, determining physico-chemical characteristics of the Nairobi River and remediation of some toxic heavy metals using Fish Bones' across the sampling sites recorded COD with a mean of 260.6±248.8 mg/L. There was a significant difference in COD (t=4.570; df=11, *p*=0.001) between Nyaguru (upstream) and Daraja (Downstream) of Nyakomisoro spring. There was a general decrease of COD values downstream indicating that amount of organic matter was decreasing.

Biochemical Oxygen demand (BOD) is the quantity of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period [37, 38]. BOD mean levels were 8.42±0.4mg/l in Nyaguru (Downstream) and 4.92±0.45mgl Daraja (downstream). The level did not exceed the KEBs standard of 30 mg/L indicating that the water had enough oxygen. This level BOD varied significantly along sampling sites (p=0.002, ANOVA) and ranged from 16.4 to 325.5 mg/l according to the study done by [38]. There was a significant difference in BOD (t=8.042; df=11, *p*=0.001) between Nyaguru (upstream) and Daraja (Downstream) of Nyakomisoro spring. There was a general decrease of COD values downstream indicating that amount of organic matter was decreasing

The mean levels of Total Dissolved Solids (TDS) were 20.25±0.5 mg/l in Nyaguru (Downstream) and 3.65±0.34 mgl Daraja (downstream). Total Dissolved Solids (TDS) recorded significant differences (t=3.068; df=11, *p*=0.001) between the two sampling sites. [38] Recorded a concentration which ranged from 5.6 – 68 mg/l, values which were greatly below desirable concentration of 500 mg/l in River Kibisi, Kenya which concur with our study.

Dissolved oxygen levels measured were 3.75±0.21mg/l in Nyaguru (Downstream) and 6.84±0.02mgl Daraja (downstream). Using paired sample t-test, shows there was no significant difference in dissolved oxygen between sites Nyaguru and Daraja (P=0.064, df=11 T=0.480). Low levels of DO in River Nyakomisaro were recorded during our study. This could be attributed to increase flow rate which increases turbulence causing aeration. In addition, the low dissolved oxygen may be as a result of decomposition of submerged vegetation which was not deforested during construction of the river. [36] Recorded in C1 the levels in mg/l ranged from 5.3 to 7.34; 5.7 to 6.4 in C2; 1.7 to 6.46 in C3 and 2.2 to 6.9 in C4. Using paired t-test, there was significant difference in dissolved oxygen between sites C3 and C4 (P=0.001, T=-6.944). Low levels of DO in Chemususu dam were

recorded during the entire study period. This could be attributed to reduced flow rate which reduces turbulence causing aeration. In addition, the low dissolved oxygen may be as a result of decomposition of submerged vegetation which was not deforested during construction of the dam. [35] recorded the lowest and highest dissolved oxygen concentration was 1.2mg/l and 12.1mg/l measured from the National park and settlement side of the lake respectively. The oxygen concentrations on the settlement side were significantly higher than the National park side ($t$=-3.66; $p$=0.001). Significant differences in dissolved oxygen between the study sites might have been due to a number of biotic and abiotic factors in the Lake. The dissolved oxygen levels recorded in the present study (Table 2) were within limits of natural background level of 5.0 to 7.0 mg/l that supports aquatic life.

The mean levels of pH were 6.78±0.02 units in Nyaguru (Downstream) and 6.84±0.02 units Daraja (downstream). The pH values were within the normal range in the study area pH levels within the river may be due to deposition of organic matter into water due to surface runoff from forest and farmlands as well as the submerged vegetation during infilling of the dam. The partial decomposition by bacteria and fungi of this organic matter produce various organic acids that are capable of lowering the pH. Therefore our study pH value was within the acceptable limit of WHO (6.0-8.5). A study of [36, 38] had acceptable limit of the pH in their study sites.

## 5. Conclusion and Recommendation

The values of physic-chemical parameters of temperature, Chemical oxygen Demand, Biochemical Oxygen demand (BOD), Total Dissolved Solids (TDS), Dissolved oxygen of the water quality in the River Nyakomisaro in Kisii County, Kenya were found to be within the recommended limits of WHO and KEBS standards except COD. This means that this water is not good for drinking and certain protective measures should be taken to ensure that residents depending on the source are not affected by it use. Therefore, community and town residents should be sensitized on the effects of indiscriminate disposal of waste to environment and River Nyakomisaro. Also, there should be a continuous monitoring of the water quality along the river to ensure that water is safe for consumption.

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