E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 76.37
(GIF) Impact Factor: 0.549
IJFAS 2022; 10(4): 47-54

www.fisheriesjournal.com
Received: 06-05-2022
Accepted: 23-06-2022

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Macroinvertebrates as bio-indicators of water quality in Omubira Stream, in Kakamega County, Kenya

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DOI: https://doi.org/10.22271/fish.2022.v10.i4a.2707

Abstract
Human-induced environmental stress can impair freshwater ecosystems by destroying them or altering them in negativeways. Laws and ordinances that stress Kenya's water resources' correct management and utilization were prompted by worries about the management of freshwater bodies. Therefore, understanding of the health status of aquatic environments, particularly their biodiversity, is crucial in order to comprehend the status of water quality and limit the rate of pollution in our streams and rivers. Several well-known biological markers of water quality can be used for this. Bio-indicators are species or groups of species that can quickly reveal the abiotic or biotic condition of an environment, show how environmental change has affected a habitat or ecosystem. In many industrialized nations, including those in Europe and North America, macroinvertebrates are widely utilized as bio-indicators and are part of their national and technical standards for water quality monitoring. Their use is still relatively restricted in developing nations like Kenya. Furthermore, the use of aquatic macroinvertebrates as bio-indicators of water quality to assess the condition of aquatic ecosystems is not stressed by Kenyan environmental laws and regulatory bodies. This can be because the nation doesn't have a well-known and established biomonitoring system. However, only a small number of studies have begun utilizing macroinvertebrate species as bio-indicators at this time. A greater comprehension of the macroinvertebrate variety of the Omubira River could help in the stream management due to continued municipal and agricultural activities along this river. As a result, this study examined the use of macroinvertebrates as bio-indicators of river water quality and determined how they reacted to water quality in the various region of the stream.

Macroinvertebrates and selected physicochemical variables were sampled monthly in four sites for a period of four months. On each sampling sites at every sampling episode physicochemical variables including temperature, conductivity, salinity, turbidity, pH, dissolved oxygen and percentage saturation oxygen were measured using a Hydrolab Quanta Multi-Probe Meter. A Surber sampler of an area 1200 cm^2 and corer sampler were used with catching area of 20.83 cm^2 to capture macroinvertebrates. There was a general decrease of Temprature, turbidity, salinity, conductivity and pH from the town area to the forested area. However, dissolved oxygen increased from the town area to forested area. A general variation of macroinvertebrates species from manucipal area to forested area in the river was observed. The highest abundance of Belostomatidae (16.87), Chironomidae (16.77), Naididae (14.07) and Gomphidae (18.67) were found in the manucipal reach of the river. The highest abundance of Elmidae (20.49) and Notonectidae (19.87) were found in the agricultural reach while the highest abundance of Gerridae (10.53), Hydropsychidae (28.65) and Perlidae (33.92) were found at the forested reach. From the diverse makeup of the macroinvertebrates, Omubira stream's water quality can be described as moderately clean. This could be harmful to aquatic life and communities living along, which depends on highly clean water to exist. This study therefore recommends continuious monitoring and proper management of pollution sources into the stream by the pertinent authorities as well as embracing bio-indictors.

Keywords: Lotic system, macroinvertebrates, water quality, bio-indicators, biodiversity, abundance

1. Introduction

Water, as a limited-quantity asset, has unrivaled spatial circulation. It's essentiality for human life since it serves as the primary source of drinking, industrial, commercial, and recreational water. The discharge of contaminated natural or manufactured water into a river as a result of human or industrial activity to disrupt or affect the natural state of water is rampant in many streams, especially in Africa [1].

Water quality monitoring and maintenance is a very attractable problem in the world and especially in developing countries, in order to aid sustainable socio-economic progression in catchment structures. Nonetheless, the management efforts is normally faced by various uncertainties from the hydrological dynamics, erraticism pollution, sedimentation, urbanization, agricultural activities and mining run-offs [2]. One of the most widely used methods for assessing the state of aquatic ecosystems and the biological effects of stressors is the analysis of macroinvertebrate communities, according to [3]. Ecology's food webs and the highest tiers of the food chain can be harmed by the inconsistent character of the numerous communities that disrupt population structure and its relationships to the environment [4]. Studies of stream macroinvertebrates as biological tools in understanding stream health have been largely reported and discussed in the literature of [5, 6]. This is due to the ability of macroinvertebrates to occupy different microhabitat within the stream regime. The fundamental aspect of them is the level of sensitivity and tolerance to pollution and human disturbances [7]. Human impacts in terms of disturbance and pollution have been noted to causes a lot of macroinvertebrate abundance, diversity, composition and assemblage dynamics [8]. According to [9], the midstream area of River Njoro in Nakuru County, Kenya, displayed poor water quality and low macroinvertebrate abundance as a result of contamination from both anthropogenic activities and agricultural run-off.

Bio-indicators have been employed through the availability and unavailability of sensitive species abundance or composition due to the influence of pollution and human disturbance [10]. In addition to that, some macroinvertebrate families such as Trichopterans like high quality water with less pollution and can therefore be used to trace pollutants [11]. This is highly recommended especially in developing countries where resources to monitor stream health are limited. For example, Rendering to [12], the lower Yellow River, the lower Yongdinghe River, and the lower Hutuohe River were characterized as unhealthy seasonal rivers due to threatening land use practices along its regimes. Nevertheless, the use of macroinvertebrates to determine the ability of stream bio-indicators appears not to be common in most African countries even though this method delivers an inexpensive and better technique in classifying rivers [13].

Macroinvertebrates distribution and conditions stability of lotic systems is highly predicted by riparian zones. It has been employed largely in European and American ecosystems, which is alluded to the sufficient data and knowledge [14]. Presently, most African countries uses physical and chemical monitoring methods and they have been considered as the most preferred approaches of conservation in comparison to biomonitoring [15]. On the other hand, many studies have concentrated on how rivers get polluted, for example [10] observed that nutrients and physicochemical parameters tend to decrease as one moves downstream, most likely because of uptake by phytoplanktons but very few evidence is available to support these findings. The time of detecting water quality deterioration is also a major challenge in most developing countries. On the contrary, employment of bio- indicators enables timely detection and applying of appropriate conservation strategies. Some studies have affirmed that bio-indicators are the most effective because they can be utilized by everyone and even suggested the establishment of classified keys for the African macroinvertebrates exclusively at the species level [16].

The present study is anchored in investigation of physicochemical characteristics and species variety and abundance in town area, agricultural areas, and forested areas along the Omubira River, as well as zeroing down into the relationship between physicochemical parameters and land use activities. Our aim is to find how physicochemical parameters are altered by changes in land uses that ultimate affect the diversity and distribution of macroinvertebrates in the Omubira Stream. Understanding how macroinvertebrates can be used to identify pollution levels will go a long way in tackling the issue of water stream pollution in many developing countries' ecosystems. In this situation, it's crucial to consider how rivers get contaminated contaminants like excess nutrients, maintain normal nutrient levels and maintain normal physical qualities and the changes in macroinvertebrates species along the stream regime.

2. Materials and methods

2.1 Study site

The study was conducted in Kakamega County in Omubira stream which transverses across different land uses including a municipality residential area, agricultural land and MMUST forests which was part of the larger Kakamega tropical rainforest. Kakamega county lies between latitudes 0º 07' 03'' N and 0º 15' N and longitudes 34 º 32' East and 34 º 57' East. The County has varying topography with altitudes ranging from 1250 m to 2000 m above sea level. Kakamega County has two rainy seasons, the long rains and short rains. The long rains occur from March to June with peak in May while the short rains commence in July and end in September and peaks in August. The driest months are December, January and February. The rainfall varies from 1000 mm per annum in Northern parts of the county to 2400 mm per annum in Southern parts. The county has an average maximum temperature of 28 ºC to 32 ºC and minimum of 11 ºC to 13 ºC. Low temperatures are usually recorded at night and very high during the day. The mean annual rainfall ranges from 1600 mm to 2100 mm with high humidity and low evaporation rates.

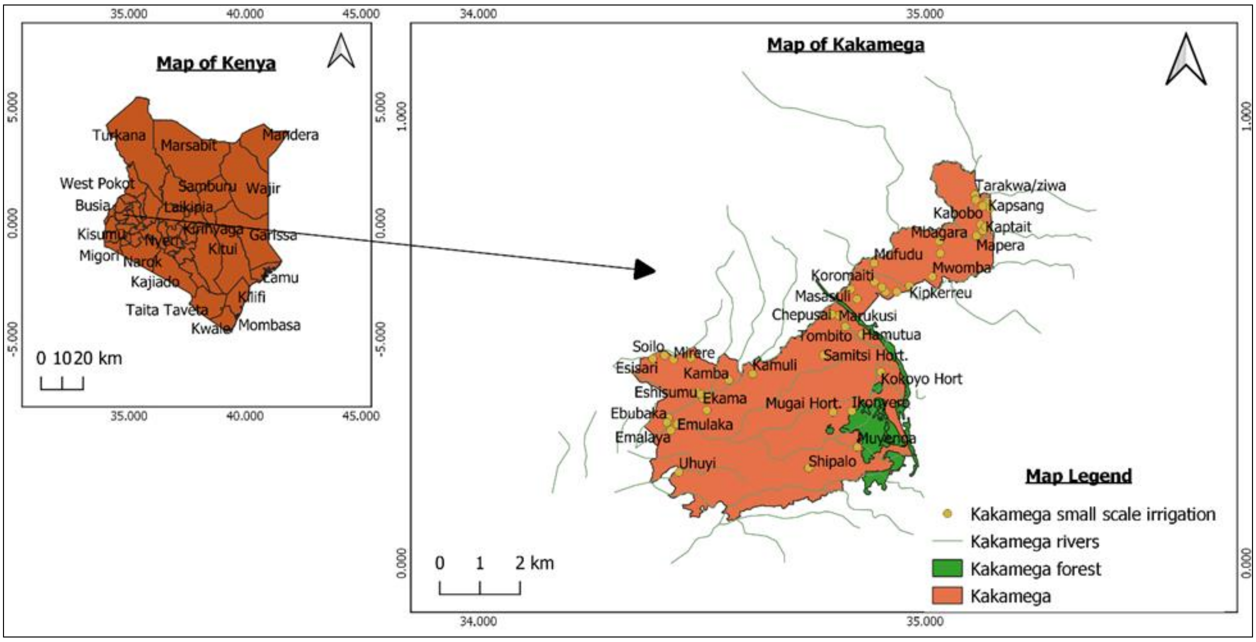

Fig 1: Map showing Kakamega Rivers and stream, including River Omubira.

2.2 Study Design
The study was conducted using a stratified randomized design. The stream was divided into three strata which is town area, agricultural land and the forested area. The stream was purposively selected as a case study of self-purification system because it transverses different land uses.
Nine sampling sites were selected along River Omubira on the basis of different land use types in three strata of the town, agricultural and forested area. For each land use type, two sampling sites were selected at random.

2.2 Data collection
Sampling was done twice a month in the first and last week from January 2020 to April 2020 of from the Omubira Stream (from town area to forested area) in three replications from each station.
According to the various land uses, sampling stations from three different areas were chosen for monitoring and evaluation. Due to the increased likelihood of biological diversity in the current river stretch and among the sampling stations, changes in biological and environmental parameters could be studied more thoroughly and accurately.

2.3 Physicochemical parameters
On each sampling occasion temperature, conductivity, salinity, turbidity, pH, dissolved oxygen and percentage saturation oxygen were measured *in situ* using a Hydrolab Quanta Multi-Probe Meter (Quanta Sonde Model).

2.4 Macroinvertebrates
A Surber sampler of an area 1200 cm^2 was used in shallow lotic water with gravels and pebbles. Meanwhile, these parameters were observed at the forested area sampling sites. It was placed at the benthic of the stream against the current flow. At the town area and agricultural areas with fine sand, muddy and silts substrates a corer sampler was used with catching area of 20.83 cm^2. All captured macroinvertebrates were place in specimen bottles and preserved with 70 % alcohol. In the laboratory the benthos were sieved by using 0.5 mm stainless sieve. Sorted into a petri dish and identified by using a taxonomic key to the lowest possible level. For big benthos macroinvertebrates, they were sorted by naked eye. A dissecting microscope through the aid of forceps was used in sorting smaller macroinvertebrates. The samples were then sorted in a fresh 70 % ethanol before using appropriate taxonomical key [17].

2.5 Data analysis
Statistical Package for the Social Sciences (SPSS) version 23 was used to calculate the mean values of temperature, dissolved oxygen, pH, salinity, percentage saturation of oxygen, conductivity and turbidity for each sampling site on each sampling occasion for the study period. One way ANOVA was used to analyze the significance differences in physicochemical variables. Macroinvertebrates were washed through 100µm mesh-size sieves. The macroinvertebrates were then sorted in a petri dish and counted in a Leica Stereo Microscope. Identification to family was done according to [17]. The mean abundance (individual. dm^2 and relative abundance of macroinvertebrate stream fauna samples were also calculated for each site using SPSS.

3. Results
3.1 substrate characteristics of the selected sampling sites along river Omubira

Table 1: Characteristics of selected sampling sites along River Omubira of Kakamega County

Strata	Sampling sites	Substrate	Vegetation cover	Human activities
Town area	A	Sand, Mud, swampy bank	None	Hotel activities
	B	Sand and mud	None	Residential places
	C	Fine Sand, silt	Little	Napier farming
Agricultural area	A	Sand	Moderate	mixed cropping
	B	Sand, mud, organic debris	Moderate	Education facilities

	C	Sand, mud	Moderate	Washing of clothes
Forested area	A	Silt, organic debris	High	Natural forests
	B	Gravel, coarse sand	High	Psidium guajava forests
	C	Rocky swampy bank, rocks	High	Natural grass covers

Table 1 shown the substrate characteristics of the selected sampling sites along river Omubira. The town area and agricultural area is majorly composed of sand particles while the forested area is composed of stable substrate mostly gravel and coarse sands.

3.2 Human Activities along River Omubira

Results in Figure 2 show that the sampling sites are dominated by different human activities along the course of River Omubira. The sites had the following human activities; In the town area town area activities accounted for 75% and water drawing accounted for 25%; Agricultural land, town area activities accounted for 5%, mixed farming accounted for 65% and water drawing accounted for 30% and in the forested area, grazing accounted for 10%, water drawing accounted for 10% and forest cover accounted for 80%.

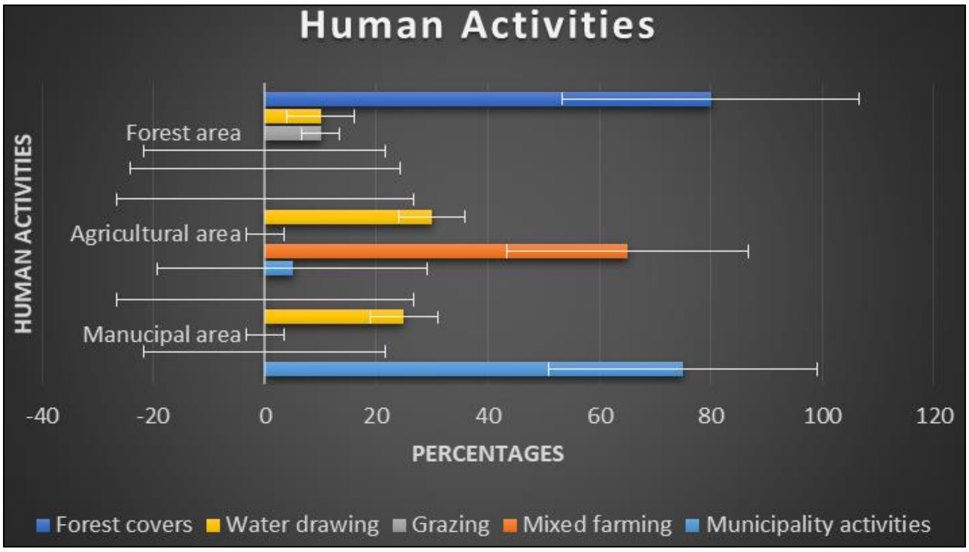

Fig 2: Bar showing the human activities in the respective sampling sites along River Omubira, Kakamega County.

The different colors of the bars show specific human practices in respective sampling sites. The human activities practices were municipal activities, mixed farming, grazing, water drawing, forest covers.

There was a general decrease in temperature from town area to forested area of Omubira stream during the study (Table 2). The highest temperature (23.22±2.21) was observed at site C town area while the lowest mean temperature (18.78±0.40) was recorded at a sampling site forested area.

3.3 Spatial variation in physicochemical Parameters

During the investigation, there was a general drop in temperature from the town area to the forest area of Omubira stream (Table 2). The town area at site C reported the highest temperature (27.17±1.31) while the forested region at site A recorded the lowest mean temperature (20.68±0.72). During the study period, there was a general tendency for conductivity to decrease from a town area to a forested area. During the investigation, C sampling site town area had the highest mean conductivity (104.45±32.26 S/cm), whereas C forested area had the lowest (54.12±20.47 S/cm) (Table 2). The conductivity values at sample locations A and B for the wooded region were 70.11±23.56 S/cm and 64.55±22.24 S/cm, respectively, showing the forested area has low conductivity. In Omubira stream, salinity and turbidity dropped from the town area to the forest area along the same drift as conductivity. The town area of the stream, C, had the highest mean salinity readings (104.45±32.26 g/L), while the forested area, B, had the lowest readings (54.12±20.47 g/L) (Table 2). The town area's B site had the highest turbidity reading (208.57±64.29 NTU), while the stream's C sampling site in the forested region had the lowest (81.86±14.86 NTU). This indicates that salt and suspended matter concentrations drop spatially from the town area to the stream's forested section. From the town area to the part of the stream that is forested, the pH exhibited a gradual decline. The pH ranged from (7.15±0.141) at sampling site C in the forested region to (9.49±0.33 at sampling site B in the town area. This shows that the pH of water varies from alkaline to neutral values as one travels from the town area to the forested MMUST land of Omubira stream. The forested area's C sampling site had the greatest mean dissolved oxygen readings (14.96±4.023), while the town area C (5.63±2.58) had the lowest readings (Table 2). Accordingly, at the town area reach of the stream, B had the maximum oxygen saturation (115.3±7.48 %) and C had the lowest (66.61±2.82 %). This is a problem since the town has microorganisms that perform a lot of decomposition and consume a lot of oxygen.

Table 2: Show spatial variation of mean physicochemical parameters (mean± standard deviation) along Omubira Stream of Kakamega County during the study period. The mean physicochemical parameters were used to study the ability and capacity of the stream to indicate water deterioration.

Land use reaches	Town Area			Agricultural Area			Forested Area		
Sites and parameters	A	B	C	A	B	C	A	B	C
Temperature (^{0}C)	26.9±1.1	27.17±1.31	26.53±1.08	23.52± 1.42	21.99±1.98	22.64±1.27	20.68 ± 0.72	21.14±1.03	21.65±1.96
Conductivity (µS/cm)	98.45±40.05	100.78±32.25	104.45±32.26	87.45±40.15	90.25±36.25	88.25±56.12	70.11±23.56	54.12±20.47	64.55 ±22.24
Dissolved Oxygen (mg/L)	6.62±0.94	5.76±1.36	5.63±2.58	9.13±1.27	8.72±0.96	9.73±0.85	12.11±1.85	13.79±0.61	14.96±4.023
pH	9.21±0.19	9.49±0.33	9.33±0.2	8.26±0.299	8.28±0.27	8.49±0.27	7.29 ± 0.48	7.3±0.26	7.15±0.141
Salinity (µg/L)	0.079±0.004	0.073±0.008	0.083±0.008	0.061±0.009	0.053±0.01	0.05±0.005	0.034±0.005	0.04±0.009	0.043±0.008
Oxygen saturation (%)	68.71±6.57	67.047±4.61	66.61±2.82	88.08±6.76	91.96±2.74	94.49±1.69	113.17±12.68	115.3±7.48	115.15±6
ORP (mV)	217.14±11.25	225.92±7.94	218.52±6.15	329.86±13.42	324.43±6.85	308.29±6.87	356.43±29.43	407.43±25.57	387.59±21.72
Turbidity (NTU)	196.43±14.32	208.57±64.29	205.57 ±11.94	150.43±16.36	141.86±15.18	156.43±34.46	94.57±28.09	110.29±22.42	81.86±14.86

3.4 Macroinvertebrates distribution in River Omubira

Their was a general variation of macroinvertebrates species from manucipal area to forested area in the river. The highest abundance of Belostomatidae (16.87), Chironomidae (16.77), Naididae (14.07) and Gomphidae (18.67) were found in the manucipal reach of the river. The highest abundance of Elmidae (20.49) and Notonectidae (19.87) were found in the agricultural reach while the highest abundance of Gerridae (10.53), Hydropsychidae (28.65) and Perlidae (33.92). were found at the forested reach (Table 2). These observation indicate that macroinvertebrates species abundance and diversity changes from one land uses practices to the other.This is perhaps linked to growth of disruption and anthropogenic activities from Town area to forested reach along River Omubira.

Table 3: Show abundance of macroinvertebrates along Omubira Stream in Kakamega County during the study period. The macroinvertebrates were used to study the ability and capacity of the macroinvertebrates species to sense to pollution levels.

Strata	Town area			Agricultural area			Forested area		
Sampling sites/families/species	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Belostomatidae	16.87	7.60	11.98	4.14	4.51	2.93	0.01	1.17	2.81
Hydropsychidae	0.60	0.00	0	1.38	5.74	4.89	0.18	21.64	28.65
Naididae	12.95	13.68	14.07	7.24	2.05	4.89	0.07	5.85	5.62
Gomphidae	18.67	11.25	16.47	5.86	3.28	4.23	0.03	1.17	0.56
Perlidae	0.30	0.00	0.6	0.69	1.23	1.63	0.33	33.92	26.97
Elmidae.	6.02	8.51	6.89	15.52	20.49	18.24	0.04	6.43	3.93
Notonectidae	6.63	8.21	8.98	20	19.26	19.87	0.09	8.19	8.99
Chironomidae	7.53	14.29	16.77	3.79	4.1	5.21	0.01	0	0
Gerridae	9.34	7.60	5.39	24.14	18.44	20.2	0.12	10.53	11.8

Results in Table 3 show the spatial variation in macroinvertebrates abundance in sampling sites along River Omubira during the study.

Plate 1: The Town area of Omubira stream

Plate 2: The Agricultural Area of Omubira stream

Plate 3: The forested area of omubira stream

4. Discussion

Human activities along a stream regime change the composition and colonization of macroinvertebrates in most tropical streams. The deteriorated water quality within the Town area is associated with the higher municipal activities and domestic uses of water. The pollution of this area is squarely linked to the run-off of wastes and domestic wastes due to uncontrolled uses of the water. Apart from the town area activities, the stream also passes through agricultural land which adds up the pollution through agricultural leaching and physical dumping of agricultural residues, all these area suspected to have a strong influence on the macroinvertebrates composition, since each taxa of macroinvertebrates have different survival rates in pollution [18]. There was a general decrease in physicochemical parameters from the municipality to the forested area. However, dissolved oxygen increase from the town area to the forested area. This is suspected to be caused by microorganisms that perform a lot of decomposition and consume a lot of oxygen, among the town area sampling sites (Table 2).

Also during the sampling period, the macroinvertebrate diversity and abundance at the town area, agricultural area and forested area sampling sites appeared to respond to the deterioration in water quality (Table 2 and 3). Low disturbance levels and low pollutant inputs were associated with the forested area's high species diversity and abundance, while reduced species diversity and abundance in agricultural areas typically reflected environmental stress brought on by town runoff and agricultural pollutants. The majority of Tricoptera and Ephemeroptera species are typically considered to be vulnerable to environmental stressors and pollution [9]. Within the forested area, there were several Ephemeroptera species (Table 3). This validated the use of macroinvertebrates in determining water quality because Ephemeroptera and Trichoptera such as *Cheumatopsyche sp.,* are known to be sensitive to contaminants [19]. Naididae, a Tubificida noted for colonizing heavily contaminated stream reaches [20], predominated the town area. In some cases, a high abundance of Naididae has been linked to low oxygen levels and organic decomposition [21]. Therefore, their high concentration in a lotic system is a great sign of pollution. Some Belostomatidae species could therefore serve as a bio-indicators of a river ecosystem that is contaminated. This was in line with what [21] who concluded that the downstream of Semenyih River, is polluted due to the presence of Belostomatidae species. The dominance of Belostomatidae and low oxygen concentrations at the upper stations of the Neches River estuary were indicators of some organic enrichment, according to [22] findings. Therefore, their presence at the Omubira River's town sites indicated the level of pollution in the area. Chironomid taxa designated as sensitive were only discovered at the forested sites. This is in line with study by [19], who observed them in the upstream where water was extremely clean. These findings support our eco toxicological hypothesis that alterations in the distribution of benthic macroinvertebrates in the Omubira stream were caused by anthropogenic activities, which directly alter the water quality. In most cases, anthropogenic sources in rivers come from land-based sources like municipal activities, agricultural activities, factories and settlements. The amount to which human activities have affected the concentration of pollutants at a certain area is crucial information for the local authority since it determines whether or not there is a need to restrict pollutants release, in terms of effluents into the aquatic ecosystem. It is crucial that the regulatory authorities establish and enforce adequate strategies to monitor, regulate and safeguard this segment of the stream.

In summary, macroinvertebrate distribution and assemblages usually undergo predictable changes in response to pollution stress. In some studies this has served as the foundation for the creation of biological criteria to assess the effects of anthropogenic factors [23]. The reactions were categorized by [24] into three groups: decreased diversity, increased dominance by a single and decreased individual size. Data from the Omubira Stream's macroinvertebrates revealed the first two.

5. Conclusion and recommendation

Due to the diverse makeup of the organisms, Omubira stream's water quality can be described as moderately clean. This could be harmful to aquatic life, which depends on highly clean water to exist. Residents who utilize the stream's water for various domestic reasons could be exposed to health risks if it is not properly regulated. This study therefore suggests that the pertinent authorities should constantly check on and manage the sources of pollutants. The report also urges the appropriate authorities in Kenya to embrace biological indicators and related indices as instruments for evaluating the health of rivers and other streams. Additionally, the Omubira stream has to be safeguarded and routinely monitored because to recent increases in nearby towns, trash disposal and population growth.

6. Acknowledgement

We would like to thank our colleague Madam Dorothy from the University of Cape Coast for her comments that greatly improved the manuscript. We also like to express our appreciation to several of the Environmental Science class of 2020 students who helped with data gathering and macroinvertebrate identification. Our sincere thanks go to laboratory technicians at Masinde Muliro University of Science and Technology for their support. Special thanks to my Supervisor Professor Shivoga for assisting me with *in-situ* measurement tools and for his guidance. Biological sciences department for providing the platform to do the research and provision of necessary research tools. And above all, we thank the Almighty God for the good health amidst COVID-19 pandemic.

7. Conflict of interest declaration

The authors declare no conflict of interest regarding the publication of this paper.

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