Impact of Pollution on Aquatic Macroinvertebrate Abundance in the Okulu River Eleme, Rivers State, Nigeria

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DOI: https://dx.doi.org/10.47772/IJRISS.2025.9020286

Received: 06 February 2025; Accepted: 13 February 2025; Published: 19 March 2025

ABSTRACT

The Okulu River which flows from Oyigbo down to Eleme and empties into the mangrove swamp of Okrika in the Southern part of Rivers State is strategic and plays a significant role to the aquatic needs of the people in the state and its environs. However, the information on the quality of the river is scanty hence it became imperative to study the impact of pollution on aquatic macro invertebrate abundance in the Okulu River Eleme, Rivers State. Water and macro invertebrates were sampled at different stations along the river. Macro invertebrates were sampled using a modified Surber-type sampler, while water was sampled for physico-chemical parameters such as Electrical Conductivity (EC), Salinity, Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Dissolved Solid (TDS), Nitrate (NO3), Phosphate (PO4), Sulphate (SO4), Zinc (Zn), Lead (Pb), Cadmium (Cd) and Chromium (Cr). The Water Quality Index (WQI) was determined using Brown's method. The findings revealed that the water quality of the Okulu River was unfit for domestic activities. Mean value of Temperature (27.25), Salinity (59.30), conductivity (769.47), pH (7.11), DO (6.36), COD (32.39), BOD (4.65), Zn (0.097), Pb (0.225), Cd (0.017), NO_3 (0.49), SO_4 (350) and PO_4 (0.055) correlated with abundance of macro invertebrates. Macro invertebrate abundance across the different stations were in the order of S1 (3400)>S2 (2425)>S4 (1850)>S3 (1550). Dominance of macro invertebrates followed the order; Arthropoda (82.11%) > Mollusca (10.29%) > Annelida (7.5%). Specific parameters used for calculating the WQI such as EC, TDS and SO_4 exceeded the WHO acceptable limit. It is therefore recommended that regulatory agencies should continue to enforce environmental standards on industries and other stakeholders whose activities may have an environmental impact on the aquatic ecosystem.

Keywords: Macro invertebrates, Water Quality Index, Pollution, Abundance, Impact, Okulu Rivers

INTRODUCTION

The natural environment is a beautiful place endowed with a lot of nature's resource such as the land, vegetation, water, minerals etc. These endowments have for a long time served as man's means of survival. The earth's system contains four spheres: the geosphere, the hydrosphere, the biosphere and the atmosphere and that these spheres are linked through the biogeochemical cycles that move matter and energy through various parts of the Earth's system (Soltiset al., 2021). The biosphere comprises of surface and underground water and its functions ranged from the regulation of the climate, provision of habitat, human needs, and provision of food and shelter for organisms and as being the most important part of living cells. River ecosystems constitute a tiny fraction (0.0002%) of the world's total water, but surprisingly hold a large fraction of global biodiversity (Hamid et al., 2021). Suffice it to say that the world's major challenge in modern time has been identified as pollution. According to Group of Experts on the Scientific Aspect of Marine Pollution (GESAMP), pollution is defined as, "introduction by man directly or indirectly of any substances or material into an environment which may result to harm to living resources, endangerment to human health, hindrances to marine activities including fishing, impairing of standard for use of seawater and decrease of services" (Purwendahet al., 2020). Ahmed et al. (2015) reiterated that, "Water pollution is the defilement of water bodies (e.g. ponds, lakes, streams, rivers, oceans and groundwater), and this occurs when pollutant are introduced into aquatic media without sufficient treatment to remove dangerous compounds". Aquatic fauna are organisms that inhabits the aquatic environment be it macro vertebrates or invertebrates. This habitation is made possible as a result of the quality of the aquatic ecosystem. Studies have shown that an aquatic ecosystem with a good water quality index (WQI) is ideal for propagating the abundance and diversity of aquatic community. As a result, Hamid et al. (2021) stated that, "knowing the spatio-temporal patterns of benthic macro invertebrate populations will assist us understand their ecological process, as well as bioassessment and management". Most researchers seem to share the view that water bodies flowing through densely populated area may be at risk of being contaminated or polluted (Bashar et al., 2020; Yin et al., 2021). Hence, exposing aquatic ecosystem to organic and inorganic pollution load from adjacent industrial, municipal and agricultural activities as well as disturbance created by the activities of miners may have a negative effect on the aquatic system by reducing the water quality, which subsequently affects the assemblages of aquatic fauna thereon. The Okulu River may not be an exception to this phenomenon as it is faced with the release of chemicals and untreated wastewater discharged from the activities of Indorama Fertilizer Plant, stomach and intestinal contents discharged from slaughtered animals, ashes of burnt animals and wood used in the abattoir, indiscriminate discharge of residential and municipal waste. The Okulu River is also suspected to be influenced by the activities of mining sharp sand which creates disturbance on the river bed distorting and displacing the habitat of aquatic organisms. Inyinboet al. (2018) noted that, "the stress on our aquatic environment is as a result of increased industrialization, which puts pressure on the demand for the use of water hence, reducing the availability of clean water".. It is on this note that the research seek to investigate the impact of aquatic macro invertebrate abundance in the Okulu River Eleme River State.

MATERIALS AND METHODS

Study Area and Study Sites

The Okulu River in Eleme Local Government Area is located in one of the major environmental zones in Rivers State namely, the transition zone. It flows from the freshwater river of the Imo River section of Oyigbo and empties into the saltwater of the Bonny river section at Aleto. It is around the boundary area between Aleto and Akpajo, at the geographical coordinates of 4º48' to 4º51'N latitude and 7º40' to 7º7'E. The rainfall pattern in the study area exhibits a double maxima regime with peaks in July- August (Oyegunet al., 2010). The mean annual temperature in the study area is usually high and little spatial variation occurs with February being observed as the hottest month while July and August, being the coldest months. The study area is characterised by the presence of industrial and mining activities with little or no farming or grazing in the area. Sand mining activity is predominant in the area with virtually mining occurring at three out of the four selected stations. The downstream site is located well within the sand mining and industrial zone with high level of deterioration and abandoned mines. The midstream is located within the non-mining zone with the presence of slaughterhouse activities but with the absence of vegetation cover in the area. This area is characterised by the presence of anthropogenic activity. The upstream is characterised by the presence of mining activities with visible presence of light vegetation cover. A total of four sampling sites were selected along the Okulu River (one from the downstream mining and industrial zone named, The Aleto mining site 1; two sites from the midstream named, Aleto mining site 2 and Aleto slaughterhouse 3 while the fourth is the upstream named, Akpajo mining site 4). These sites were chosen to study the impact of pollution on the water quality and macro invertebrate assemblage in 2020. The sampling sites were carefully chosen to accommodate the various activities along the river and the various habitats present during sampling.

Sample Collection

Surface water was sampled in four stations along the river between the months of July to December, 2020. Water samples were collected using pre-washed plastic containers with lid. Prior to sampling, the plastic containers were washed thoroughly with clean water and then rinsed at the field with the surface water to be sampled. Triplicate water samples were collected from each station and pulled together to form a composite sample. Water samples were collected by lowering the plastic container down the water column at a depth of 25-30cm. The container was allowed to fill to the brim and thereafter corked underwater to prevent air bubbles. Thirteen water physico-chemical parameters were evaluated. Upon collection, surface water

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue II February 2025

temperature was determined using a GOODTECH digital thermometer. pH, Electrical conductivity and total dissolved solid were measured In-Situ using a portable digital pH/EC/TDS meter. Upon collection, the water samples were then transported to the Biochemistry Laboratory of the University of Port Harcourt for further analysis within 24hours after collection. At the laboratory, dissolved oxygen, total alkalinity was determined using the Winkler method. Separate water sample was preserved and incubated in the dark at 20^0C for 5 days after which biological oxygen demand (BODs) was analysed. Nitrate-nitrogen and phosphate-phosphorus were also measured based on APHA (1985). The heavy metals of Lead, Zinc, Cadmium and Chromium were digested and examined with Atomic Absorption Spectrophotometer (AAS) for heavy metals concentration. Note, these procedures were repeated for all the samples. Techniques for sampling aquatic macro invertebrates were based on that used in the work of Elliot (1971). A modified 30cm D-shape frame, 64 mesh/cm^2 net which allowed the sampling of smaller invertebrates was used at each sampling station to collect aquatic macro invertebrates. A 100metres stretch of the Okulu River, featuring pond, pool and riffle habitat was chosen. Sweeping, using the hand net was done at 10 metres of each habitat, along a 100metres stretch of the river. Macro invertebrates were captured in a 10 metres sweep by taking 3 sweeps per metre, thereby having a total of 30 sweeps per habitat. The sampler was placed beneath the shallow water surface while the bed of the river was disturbed by kicking and allowing the current to carry the dislodged materials into the net. The net was allowed to touch the bottom of the water during sweeping. By slowly moving the net upstream for a period of two minutes, this technique ensured collecting a representative quantity of materials over a large bottom area. Samples collected were rinsed in the water and washed from the net into a collecting tray and transferred into a net bag. These techniques were repeated for the other sampling stations. Collected samples were transported to the laboratory. At the laboratory, samples were washed individually with tap water in an Endecott sieve (140 mesh/cm^2) and then transferred to a larger sorting tray. Aquatic fauna were picked out from 1-5 of the division according to the amount of materials present and placed in a petri dish for counting and identification.

Table 1: Geographical location and land use/land cover features of the four sampling sites along the Okulu River

Location/Land use features	Aleto Sand Field 1	Aleto Bridge	Aleto Sand Field 2	Aleto-Akpajo Waterside
Code	S1	S2	S3	S4
Latitude	4.807045	4.807336	4.807837	4.815876
Longitude	7.097216	7.100798	7.104512	7.086069
Vegetation	Wasteland	Crop plants	Grasses	Sparse vegetation
Land use	Sand mining	Sand mining/poultry	Slaughterhouse, vehicular movement	Sand mining

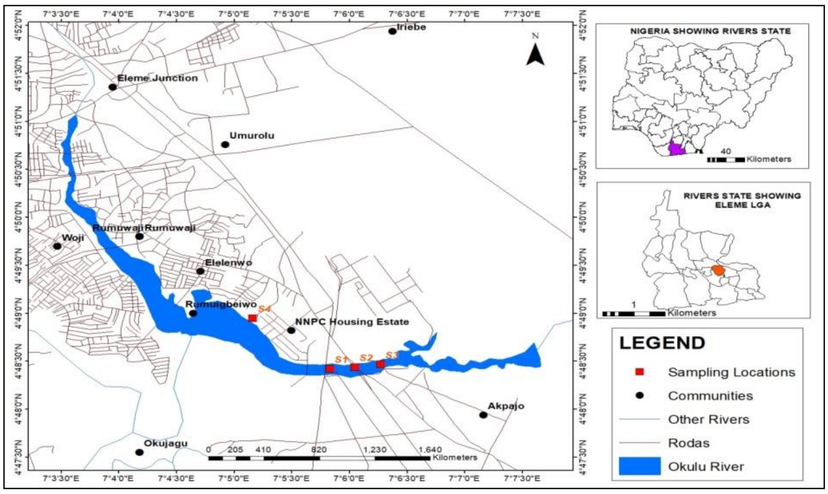

Figure 1: Okulu River showing the various sampling stations

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue II February 2025

Data Analysis

In this study, descriptive statistics was used in analysing the data. Descriptively, tables and chart were used to present and analyse data. This is because table are fairly easy to use consisting of a few columns and rows. Mean, percentage and total abundance of macro invertebrates across stations were presented using tables. Mean concentration of physical and chemical properties of the Okulu River sampled at different stations were presented in tables. Tables were also used to present the calculated water index values of the different stations, phylum, class and family to which each macro invertebrates belong. Chart on the hand was used to compare the physico-chemical parameters of the Okulu River to that of World Health Organisation (WHO) standard. Charts were also used to evaluate the variation in abundance of macro invertebrate across stations. The formula of Brown et al. (1972) was used to determine the water quality of the Okulu River, using the Weighted Arithmetic Index (WAI) method given as follows:

$$WQI = \frac{\sum QnWn}{\sum Wn}$$

Where, Qn = Quality Rating; Wn = Unit Weight

$$Qn = 100\frac{(Vn - Vio)}{(Sn - Vio)}$$

Where, Vn = Estimated values for nth water quality parameters of

Collected samples; Sn = Standard permissible value of the nth water quality parameters;

Vio = Ideal value of the nth water quality parameter in pure water (it is 0 for other parameters except pH, which is 7 and DO which is 14.6). The unit weight (Wn) was obtained by calculating a value inversely proportional to the recommended standard value (Sn) of the corresponding parameter (i.eWn = 1/Sn). All statistical analysis was performed using the Excel Spread sheet (V. 16).

RESULTS AND DISCUSSION

Water Quality

From the study, physico-chemical parameters of the Okulu River such as, temperature, pH, EC, TDS, DO, COD, BOD, Pb, Zn, Cd, Cr, NO_3, SO_4 and PO_4 were evaluated and used to calculate the index value of each station along the Okulu River thereafter compared with the WQI given by Brown et al. (1972). From Table 2, the index value at S1 (230.82) exceed the WQI range given by Brown et al. (1972). This implies that the water quality status of the Okulu River at S1 is unfit for consumption however, could be used for other activities like irrigation or recreational activities. At S2, it is also clear that the index value followed a similar pattern as in S1. A calculated index value of (189.97) at S2 exceeds the WQI given by Brown et al. (1972). This implies that the water quality for S2 is unfit for consumption but may be used for other activities like irrigation and recreational activities. At S3, a calculated index value of 241.49 was recorded which is > than those given by Brown et al. (1972). Hence, the water status of the Okulu River at S3 is said to be unfit for consumption however, may be used for other activities like irrigation and recreation. At S4, a calculated index value of 234.87 was recorded which is > than the WQI given by Brown et al. (1972). Hence, the water status of the Okulu River at S4 is said to be unfit for consumption, but may be used for other activities such as irrigation and recreation. The results also showed that overall quality of the Okulu River is said to be polluted since the calculated index values from all stations along the river exceed the water quality index range. From Table 3, with the physico-chemical parameters of Salinity, Conductivity, TDS, and Cadmium increasing above limit and DO and BOD decreasing below limit, suggest that the River is organically polluted. Belmer, et al. (2014) also noted that wastewater discharge increases salinity, metals, pH, and water temperature. It is therefore noted that the poor water quality, physical and chemical conditions of the River like decreasing value of DO indicates the presence of organic pollution caused by wastewater discharged into the river from the Indorama Fertilizer Plant, Slaughterhouse effluent, farm waste and urban run-off.

Table 2: Calculated index values of water samples from the Okulu River

Sampling Stations	Calculated Index Value	Water Quality Index	Water Quality Status
S3	241.49	0 – 25	Excellent
S4	234.87	26 – 50	Good
S2	189.97	51 – 75	Poor
S1	230.82	76 – 100	Very Poor
		>100	Unfit for Consumption

Keywords: S = Stations

Table 3: Physico-chemical characteristics of water samples from the Okulu River

	Mean value at various stations				
Parameters	S1	S2	S3	S4	WHO STD
Temp. (^oC)	27.0	27.2	27.4	27.4	20–30
pH	7.11	7.24	7.06	7.07	6.5–8.5
EC (µs/cm)	685.8	883.9	734.6	749.6	100
TDS (mg/L)	342.25	445.55	365.22	368.50	250
Salinity	54.09	50.68	66.13	66.31	80
DO (mg/L)	7.06	6.11	6.25	6.05	>4
BOD (mg/L)	7.69	1.64	4.65	4.62	10
COD (mg/L)	28.81	34.00	32.75	34.00	40
NO_3 (mg/L)	0.43	0.62	0.44	0.47	10
SO_4 (mg/L)	375.58	420.55	302.44	303.01	250
PO_4 (mg/L)	0.01	0.05	0.08	0.08	5.0
Pb (ppm)	0.15	0.24	0.25	0.26	0.5
Zn (ppm)	0.05	0.18	0.02	0.14	5.0
Cd (ppm)	0.02	0.02	0.01	0.02	0.01
Cr (ppm)	ND	ND	ND	ND	

Keywords: ND = not detected, WHO STD = World Health OrganisationStandard

Variation in the Abundance of Aquatic Lives

The variation in the mean abundance of aquatic lives among the different stations can be seen in Fig. 2. The result showed that False Spider Crabs, Hermit Crabs, Shrimps, Snails and Worms were the macro invertebrates caught at the Okulu River. A total of 9225 macro invertebrates were caught from the river. The variation on abundance of individual species of macro invertebrates sampled followed the order, Shrimp (4525) >Hermit Crab (1800)>False Spider Crab (1250)> Snail (950) > Worm (700) as shown in table 4. Macro invertebrate abundance across the different stations were in the order of S1 (3400)>S2 (2425)>S4 (1850)>S3 (1550) as shown in figure 2. From Figure 1, the high density of macro invertebrates at station S1 could be attributed to the proximity of the station to the wastewater discharge from the Fertilizer Plant. Also, the increasing level of TDS and SO_4 could also be a contributing factor. This is followed by S2 which is the sand mining/poultry zone exhibiting a similar feature to S1. The Decreasing abundance of macro invertebrates at S4 which is can be attributed to the absence of habitats, high current, sparse vegetation and canopy cover. The low abundance of macro invertebrate recorded at S3 can be attributed to the high flow rate experienced and insufficient habitat around that zone. This is the zone around the slaughterhouse and close to the bridge. Also, three phyla were recorded from the entire macro invertebrate sampled with Arthropoda(82.11%) being the dominant phyla which is followed by Mollusca(10.29%) and Annelida(7.5%) as shown in table 4. The presence of Arthropoda, Mollusca and Annelida suggest that these are the pollution-tolerant species with low species diversity found in the Okulu River and that other species may have either died from the polluted water or migrated to a safer zone. These findings are in agreement with that of Vinson et al. (2008); Arimoroet al. (2007); Cincotta, et al. (1976). (Suleiman, et al., 2011) pointed out that the presence or absence of macro invertebrates in any freshwater ecosystem is a function of habitat quality and regional taxonomic pool.

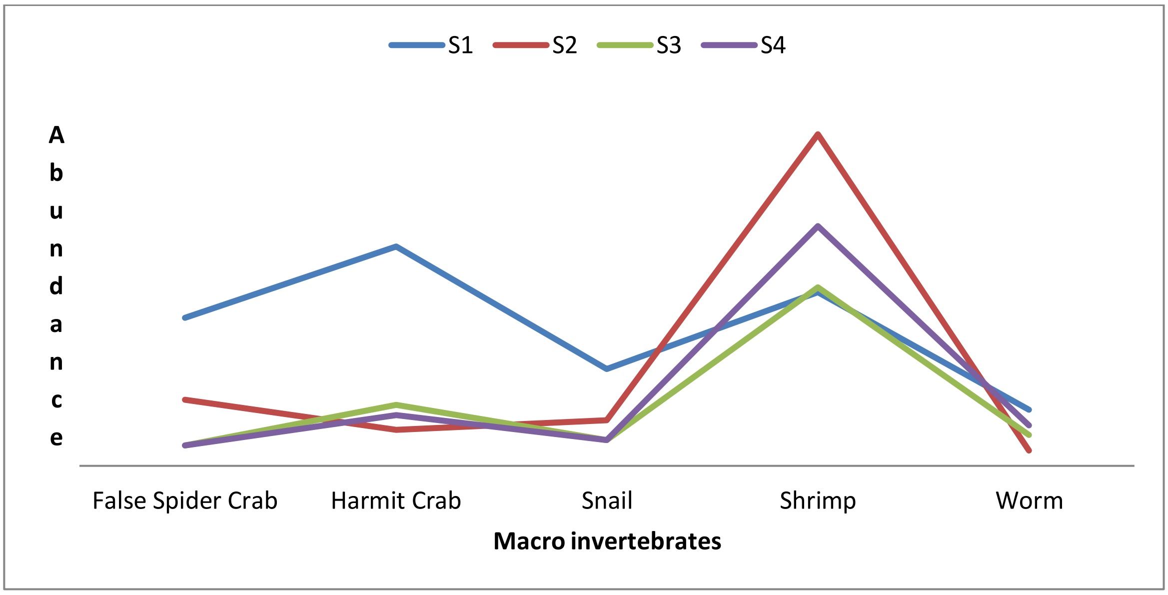

Figure 2: Variation in macro invertebrate abundance across the stations

Keyword: S = Stations

Table 4: Phylum, class and family of macro invertebrates

Macro invertebrates	Phylum	Class	Family	Total
Shrimp	Arthropoda	Malacostraca	Atyidae	4525(49%)
Harmit crab	Arthropoda	Malacostraca	Paguridae	1800(19.5%)
False Spider crab	Arthropoda	Malacostraca	Hymenosomatidae	1250(13.5%)
Snail	Mollusca	Gastropoda	Hydrobidae	950(10.2%)
Worm	Annelida	Oligochaeta	Lumbriculidae	700(7.5%)

Comparison of the physico-chemical characteristics of the Okulu River with WHO STD.

Figure 3 compared the physico-chemical parameters of the Okulu River to that of WHO. Figure 3 clearly shows that temperature values at S1 (27.0ºC), S2 (27.2ºC), S3 (27.4ºC) and S4 (27.4ºC) were recorded across all stations. These indicate that the surface water temperature is within limit for WHO and thus has no effect on the water status of the river. pH values of S1(7.11), S2(7.24), S3(7.06), S4(7.07) were recorded for the corresponding stations along the river. This implies that the pH of the river across stations were all within limit set by WHO (6.5-8.5) thus, did not impact on the status of the river. With EC, BOD, COD, NO_3, PO_4, Zn and

Salinity decreasing below WHO standard, while TDS and SO4 increasing above WHO standard across stations suggest an area of intense organic pollution. The result above further correlate with the low abundance of macro invertebrate recorded at the Okulu River across all sampled stations. Suleiman et al. (2011) pointed out that the presence or absence of macro invertebrates in any freshwater ecosystem is a function of physico-chemical parameters. Hence, the aquatic ecosystem is essential for both flora and fauna organisms as both depend on it for survival. Preservation of the aquatic ecosystem cannot be overemphasized. Observation along the Okulu River by local fishermen and miners reveal a sharp decline on the number of organisms like fishes, prawn and crabs that they usually catch these days. A direct relationship seem to exist between the activities of the miners, the wastewater discharged from the Indorama plant, municipal waste discharge and the slaughterhouse effluent discharged into the Okulu River. The present research is not oblivious of the fact that ecological data on water parameters and aquatic fauna have been studied from various surface waters in Rivers State; however, information on the impact of pollution on the abundance of macro invertebrate seems insufficient and scarce

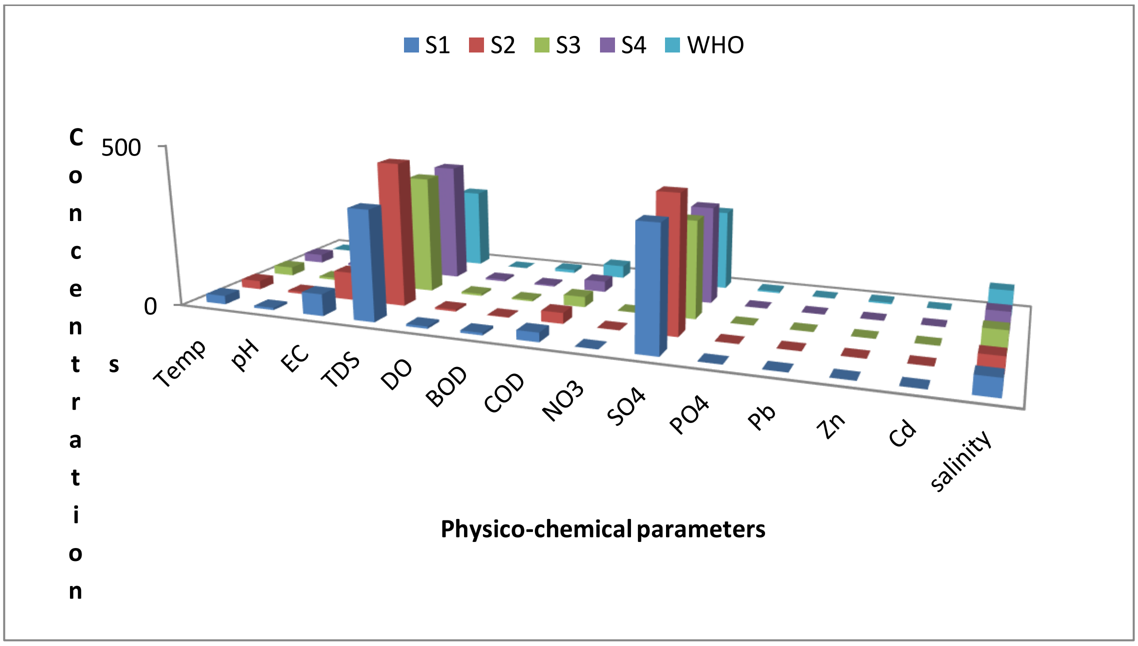

Figure 3: Comparison of physico-chemical parameters of the Okulu River to WHO standard

Keywords: S = Stations, WHO = World Health Organisation

CONCLUSION

Based on the findings from the study, the Okulu River is said to be organically polluted and unfit for consumption. The variation on abundance of individual species of macro invertebrates sampled followed the order, Shrimp (4525) >Hermit Crab (1800)>False Spider Crab (1250)> Snail (950) > Worm (700) while, macro invertebrate abundance across the different stations were in the order of S1 (3400)>S2 (2425)>S4 (1850)>S3 (1550). The decreasing values of EC, BOD, COD, NO_3, PO_4, Zn, and Salinity below WHO standard, and an increase in TDS and SO4 above WHO standard across stations suggest an area of intense organic pollution. Therefore, it is suspected that the mining of sharp sand is suspected to have impacted on the water quality as well as the assemblage of aquatic fauna in the study area.

COMPETING INTEREST

The authors declare that they have no competing interests.

ACKNOWLEDGEMENT

Sincere gratitude goes to the laboratory technician for his assistance throughout the period of this research.

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