Annals of Animal and Biological Research, 2023; 3(1)

Original Article

Macrobenthos diversity and the physico-chemical parameters of Ogbese River, Ondo State, Southwest Nigeria

K. E. Olatunji and D. O. Odedeyi

Department of Animal and Environmental Biology, Adekunle Ajasin University, Akungba- Akoko, Nigeria

Article Information
Keywords
Freshwater, Water quality, Macrobenthos, Diversity

Correpsonding author
K.E. Olatunji
kehinde.olatunji@aaua.edu.ng

Article History
Received: December 22, 2023
Accepted: December 27, 2023
Published: December 31, 2023

Article can be accessed at
www.aabrjournalaaua.org.ng

Abstract
An investigation into the macrobenthos and physico-chemical parameters of Ogbese, River, Ondo State South West, Nigeria were investigated between February, 2022 and January, 2023. The research was to assess the health of the water body using macrobenthos as bio-indicator. Macrobenthos in the sediment were collected with the use of Van-veen grab and were identified with the help of standard identification key. Diversity of macrobenthos was estimated using Shannon-Wiener Diversity Index (H). Physico-chemical parameters were determined *in-situ* using probe meter. A total of 486 macrobenthos members belonging to one Phylum (Mollusca), two classes (Gastropoda and Bivalvia) and nine species were recorded throughout the study period. *Lymnaea stagnalis* had the highest relative abundance (61.73%) while *Pisidium pseudophaerium* and *Valvata piscinalis* had the least RA (0.41%). Highest (17.08%) relative abundance was observed in June and the least (2.91%) observed in December. The Shannon-Wiener's diversity index indicated 1.29 and the Evenness (E) was 0.59. The results of the physico-chemical parameters were within the acceptable range except Dissolved oxygen which was lower than the acceptable limit for aquatic organism. The low diversity and abundance recorded were indicators of a poor water quality in Ogbese River. Therefore, there should be proper measures in managing various discharges that constitute pollutants in the water body.

INTRODUCTION

Benthic macro fauna are those organisms that live on or inside the deposit at the bottom of a water body (Idowu and Ugwumba, 2005). They live in the mud, sand, gravel, stone or organic waste of the water bodies and therefore, stick to the bottom of the water, hence, unable to escape from environmental disturbance. In the brackish water ecosystem, they include several species of organisms, which cut across different phyla including annelids, coelenterates, molluscs, arthropods and chordates. These organisms play a vital role in the circulation and recirculation of nutrients in aquatic ecosystems. Macrobenthic invertebrates are useful bio-indicators providing a more accurate understanding of changing aquatic conditions than chemical and microbiological data, which at least give short-term fluctuations (Ikomi *et al.,* 2005).

How to cite this article:
K. E. Olatunji and D. O. Odedeyi (2023). Macrobenthos diversity and the physico-chemical parameters of Ogbese River, Ondo State, Southwest Nigeria. *Annals of Anim. Bio. Res.,* 3(1): 59-66

The occurrence and distribution of macro-invertebrates are governed mostly by the physical and chemical quality of water and the immediate substrate of occupation (Dance and Hynes, 1980). Macro-invertebrates play an important role in aquatic community which includes mineralization, mixing of sediment, and flux of oxygen into sediment. Macrobenthic invertebrate species exhibit a wide variation of response to disturbances and have been extensively monitored in water bodies to evaluate water quality and complement physico-chemical surveys (Uwadiae *et al*., 2014). The most popular biological method in the assessment of freshwater bodies is the use of benthic macro-invertebrates (Odiete, 1999). In the same vein, their composition, abundance and distribution can be influenced by water quality.

Monitoring of water quality is the first step that can lead to management and conservation of aquatic ecosystem (Agali and Edema, 2016). The seasonal variation in physico-chemical factors have a profound effect on the distribution and population density of both fauna and flora in any aquatic ecosystem (Rafique *et al.,* 2002). Rapid deterioration in water quality is due to increasing population pressure, rapid urbanization and industrialization, and inadequate sanitation facilities, with water resources being contaminated by a variety of hazardous chemicals and virulent pathogens (Ogedengbe and Akinbile, 2004). The objective of the study was to determine the health of Ogbese River using macrobenthos abundance and physico-chemical parameters as indicators of water pollution.

MATERIALS AND METHODS

Ogbese River is located in Ayede, along the Akure-Benin expressway in Ondo State. The area lies within latitude E6°SE8° and longitude N4°N6°E. The river has its source from Ayede-Ekiti in Ekiti State and flows through Ogbese in Ondo State to Edo State. The Ogbese community is about 10 km east of Akure, the Ondo State capital (Figure 1). The river is surrounded by farmlands and it is a major discharge points for industries. Other major anthropogenic activities in the catchment area are automobile workshops, car wash and laundry. The physico-chemical parameters that were examined include: Dissolved oxygen (DO), Salinity, Total dissolved solids (TDS), Conductivity and Temperature which were measured monthly using Hanna-HI928 multi-parameter water analysis meter (made in Romania).

Macro-benthic invertebrates sample collections were conducted monthly over a period of 12 months (February, 2022 to January, 2023). Sampling was done at three stations (upper, middle and the downstream). At each sampling station, three replicates samples of benthic macro-invertebrates were collected using 0.1m^2 Van Veen Grab. The sediment samples were washed through sieve of 1mm by 1mm mesh size. The retained macrobenthos were poured into white tray and sorted using forceps, identified using identification key by Gill (2011), and counted. The residues in the sieve were preserved in 10% formalin solution and kept in the labeled plastic containers for further laboratory analysis following the procedure of Uwadiae *et al.* (2014). The Shannon-Wiener diversity index (H) which estimates both species richness and evenness of individual among the species was employed.

Shannon-Wiener Diversity Index (H) = -Σ *iP* Log *iP* (Shannon and Wiener, 1963)
Where;
i P = S (the number of individuals in species) / N (the number of total individuals in a sample)
Evenness (E)= Evenness =H/H_{max}
H_{max} = Maximum diversity possible

Physico-chemical parameters of the river were subjected to one-way analysis of variance (ANOVA) test and the means were compared for significant differences (P>0.05) using SPSS (statistical package for social scientists) software version 20.

RESULTS

Table 1 shows the macrobenthos composition of Ogbese River between the month of February 2022 and January 2023. A total of 486 macrobenthos members

Table 1: Macrobenthos composition of Ogbese River between the month of February 2022 and January 2023

Species name	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Total	(Relative Abundance)
Lymnaea stagnalis	28	48	-	41	57	21	24	16	14	18	-	33	300	61.73
Pila ampullacea	-	-	2	-	3	-	6	3	-	-	3	2	19	3.91
Pisidium pseudophaerium	-	-	-	-	-	-	-	-	-	2	-	-	2	0.41
Mytilus edulis	6	10	4	3	12	-	1	4	13	4	4	6	67	13.79
Margaritifera margaritifera	4	7	6	7	-	6	-	-	6	-	6	-	42	8.64
Anadonta anatine	-	-	-	-	3	-	-	-	2	-	-	-	5	1.03
Physa carolinae	6	-	-	-	8	7	3	2	3	-	4	3	36	7.41
Tylomelania palicolarium	-	-	6	-	-	4	-	-	-	-	-	3	13	2.67
Valvata piscinalis	-	-	-	-	-	-	-	-	-	-	2	-	2	0.41
Monthly total	44	65	18	51	83	38	35	25	38	24	19	47	486	
Monthly RA	**9.05**	**13.37**	**3.73**	**10.49**	**17.08**	**7.82**	**6.70**	**5.14**	**7.82**	**4.94**	**2.91**	**9.67**		

Table 2. Taxonomy of Macrobenthos in the Ogbese river

Phylum	Family	Class	Species
Mollusca	Lymnaeoidae	Gastropoda	*Lymnaea stagnalis*
Mollusca	Mytilidae	Bivalvia	*Mytilus edulis*
Mollusca	Margatitiferidae	Bivalvia	*Margaritifera margaritifera*
Mollusca	Ampullaridae	Gastropoda	*Pila ampullacea*
Mollusca	Valvatidae	Gastopoda	*Valvata piscinalis*
Mollusca	Unioidae	Bivalvia	*Anodonta anatine*
Mollusca	Physidae	Gastropoda	*Physa carolinae*
Mollusca	Sphaeriidae	Bivalvia	*Pisidium pseudosphaerium*
Mollusca	Pachychilidae	Gastropoda	*Tylomelania palicolarium*

Table 3. Water quality parameters of Ogbese River between February, 2022 and January, 2023

rameters	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Sig.
I	6.50±0.20	6.00±0.00	6.50±0.29	6.50±0.00	6.00±0.00	6.50±0.00	6.50±0.20	6.50±0.00	6.00±0.00	6.50±0.00	6.50±0.0	6.50±0.20	0.323
emperature (°C)	29.47±0.37	28.93±0.54	27.40±0.06	26.10±0.06	27.97±0.88	28.57±0.72	29.20±0.12	30.10±0.17	27.00±0.06	27.40±0.24	26.70±0.17	27.60±0.12	0.000
nductivity(uS/cm)	139.00±1..73	204.00±2.31	209.00±0.58	218.00±0.58	241.00±0.58	154.00±2.31	177.00±2.89	201.00±0.58	218.00±0.58	216.00±0.58	194.00±0.58	128.00±0.58	0.000
ssolved Oxygen(mg/l)	2.99.00±0.01	2.88.00±0.01	3.41±0.01	3.30±0.00	2.04±0.01	2.63±0.02	2.62±0.01	3.22±0.01	3.41±0.01	2.86±0.01	2.91±0.01	3.07±0.05	0.000
linity (ppt)	0.06±0.01	0.06±0.01	0.07±0.00	0.06±0.01	0.06±0.00	0.06±0.01	0.06±0.01	0.06±0.00	0.06±0.01	0.06±0.01	0.07±0.00	0.06±0.01	0.742
otal Dissolved lid(ppm)	87.00±4.04	103.00±1.73	99.00±0.58	114.00±1.15	116.00±1.15	106.33±9.53	104.00±2.31	94.00±0.00	100.00±1.15	96.00±0.58	82.00±1.15	94.00±2.31	0.000

belonging to one Phylum –Mollusca (Table 2) represented by two classes: Gastropoda and Bivalvia having nine species were recorded throughout the study period. *Lymnaea stagnalis* had the highest relative abundance (RA) of 61.73% while *Pisidium pseudophaerium* and *Valvata piscinalis* had the least RA with 0.41%. Highest RA of macrobenthos (17.08%) was observed in June while the least (2.91%) was observed in December. The Shannon-Wiener's diversity index indicated 1.29 and the Evenness (E) was 0.59.

Table 3 shows the water quality parameters obtained from Ogbese river between February, 2022 and January, 2023. The water pH and salinity showed no significant differences across the months ($p>0.05$) while there were significant differences ($p<0.05$) in the values of the water Temperature, Conductivity, Dissolved oxygen and Total Dissolved Solids.

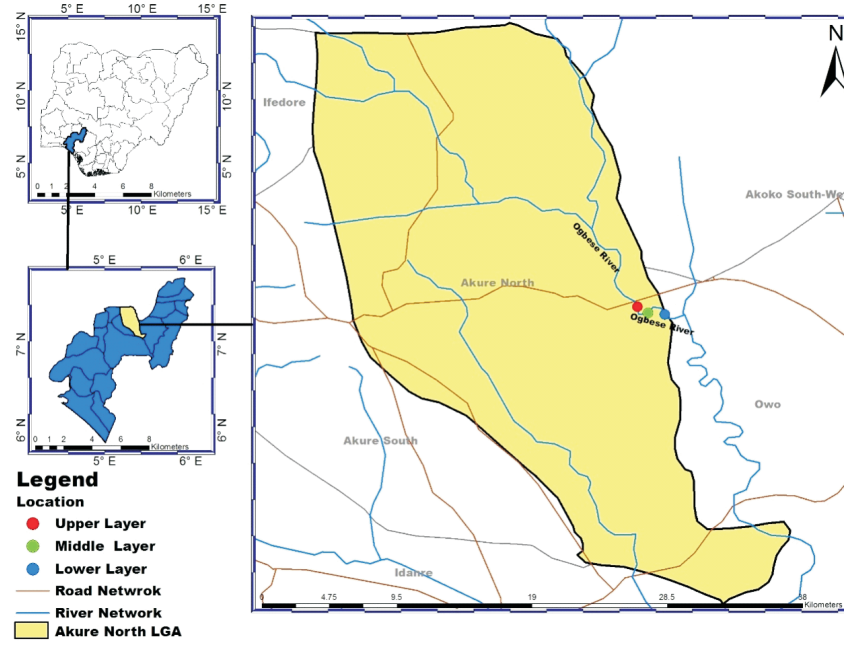

Figure 1: Map of Ogbese River showing sampling points

DISCUSSION

The abundance and diversity of macrobenthos recorded in Ogbese river were relatively low. This could be that the bottom sediment is polluted and did not support a high diversity of macrobenthos. Macrobenthic distribution could be affected by the availability of food, shelter and also physical and chemical

parameters of the water body. From this study, the gastropod, *Lymneae stagnalis* was highly abundant followed by *Mytilus edulis* which is a Bivalvia. This showed that these species were pollution tolerant and could proliferates in unfavorable environment. The dominance of gastropods and bivalve in Ogbese river could be attributed to their high level of pollution tolerance. Gastropod and Bivalvia are also the most dominant classes found in the estuary of Donan River (Hakiki *et al.* 2017) and Lamnyong River (Octavina *et al*. 2019). A species from the Gastropods class also dominated Bulaksetra Estuary (Krisnafi *et al.,* 2021).

Gastropods are one of the most common groups of molluscs found in various substrates due to their high malleability compared to other classes on rigid and smooth substrates (Baharuddin *et al.,* 2018). Wildan *et al.* (2021) reported that Gastropod becomes the most abundant taxa in Batang Toru River because of its wide adaptability and tolerance to environmental conditions. In contrast, Hart (1994) reported the predominance of crustaceans, polychaetes, and gastropods, while Nwadiaro (1987) recorded a dominance of crustaceans and insects followed by molluscs and annelids in a lower Niger Delta river (River Sombriero). On the other hand, the absence of Ephemeropterans, Placopterans and Tricopterans across the rivers indicated a deteriorated environment, since these organisms thrive mostly in clean waters and are sensitive to pollution (Emere and Nasiru 2007). Also, the low level of Dissolved Oxygen recorded throughout the study period could also be the reason for low diversity of macrobenthos.

Diversity has been considered as a measure of community stability. A low diversity is an indication of stress in the environment while high diversity is a reflection of a stress-free environment (Olomukoro, 1996). Low value of Shannon-Wiener index (1.29) of macrobenthos reported in this study is similar to the report of Aghogho (2015) who reported low diversity indices in Lagos lagoon (Shannon – Wiener index of diversity (H) ranged from 0.38 to 0.80). The relative abundance of gastropods and bivalves in Ogbese river shows how tolerant they are to physical and chemical variations in the environment. They are usually found in a wide range of habitats that favours their growth and distribution. Ajao and Fagade (2002) documented the gastropods as the most dominant benthic fauna in the Lagos lagoon.

The overall composition and diversity of Macrobenthos recorded was relatively low when compared to other less disturbed waterbodies in the tropics (Edema *et al.,* 2002; Adakole and Anunne, 2003; Ikomi *et al.,* 2005). This could be as a result of poor environmental condition like water quality, substrate instability, salinity fluctuations etc. Odum (1971) reported that species diversity tends to be low in physically disturbed ecosystem. It is only the opportunistic species that proliferates in such environment.

The physico-chemical parameters in this study were within the range of tolerance for the survival of aquatic organism expect the Dissolved oxygen values which were low throughout the study period. The pH values ranged between 6.0 and 7.00 which were within the normal range for fresh water body and certain organisms may even survive in more acidic water (Effendi, 2003). However, in acidic water the release

of heavy metals from waste into water is high (Li *et al.,* 2013) which may have detrimental effect on macrobenthos. The values of temperature were 26.0 - 30.8 °C, while the optimum temperature range for aquatic organisms according to Effendi (2003) is 20-30 °C. Some organisms may tolerate higher temperature, i.e., (30-35) °C (Bhatnagar and Devi, 2013), but at these higher temperature 30-35 °C the release of heavy metals from waste into water is high (Li *et al*., 2013). These results compared favourably with study of the Upper Nun River around Polakuaxis by Kwen *et al.* (2012) who found temperature range of 25.5°C to 30.5°C. These values also agreed with results from other fresh water rivers and creeks in the Niger Delta region. For example, Seiyaboh *et al.* (2017), reported the temperature range of 26.60C to 32.0 °C for Igbedi Creek. Seiyaboh *et al.* (2016) recorded a temperature range of 24 to 28 °C in Epie Creek Stream Bayelsa State.

The dissolved oxygen in the study sites ranged between 1.34 and 3.91 mg/l, while the optimum DO for fish and other aquatic organisms is >5 mg/l (Bhatnagar and Devi, 2013). The range of DO in this study was lower than the value reported by Kwen *et al.* (2012) which was 6.0 to 10.0mg/l in the Upper Nun River, Niger Delta. Ogamba *et al*. (2015) recorded DO values of 3.6 to 7.79mg/l in the Nun River around Amassoma axis. Seiyaboh *et al.* (2017) reported a range of 4.4 to 7.9mg/l in Sagbama Creek, Niger Delta. Adeleke and Babalola (2014) reported a range of 1.18 to 2.95 mg/l. Idodo-Umeh (2002) recorded higher values of 6.73 to 34.0 mg/l in River Areba at Olomoro, Isoko South, Delta State, Nigeria and attributed it to high DO caused by environmental factors. The DO values recorded across the twelve months for this study were lower than acceptable limit. This could be attributed to the cumulative impact of human activities on the river. Murphy (2007) implicated industrial sewage as one of the sources of organic wastes into water bodies. These organic materials are subsequently degraded by bacteria and using up oxygen in the process (Mahre *et al.,* 2007).

High concentrations of total dissolved solids (TDS) may reduce water clarity, which contributes to a decrease in photosynthesis and lead to an increase in water temperature. When water temperature is increased, DO is lowered which can negatively affect aquatic organisms. Changes in the amount of dissolved solids can be harmful to the macrobenthos because the density of TDS determines the flow of water in and out of an organism's cell. In this study, the TDS ranged from 51 - 192 ppm in the river which is far below the recommended value.

Low conductivity (0 to 200 µS/cm) is an indicator of background conditions. Mid-range conductivity (200 to 1000 µS/cm) is the normal background for most major rivers. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or bugs. High conductivity (1000 to 10,000 µS/cm) is an indicator of saline conditions. Waters that have been heavily impacted by industry can fall into this range (Wetzel, 1983). The value of conductivity in this study (139.0-241.0 µS/cm) was within the normal range recommended by Wetzel (1983) as conductivity is ruled out from the factors that may affect species abundance in this study.

CONCLUSION

The macrobenthic invertebrates encountered in Ogbese River mainly

belongs to the class gastropod and bivalvia. These species have been used as indicators of organic pollution in the water body and they are pollution tolerant species. These observations confirmed Ogbese River to be polluted and this calls for a sustainable approach in handling the anthropogenic activities around the river.

Conflict of interest: The authors declare no conflicts of interest.

REFERENCES

Adakole, J.A and Anunne, P.A. (2003). Benthic macroinvertebrates as indicators of environmental quality of an urban stream in Zaria, Northern Nigeria. *Journal of Aquatic Science,* 18: 85-92.

Adeleke, T.A. and Babalola, A.F. (2014). Estimate of primary production in Ologe Lagoon, Lagos. In S.G Solomon (Ed.). Proceedings of the 29th Annual Conference of the Fisheries Society of Nigeria, Makurdi, Benue State. pp. 266 – 271.

Agali, G. and Edema, C.U. (2016). Physico-chemical characteristics, diversity and relative abundance of fishes of Obueyinomo River, Southern Nigeria. *European International Journal of Science and Technology,* 5 (8): 15 – 24.

Aghogho, O. and Daniels (2015). Composition and Abundance of Macrobenthos in the Lagos Lagoon. *International Journal for Innovation Education and Research,* 3 (8): 154-159

Ajao, E.A and S.O. Fagade, (2002). The benthic macro-in fauna of Lagos lagoon. *Zoologist,* 1:15.

Baharuddin, N, Basri N. B and Syawal N. H. (2018). Marine gastropods (Gastropoda; Mollusca) diversity and distribution on intertidal rocky shores of Terengganu, Peninsular Malaysia. *AACL Bioflux* 11 (4): 1144-1154.

Bhatnagar A. and Devi, P. (2013) Water quality guidelines for the management of pond fish culture. *International Journal of Environmental Sciences* 3(6):1980-2009.

Dance, K.W. and Hynes, H.B.N. (1980). Some effects of agricultural land use on stream insect communities. *Environmental Pollution Series,* 39(4): 337-349.

Edema, C.U., Ayeni, J.O. and Aruoture, A. (2002). Some observations on the Zooplankton and Macrobenthos of the Okhuo River, Nigeria. *Journal of Aquatic Science,* 1(7):145-149.

Effendi, H. (2003). Telaah kualitas air bagi pengelolaan sumber daya dan lingkungan perairan. *Kanisius, Yogyakarta*, 145 p.

Emere, M.C. and Nasiru, C.E. (2007). Macroinvertebrate as indicators of the water quality of an urbanised stream, Kaduna, Nigeria. *Medwell Journal of Fisheries International,* 2(2): 152-157.

Gill, K. (2011). Identification Guide to Freshwater Macroinvertebrates. Retrieved June 10, 2022, from https://stroudcenter.org/wpcontent/uploads/MacroKey_Complete.pdf.

Hakiki, T. F, Setyobudiandi I, and Sulistiono R. (2017). Macrocoobenthos community structure in the estuary of Donan River, Cilacap, Central Java Province, Indonesia. *Omni-Aquatica* 13 (2): 163-179.

Hart, A.I, (1994). The Ecology of the communities of benthic macro fauna in the mangrove swamp of Port Harcourt area of the Niger Delta. Ph.D. Thesis, University of Port Harcourt, Rivers State, pp: 262.

Idodo-umeh, G. (2002). Freshwater fishes of Nigeria (Taxonomy, Ecological Notes, Diet and Utilization). Idodo-umeh. Publishers, p.11-211.

Idowu, E.O. and Ugwumba, A.A.A. (2005). Physical, chemical and benthic faunal characteristics of a Southern Nigeria Reservoir. *The Zoologist,* 3: 15-25.

Ikomi, R.B., Arimoro, F.O and Odihirin,O. K (2005). Composition, distribution and abundance of macroinvertebrates of the upper reaches of River Ethiope Delta State, Nigeria. *The Zoologist,* 3: 68-81.

Krisnafi, Y., Novianto, D., Aamsah, S. and Wibowo, A. C. (2021). Distribution of macrozoobenthos species and communities in Bulaksetra Estuary. *Conference Series of Earth and Environmental Science,* 750 (1): 012001. DOI: 10.1088/1755-1315/750/1/01200.

Kwen, K., Davies, O.A. and Okaeme, A.N. (2012). Temperature, dissolved oxygen, hydrogen ion concentration and transparency conditions in the Upper Nun River, Niger Delta. *Journal of Aquatic Sciences,* 2(2):

135-145.

Li, H., Shi, A., Li, M. and Zhang X. (2013). Effect of pH, temperature, dissolved oxygen, and flow rate of overlying water on heavy metals release from storm sewer sediments. *Journal of Chemistry,* Article ID 434012, https://doi.org/10.1155/2013/434012

Mahre, M.Y., Akan, J.C., Moses, E.A. and Ogugbuaja, V.O., (2007). "Pollution indicators in River Kaduna, Kaduna State, Nigeria." *Trends in Applied Sciences Research*, 2(4): 304-311.

Murphy, S. (2007), "BASIN: General Information on Dissolved Oxygen." City of Boulder/USGS Water Quality Monitoring. bcn.boulder.co.us/basin/data/NEW/info/DO.html. (Accessed on 20th October 2018).

Nwadiaro, C.S., (1987). The longitudinal distribution of macroinvertebrates and fish in the Lower Niger Delta river (River Sombreiro) in Nigeria. *Journal of Aquatic Science* 7(1): 18-25.

Octavina, C., Dewiyanti, I., Nurfadillah, N., Ulfah, M., Razi, N. M., Sakinah, R. and Agustiar, M. (2019). Community structure of macrozoobenthos in Lamnyong River, Aceh Province. *Conference Series of Earth and Environmental Science,* 348 (1): 12-70.

Odiete, W. O. (1999). Environmental physiology of animal and pollution. *Diversity resources Lagos Nigeria*.

Odum, E.P. (1971). Fundamentals of Ecology. 3rd Edn, W.B. SuandersCompny, *Philadelphia,* pp: 574.

Ogamba, E. N., Izah, S. C. and Oribu, T. (2015). Water quality and proximate analysis of *Eichhornia crassipes* from River Nun, Amassoma Axis, Nigeria. *Research Journal of Phytomedicine*, 1 (1): 43-48.

Ogedengbe, K. and Akinbile, C.O. (2004). Impact of Industrial pollutants on quality ground and surface waters at Oluyole industrial estate Ibadan. *Nigerian Journal of Technological Development,* 4(2):139–144.

Olomukoro, J.O. (1996). Macrobenthic fauna of Warri river in Delta state of Nigeria. Ph.D. Thesis, University of Benin, Benin City, Nigeria. 350pp.

Rafique, R.M., Mahboob, M.A. and Saleem, S. (2002). Seasonal limnological variations in Mangla Reservoir at Sukhian, Mirpur (Azad Kashmir). *International Journal of Agriculture and Biology,* 4(2): 223-226.

Seiyaboh, E. I., Inyang, I. R., and Izah, S. C. (2016). Spatial variation in physico-chemical characteristics of sediment from Epie Creek, Bayelsa State, Nigeria. *Greener Journal of Environment Management and Public Safety,* 5 (4): 45-49.

Seiyaboh, E. I., Izah, S. C. and Oweibi, S. (2017). Physico-chemical characteristics of sediment from Sagbama Creek, Nigeria. *Biotechnological Research,* 3 (1): 25-28.

Shannon, C. E and Wiener, W. (1963). *The Mathematical Theory of Communication*. University of Illinois Press, Urbana, Illinois.

Uwadiae, R. E, Oni., O., Egue, O. E, Idowu, T. and Ezekwe, F. E. (2014). Patterns and determinants of benthic macro invertebrate's functional assemblages' function environment. Interrelationship in a Lagoon Ecosystem. *World Journal of Biological Research*, 5(2):67-73.

Wildan, D. M, Sulistiono, Simanjuntak, C.P.H., Rahardjo, M. F, Hestiranoto, T., Shafrudin, D.,

Nugroho, T., and Ismanto, A. J. (2021). Study on macrozoobenthos diversity in Batang Toru River and its surrounding, North Sumatra, Indonesia. *IOP Conference Series: Earth and Environmental Science,* Volume 744.

Wetzel, R. G. (1983). *Limnology*. 2nd Edition. Saunders College Publishing. 760 pp.