Innovations

Biological assessment of Okwagbe waterside along the Forcados river using environmental bio - indicators

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Abstract

The pollution status of Okwagbe waterside along the Forcados River in, Delta state, Nigeria was investigated using environmental bio-indicators. Samples were taken bi-monthly between July and August, 2022 from two sampling stations with the aim of evaluating the macro-invertebrate composition and abundance as well as the sediment quality. The mean values of sediment physicochemical parameters were;25.50±0.58°C and 26±1.83°C for temperature, 6.74±0.10 and 6.71±0.12 for pH, Total hydrocarbon content 2.59±0.587mg/kg and 3.82±0.53mg/kg for total hydrocarbon content, 6.16±1.19Cmol/kg and 6.11±0.48Cmol/kg for exchangeable acid, 3.36 ±0.65% and 6.02 ±0.49% for organic matter, 0.11 ±0.04% - 0.06 ±0.01% for total nitrogen, 12.98 ±1.47meq/100g - 16.02 ±1.43meq/100g for cation exchange capacity for Station 1 and Station 2 respectively. Sediment particle size distribution indicated higher proportion of sand and in decreasing order: (sand>clay>silt) in Station 1 while it follows sand>silt>clay in Station 2. The mean percentage composition of sand, clay and silt is 92.75% ±0.96% and 92.50%±1.30%, 5.75%±0.96% and 2.00% ± 0.82% 1.50±0.58% and 5.50 ±1.29% respectively. A total of 118 individuals belonging to 5 orders and 7 species were recorded during the study.The class Malacostraca ;Decapoda(93.6%) was the most abundant order, followed by class Clitellata Opisthopora (55.5%) and Tubificida (37.0%).While class Insecta ; Coleoptera (7.40%) and Dermaptera (6.25%) were low. During the study Decapoda, Opisthopora and Tubificida (Palaemon species and Lumbricus terrestris) were abundant in the sampling stations.This an indication, of polluted sediment as a result of anthropogenic activities on the water body. The macro-invertebrates were classified into functional feeding groups as shredders, collectors, scrappers and predators with the collector recorded the highest abundance of (50.84%) because if the presence of suspended organic particles of all sizes. The diversity index shows that station 2 is richer and more diverse than station 1. Principal component analysis showed that clay and total nitrogen influenced the abundance of Dermaptera and Decapoda; whereas sand influenced the abundance of Tubificida.

Keywords: 1.*Physico –chemical, 2.sediment, 3.macro-invertebrates, 4.diversity indices*

Introduction

Due to man's reliance on the environment's resources, there are an increasing number of water bodies that are under anthropogenically stressful conditions worldwide and the exploitation of these resources will have disastrous effects on river resources, particularly the flora and fauna and the habitats that support them (Iloba *et al.*, 2018). The diversity, abundance, and distribution of macro-invertebrates in aquatic environments are structured by both natural and anthropogenic factors, and these factors depend on the features of their environment, such as the level of pollution, the amount of organic matter in the soil, the type of sediment, and the type of food available (Barbosa *et al.*, 2016).

Biological assessment of rivers is widely recognized as a technique to determining the health status of aquatic ecosystem (Adam and Russel, 2019). Macro-invertebrates are environmental bio-indicators since they have various tolerance from different anthropogenic activities released into water bodies. Their preference is based on their ability to respond to changes, these include; sediment quality, water quality, hydrological conditions, shading and biological factors (Bonada *et al.*, 2006). They are widely used for ecological water quality monitoring and are regarded as one of the most representative taxa for identifying the health status of aquatic ecosystems as they reflect changes in the environment in an integrative and continuous manner (Iloba *et al.*, 2019). Their complete selective sensitivity and tolerance to environmental stress variables account for their performance as indicators of water quality (Iloba and Ikechukwu, 2014). Additionally, macroinvertebrates play a number of significant roles in the freshwater ecosystem, including the recycling of nutrients and minerals, the retention and breakdown of organic material, and the processing of energy at various trophic levels (Erasmus *et al.*, 2021).

Sediment can come from soil erosion or from decomposition of plants and animals Sediment input may impact rivers communities through a variety of direct and indirect processes. Minerals within sediments may include clay, silt, sand, gravel, organic matter and shells (Gupte and Shaikh, 2014). Sediment play pivotal role in the determination of the pollution status in rivers (Wepener and Vermulen, 2005).

The structure of the sediment in the zones plays a major role in the distribution of the macro invertebrates and show habitat preference for specific types of sediment. (Ikomi *et al.*, 2005). Sediment studies is a complex environments due to fluctuating physicochemical characteristic, these include pH, organic matter, total nitrogen, total hydrocarbon content. These parameters are known to manipulate the interaction of pollutants within sediment pattern. (Vincent-Akpu *et al.*, 2015). Sediment acts as a reservoir and source of pollutants in aquatic environments under favorable conditions (Eliku and Leta, 2018). Sediment quality is of great concern to aquatic life of Okwagbe waterside along Forcados River due to high human activities have contributed vast amount of poor sediment quality that pose serious threat to the aquatic habitat and humans.

The aim of this study is to evaluate sediment quality and community structure of macro- invertebrates in Okwagbe waterside along the Forcados River, Delta state, Nigeria.

Study Area

Okwagbe is a commercial town located on the right bank of Forcados River. Okwagbe waterside is located in Ughelli South Local Government Area of Delta State, Nigeria. It lies between Latitude 5°31’43″N (5.5285) to Longitude 5°47’23″E (5.7898). The climate is equatorial and is marked by two distinct seasons (dry and rainy season). The dry season lasts from about November to April and is marked by the cool dusty haze from the north-east winds although, the rainy season’s spans from May to October with a brief dry spell in August, it frequently rains even in the dry season. The area is characterized by an annual temperature of 26°C and annual rainfall amount of 2673.8mm. The natural vegetation consists of mangroves swamp forest and forest rich in timber and palm trees. Okwagbe waterside along the Forcados River is among the most widely used water bodies in Delta State for domestic, municipal, industrial and commercial purposes. The main tributaries of Forcados River are Niger River and Nun River. The coordinates of each sampling stations were determined with the aid of the Global positioning system (GPS) (Figure 1).

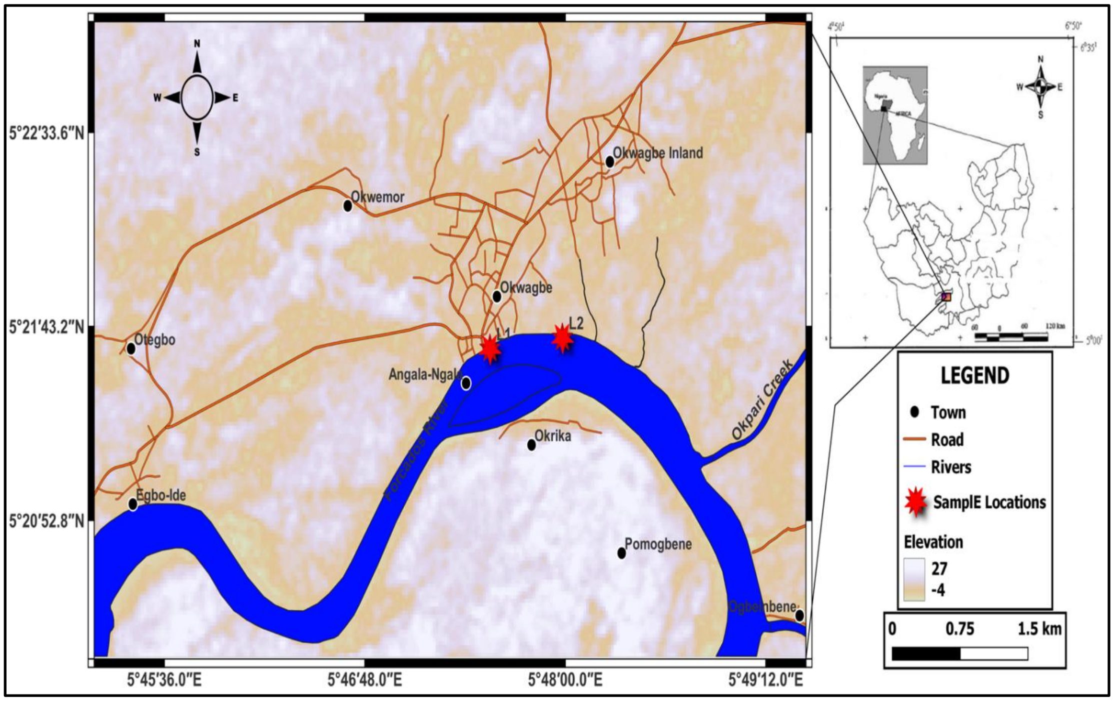

Figure 1: Map of Study area showing the sampling stations

Sampling Stations

Two sampling stations were demarcated in the River

Station 1

This station is located close to the Okwagbe market where buying and selling of fishes, shrimps, kerosene and other foodstuffs products. Human activities here include; domestic, agricultural, dredging, logging, boating and fishing activities including bathing and laundry as well as cleaning of market tools and disposal of any kind of waste like fish slaughter waste. Vegetation includes Halfa grass (*Desmostachya bipinnata*) and Water hyacinth (*Eichhornia crassipes*)

Station 2

This station is located about 50m upstream from station 1. Human activities taking place upstream include abattoir, boating and fishing. Vegetation includes Halfa grass (*Desmostachya bipinnata*) and other grasses at the bank of the River

Sediment Sample Collection

Two sampling stations were selected stations using Van-veen grab sampler. Composite samples were collected bi - monthly during the study period June to August, 2022. The sediment samples were wrapped with aluminum foil. Samples were then taken to the Research Laboratory at Delta State University, Abraka. The samples were air dried for several days at room temperature, grounded with mortar and pestle and served with a 2mm mesh sieve (USEPA, 2001) and kept in a polyethylene bottle for further analysis using standard methods ((AOAC, 2019 and ASTM, 2008). Some selected physicochemical parameters were monitored (Temperature, pH, Total hydrocarbon content, Exchangeable acidity Total organic matter, Total nitrogen, Cation exchange capacity and Particle size distribution.

Macro invertebrates Collection and Identification

Macroinvertebrates collection was bi-monthly at each Stations using a standard dip net of 500µm mesh size, handpicking of macroinvertebrates from and aquatic plants (*Desmostachya bipinnata*) and (*Eichhornia crassipes*). This was transferred to a sieve bucket contained with water and shaken to remove sediment and debris and the sample was transferred from sieve to a sample jar which was preserved with 10% formalin from the River between July and August, 2022. The samples were taken to the laboratory for sorting. Some of the macro-invertebrates were sorted under a binocular dissecting microscope. Identification of specimen was done following available manuals and keys (Tachet *et al.*, 2010).

Statistical Analysis

Microsoft Excel (2021) was used for graphical illustrations. T-test to compare the two stations was done using (SPSS version 13) and Principal component analysis (PCA) and Diversity indices were done using Paleontological Studies (PAST).

Results

Summary of physicochemical parameters of sediment samples collected from sampling stations at Forcados River in Okwagbe waterside are presented in Table 1.

Table 1: Physicochemical parameters of Sediment in Station 1 and Station 2 of Forcados River in Okwagbe waterside

Parameters	Station	Mean	SD	t-cal	p-value	Comment
Temperature (°C)	1	26.00	1.83	0.522	0.632	Not Significant
	2	25.50	0.58			
Ph	1	6.74	0.10	0.389	0711	Not Significant
	2	6.71	0.12			
Total Hydrocarbon Content (mg/kg)	1	2.59	0.587	3.127	0.021	Significant
	2	3.82	0.53			
Exchangeable Acid ($Cmolkg^{-1}$)	1	6.16	1.19	0.070	0.948	Not Significant
	2	6.11	0.48			
Organic matter content (%)	1	3.36	0.65	6.492	0.001	Significant
	2	6.02	0.49			
Total Nitrogen (%)	1	0.11	0.04	2.244	0.102	Not Significant
	2	0.06	0.01			
Cation Exchange Capacity (mg/100g)	1	12.98	1.47	2.953	0.026	Significant
	2	16.02	1.45			
Sand (%)	1	92.75	0.96	0.311	0.766	Not Significant
	2	92.50	1.30			
Silt (%)	1	1.50	0.58	5.657	0.004	Significant
	2	5.50	1.29			
Clay (%)	1	5.75	0.96	5.960	0.001	Significant
	2	2.00	0.82			

S.D= standard deviation, p-value indicates the level of probability which indicates that the means are significantly different at (< 0.05) and not significantly different at (> 0.05)

Composition and Abundance of Macro-invertebrate Fauna in Okwagbe Waterside

Table 2: Composition, Abundance and Functional Feeding groups of Macro-invertebrates in the Studied Stations of Okwagbe waterside section of the Forcados River.

Order	**Family**	**Species**	**FFG**	**Station 1**	**Station 2**	**Total species**
Coleoptera	Noteridae	*Suphisellus semipuntatus*	Predator	0	2	2
	Carabidae	*Clivina collaris*	Predator	0	2	2
Dermaptera	Forficulidae	*Forfocula auricularia*	Predator	4	0	4
Decapoda	Palaemonidae	*Palaemon elegans*	Collector-gatherer	30	0	30
		Palaemon adspersus	collector-gatherer	30	0	30
Opisthopora	Lumbricidae	Lumbricus terrestris	Shredders	0	30	30
Tubificida	Enchytraeidae	Enchytraeus sp.	Scrapers	0	20	20
Total Number of species				64	54	118
Number of species				3	4	7

Table 3: Diversity Indices of macro-invertebrates in station 1 and 2 of Forcados River in Okwagbe waterside

Indices	**Station 1**	**Station 2**
Simpson index	0.2076	0.5487
Shannon	0.3266	0.8872
Margalef	0.2836	0.5014

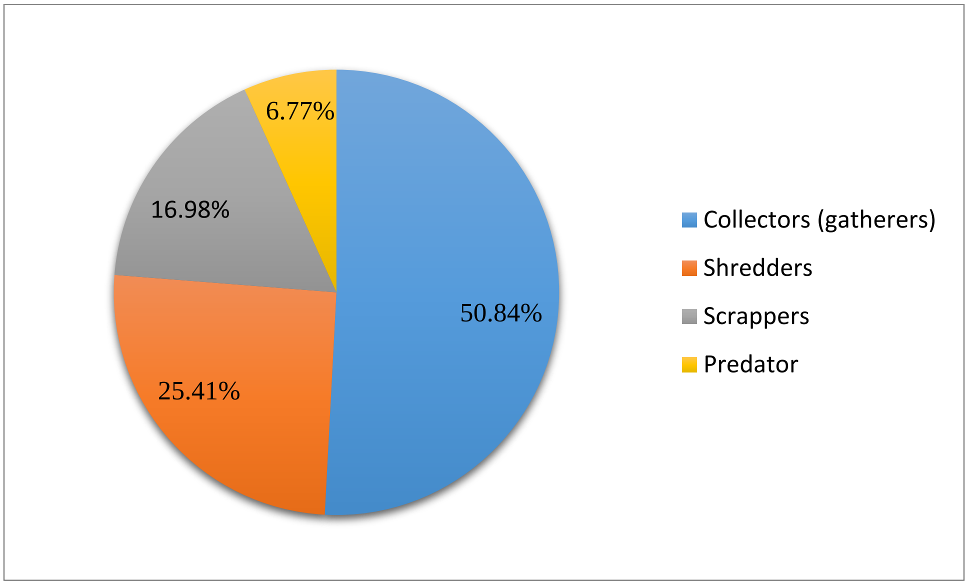

Figure 2: Functional feeding groups (FFGs) of macro-invertebrates of Forcados River in Okwagbe waterside

Principal component analysis (PCA) on the physicochemical parameters of sediment that favors the abundance and distribution of macro-invertebrates in station 1 and 2 of Forcados River in Okwagbe waterside

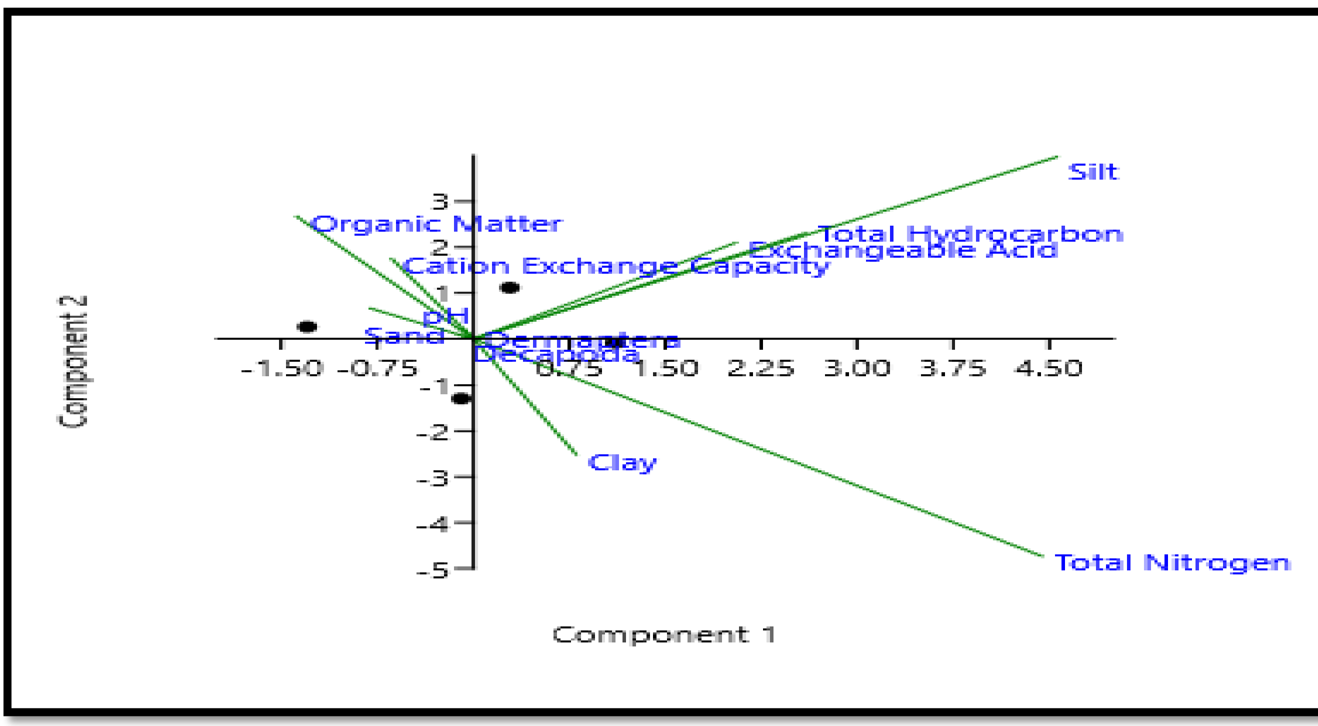

Figure 3: Shows that clay and total nitrogen influenced the abundance of Dermaptera and Decapoda found in station 1

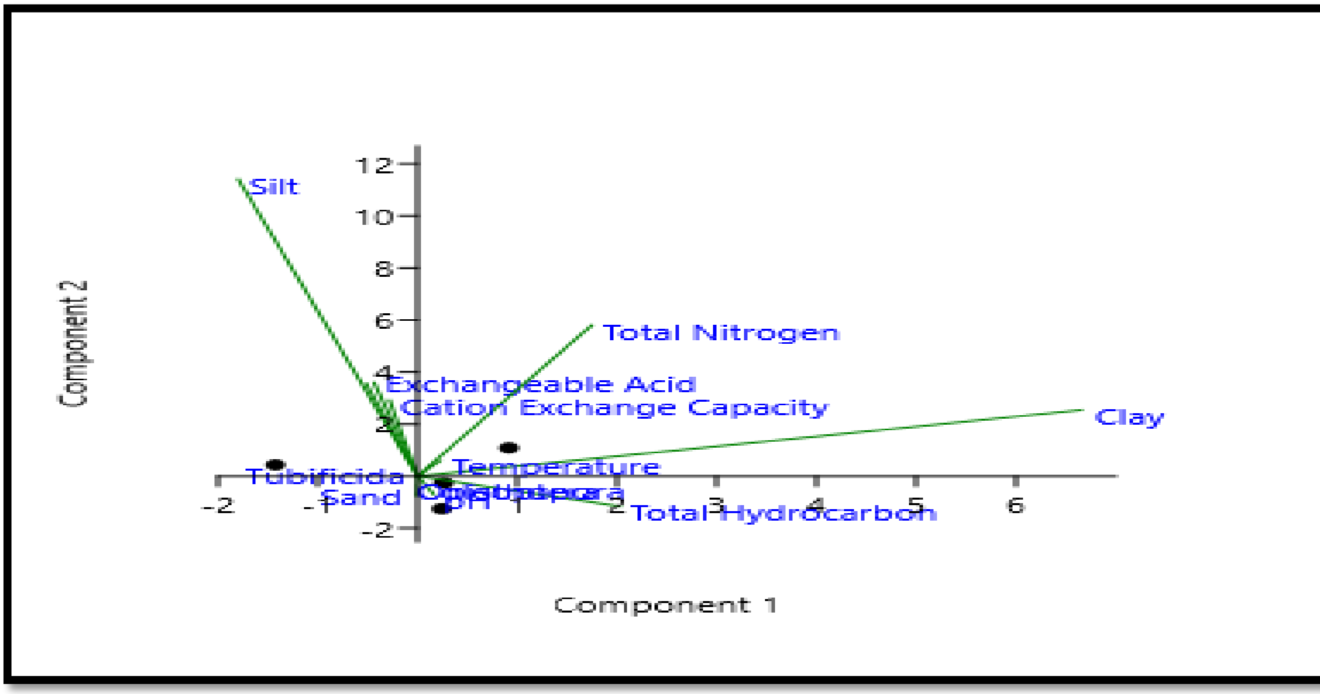

Figure 4: Principle Component Analysis of Station 2 showing the affinity between Tubificida and sand

Discussion

The mean values for sediment temperature were between 25.50±0.58°C - 26±1.83°C (Table 1) for both stations. The value for this study disagrees with the report of Otolo *et al.*, (2017) in Ethiope River, Delta State, Nigeria, who reported a mean value of 28.60±0.01ºC to 29.80±0.00°C, Rashedul and Zafar (2018), who obtained a lower mean of 20.18±10.7ºC in the Bay of Bengal, Bangladesh, and Zubia *et al.*, (2015) who reported 28°C in Rawal Dam, Islamabad. These variations may be due to special disparity between these study areas. The observed sediment temperature for this research is however in close proximity with that (25.0±1.77 – 31.4±0.98) reported by Iloba (2021) in the mid-Ethiope River.

The mean value of the pH of sediments from the studied stations of the Forcados River in Okwagbe Waterside varied between 6.74±0. and 6.71±0.12 (Table 1). This value agrees with the range value obtained by Seiyeboh *et al. (2017)*, who recorded a range of 6.73–6.87 in Sagbama Creek, Niger Delta, Nigeria, and Ebong and John (2021), which is 6.58–6.69 from major river estuaries in the Niger Delta Region. The pH mean value 6.5–8.5 is also within the WHO (2013) permissible limit. The range values reported by Seiyaboh *et al.* (2016) recorded 7.01–7.25 at Ikoli Creek, Niger Delta, Nigeria, and Edori *et al.*, (2019) obtained 7.18–7.28 from Silver River, Bayelsa State, Nigeria, which disagrees with the pH values for this study.

The total hydrocarbon content (THC) of sediments from the studied stations showed a mean value of 2.59 mg/kg for station 1 and 3.82 mg/kg for station 2, with a p-value of 0.021 being statistically significant (Table 1). The high total hydrocarbon content recorded at station 2 showed the abundance of Opisthopora and Tubificida which are generally pollution-tolerant. The values obtained from this study concur with those of Seiyaboh *et al.* (2016), who recorded a range between 2.31-6.10 mg/kg in Ikoli Creek, Niger Delta, but disagree with the report of Ebong and John (2021), who reported a higher mean value of 45.46±12.35 mg/kg in major river estuaries in the Niger Delta Region. The high value of the total hydrocarbon content recorded at Station 2 indicates the oil spill from boating activities in this station.

Exchangeable acidity of sediment in the studied stations obtained a mean value of 6.16 ±1.19 Cmolkg-1 (station 1)and 6.11 ±0.48 Cmolkg-1(station 2) with a p- value of 0.987, which was not statistically significant Table 1. The values obtained in this studied disagrees with the reported values of Ubuoh *et al.*, (2021) recorded varied exchangeable acidity values of 0.89-1.1 Cmolkg-1 in station 1, 0.66-1.34 Cmolkg-1 under station 2 and 0.45-0.88 Cmolkg-1 at station 3 of Nworie River watershed, Imo State, Nigeria. The high values recorded in this study may be due to potential metals toxicity accumulated overtime in the sediments

Sediment organic matter had a mean value of 3.36 0.65% at station 1 and 6.02 0.49% at station 2.Organic matter in sediment recorded its highest mean in station 2 (Table 1). Similarly ,the mean values for this study agrees with the studies of Rashedul and Zafar (2018) obtained 3.14±1.13%in Bay of Bengal, Bangladesh and Edori *et al.*, (2019) recorded 4.09±0.09% in Silver River, Bayelsa State, Nigeria. Vincent-Akpu *et al.*, (2015) obtained mean values of 0- 5.5% in Bodo Creek, Nigeria. This is a clear indication of deposit from logging, agricultural activities and waste from fish slaughter.

The total nitrogen of the studied area showed no significant differences in mean values for total nitrogen, with a mean value of 0.11±0.04 % station 1 and 0.06±0.01% station 2. The low value recorded for this study could be attributed to low demand for nitrogenous fertilizers and increase volume of water level due high amount of rainfall. The values obtained validate the report Otolo *et al.*, (2017) who reported a mean value of 0.004±0.00% to 0.030±0.01% from Ethiope River, Delta State, Nigeria and Yirga and Hassan (2015) recorded a range between 0.07 to 0.54% with an overall mean of 0.18% from Lake Tana of Ethiope.Contrary to this study the report of Seiyaboh *et al.*, (2016) who reported a range value of 1.35-2.53 from Ikoli Creek, Niger Delta, Nigeria and Seiyaboh *et al.*, (2017) who reported a range value of 3.35 - 5.50% from Sagbama Creek, Niger Delta, Nigeria, were high when compared.

The sediment's cation exchange capacity (CEC) was statistically significant, with a mean value of 12.98 1.47 mg/100 g at station 1 and 16.02 1.43 mg/100 g at station 2, and a p-value of 0.026. Table 1. Station 2 had a high cation exchange capacity. This could be attributed to the daily activities at the Okwagbe market abbatior, which include high levels of organic waste, bones, horns, detergents, and ashes from logs used during dehairing. In contrast to this study, Nnaji *et al.* (2010) obtained mean values of 2.2 to 6.5 mg/100 g downstream and 5.9 to 16.8 mg/100 g upstream in the River Galma, Zaria, Nigeria, and Ubuoh *et al.* (2021) obtained values for sediment ranging from 6.12 to 8.85 mg/100 g across three stations with an overall mean of 7.24 mg/100 g in the Nworie River Micro-watershed, Imo, while station 1 recorded the lowest mean cation exchange capacity of the sediment.

The sediment characterization of the Forcados River in Okwagbe was dominated by sand with a mean value of 92.75% ±0.96% station 1 and 92.50% ±1.30% station 2; silt with a mean value of 1.50 ±0.58% in station 1 and 5.50 ±1.29% in station 2, which was statistically significant (p-value 0.004); and clay with a mean value of 5.75%± 0.96% station 1 and 2.00% 0.82% station 2 with a p-value of 0.001 and was statistically significant (Table 2) at station 1 (sand > clay > silt) and station 2 (sand > silt > clay). Similar trends were reported by Erhenhi and Omoigberale (2022) in the Ethiope River, Nigeria, whose range values for sand were -93.13%, clay 4.70%, and silt, 1.89% -2.57%. In addition, Udebuana *et al.* (2015) reported range values for sand (84.54%-89.64%), clay (1.93%-3.78%), and silt (7.53%-19.34% in the Okhwo River particle size distribution).On the contrary Adesuyi *et al.*, (2016) reported a range of values for clay 64.28% ±22.04% to 72.36% ±14.00%, silt 18.71% ± 12.03% to 27.32%± 22.32% and sand 8.40%±6.28% to 9.76%± 4.59 in the assessment of sediment characterazation from Nwaja creek, Niger Delta. The high percentage of sand in this present study could be attributed to increased organic matter content.

.**Macro-Invertebrate Community Structure**

The macro-invertebrate assemblage encountered a total of 118 individuals allotted to six families and seven species during the study period (Table 2). At station 1, the most common Decapoda were collector/gatherer *Palaemo elegans* and *Palaemo adspersus* from the family Paleomonidae. Thus this study showed the importance of collector-gatherers transferring energy and material from decaying organic matter to the rest of the aquatic food web thereby acting as indicator-species (moderate pollution-tolerant species) that are fairly adapted to tolerate a broad range of environmental conditions. A similar community was identified by Kay *et al.*, 2001; Al-Shami *et al.*, 2010 in Australia and Malaysia respectively. The high abundance and distribution of organically loving Lumbricidae (*Lumbricus terrestris*) and Enchytraeidae (*Enchytraeus sp.*) were seen at Station 2, an indication of an organically polluted body of water (Erhenhi and Francis 2018; Iloba, 2020). The Opisthopora and Tubificida are generally pollution-tolerant, their dominance signifies poor sediment quality, and their presence could be attributed to domestic and organic waste discharge into the river. This was also noted by Akawo *et al.*, (2021), in the River Adofi, Delta State. The low species diversity of the predator functional group in this study was represented by three families: Forficulidae (*Forfocula auricularia),* Caribidae *(Clivinacollaris), and* Noteridae *(Susphisellus semipuntatus);* this may be as a result of the fast flow of the river resulting in disruption of reproductive cycle, food chains, and migration or imposed physiological stress on the tolerant species as also noted by Adakole and Annune, 2003, in an Urban Stream, Zaria, Northern Nigeria. .

For the functional feeding group, collector-gatherers had the highest abundance (50.84%), followed by shredders (25.41%), scrappers (16.98%), and predators (6.77%) (Figure 2). This agrees with the report of Addo-Bediako (2021), who also found that collector-gatherers made up 76%of the collector-gatherer downstream of Dwars and Spekboom Rivers, South Africa. This composition and abundance of the functional feeding group of the sampled sites in Okwagbe River conforms with the ideal river continuum concept.

The diversity indices (Table 3) showed that station 2 had low but the highest Margalef's index value of (0.5014) and the lowest at station 1 (0.2836), which implied that station 2 is more rich and diverse than station 1. However, the less than 1 diversity indices characterize heavily polluted conditions.This infers that the Forcados River in Okwagbe is heavily polluted which is further confirmed by Shannon Wiener value for this study. Species diversity scales indicate that values less than 1 characterize heavily polluted conditions, values in the range of 1-3 characterize moderately polluted conditions, and a value of 3 signifies stable environmental conditions or clean water (Shah and Pandit, 2013). This study concurs with the values obtained by Ghosh and Biswas (2015) who recorded (0.29, 0.65, 0.73) in Oxbox Lake, Eastern India, and Nafiu *et al.*, (2017) who recorded (0.88) in Station 2 in Rimin Gado Dam, Kano, Nigeria, and is contrary to the report of Akawo *et al.* (2021) who recorded values, 1.266, 1.23, 1.248, in all stations of the River Adofi, Delta State, Nigeria.

Principal component analysis revealed the influence of physico-chemical parameters of sediment on macro-invertebrate abundances, which showed that sand, silts , clay organic load influences the abundance of Tubificida at station 2, while Coleoptera and Opisthopora at station 2 depend solely on pH, temperature, and total hydrocarbon. The abundance of dermaptera and decapoda was influenced by clay and total nitrogen.

Conclusion

The presence of Lumbricidae (Lumbricus terrestris), Enchytraeidae (Enchytraeus sp), and Paleomonidae (Palaemo elegans and Palaemo adspersus) is a sign of organically polluted sediment. The EPT group of macro-invertebrates

(Ephemeroptera, Plecoptera, and Tricoptera) absent from the Forcados River in Okwagbe Waterside is likely due to pollution from humans, both in the form of organic and inorganic waste.

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References

1. *Adakole, J.A. and Anunne, P.A. (2003). Benthic macroinvertebrates as indicators of environmental quality of an Urban Stream, Zaria, Northern Nigeria. Journal of Aquatic sciences, 18: 85-92.*
2. *Adam, A. D. and RusselL, G. D. (2019). Ecosystem health indicators – freshwater environments. Encyclopedia of Ecology 2: 46-60.*
3. *Addo-Bediako, A. (2021). Spatial distribution patterns of benthic macroinvertebrate functional feeding groups in two rivers of the Oilfants River System, South Africa. Journal of Freshwater Ecology, 36(1): 97-109.*
4. *Adesuyi, A.A., Ngwoke, M.O., Akinola, M.O., Njoku, K.L. andJolaoso, A.O. (2016). Assessment of physicochemical characteristics of sediment from Nwaja Creek, Niger Delta, Nigeria. Journal of Geoscience and Environment Protection, 4: 16-27.*
5. *Adjarho, U.B., Esenowo, I.K. and Ugwumba, A.A.A. (2013). Physico-chemical parameters and macroinvertebrates fauna of Ona River at Oluyole Estate, Ibadan, Nigeria. Research Journal of Environmental and Earth Sciences, 5(11): 671-676.*
6. *Akawo, O.N., Akuaka, G.O., Oriya, G.N. and Osagiese, L.A. (2021). Water quality and macroinvertebrate diversity indices of water receiving cassava effluents. International Journal of Innovative Science and Research Technology, 6(4): 555-562*
7. *Al-shami, S.A., Rawi, C.S.M., Hassan Ahmad, A. and Nor, S.A.M. (2010). Distribution of chironomidae (insecta-diptera) in polluted river of the Juru River Basin, Penang, Malaysia. Journal of Environmental Sciences, 22: 1718-1727.*
8. *American Society for Testing and Materials (ASTM) (2008). Standard Test Method for Water and Sediment in Crude Oil by the Centrifuge Method (Laboratory Procedure).*
9. *Andem, A.B., Okorafor, K.A., Udofia,U., Okete, J.A. and Ugwumba, A.A.A. (2012). Composition, distribution and diversity of benthic macroinvertebrates of Ona River, South- west, Nigeria. European Journal of Zoological Research, 1(2): 47-53.*
10. *AOAC, (2019). Official Methods of Analysis of the Association of Official Analytical Chemists: Official Methods of Analysis of AOAC International. 21st Edition, AOAC, Washington DC.*
11. *Aprile, F.M. and Bouvy, M. (2008). Distribution and enrichment of heavy metals in sediments at the Tapacura River Basin, North Eastern Brazil. Brazillian Journal of Aquatic Science and Technology, 12: 1-8.*
12. *Arimoro, F. O. and Ikomi, R. B. (2007). Response of macroinvertebrate communities to abattoir waste and other anthropogenic activities in municipal stream in Niger Delta, Nigeria. Environmentalist, 28: 85-98.*
13. *Arimoro, F.O. and Ikomi, R.B. (2008). Ecological integrity of upper Warri River, Niger Delta using Aquatic insects as bioindicators. Ecological Indicators, 395: 1-7.*
14. *Barbosa, F. A., Callisto, M. and Galdean, N. (2016). The diversity of benthic macroinvertebrates as an indicator of water and ecosystem health: a case study for Brazil. Aquatic Ecosystem health and Management. 4(1):51-59.*
15. *Bonada, N., Prat, N., Resh, V.H. and Statzner, B. (2006). Development in aquatic insect biomonitoring: Comparative analysis of recent approaches. AnnualReview of Entomology,51(1): 495-523.*

16. *Ebong, S.A. and John, R.C. (2021). Physicochemical properties, total hydrocarbon content and trace metals of water and sediments from major River Estuaries within the Niger Delta Region of Nigeria. World Journal of Advanced Research and Reviews, 12(2): 587-597.*
17. *Edori, O.S., Kieri, B.S.I. and Festus, C. (2019). Physicochemical characteristics of surface water and sediment of Silver River, SouthernIjaw, Bayelsa State, Niger Delta, Nigeria. American Journal of Environmental Science and Engineering, 3(2): 39-46.*
18. *Eliku, T. and Leta, S. (2018). Spatial and seasonal variation in physicochemical parameters and heavy metals in Awash River, Ethiopia, Applied Water Science, 8(6): 177.*
19. *Erasmus, J.H. Lorenz, A.W. Zimmermann, S. Wepener, V. Sures, B. Smit, N.J. Malherbe, W. (2021). A diversity and functional approach to evaluate the macroinvertebrate responses to multiple stressors in a small subtropical austral river. Ecological Indicators. 131: 108206*
20. *Erhenhi, O.H. and francis ,O.A (2018).Macroinvertebrate colonization of Catfish (Clarias gariepinus) carcass of River Ethiope, Delta State Nigeria, Sokoto Journal of Medical Laboratory Science, 3(4); 37- 45.*
21. *Erhenhi, O.H. and Omoigberale, O.M. (2022). Biometric indices of heavy metals in the sediments of Ethiope River. Nigerian Journal of Science and Environment, 20(1): 30-40*
22. *Ghosh, D. and Biswas, J.K. (2015). Macroinvertebrate diversity indices: A quantitative bio assessment of ecological health status of an Oxbow Lake in Eastern India. Journal of Advances in Environmental Health Research, 3(2): 78-90*
23. *Gupte, A. and Shaikh, N. (2014). Sediment analysis of Shelar Lake Maharashtra. Global Journal of Science Frontier Research, 14: 10- 15.*
24. *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.*
25. *Ilechukwu, I., Olusina, T.A. and Echeta, O.C. (2020). Physicochemical analysis of water and sediments of Usuma Dam, Abuja, Nigeria. Ovidius University Annals of Chemistry, 31(2): 80-87*
26. *Iloba, K. I, Akawo, O. N. and Nwaefiene, F. (2018). Diversity and Community structure of Macroinvertebrates in Anthropogenically stressed water body in Delta state, Nigeria. International Journal of Applied Biological Research, 9(1): 93-106.*
27. *Iloba, K. I. and Ikechukwu, M. O. (2014) Macrobenthic invertebrates and some water quality parameters in Ikpoba River, Edo State, Nigeria. Jewel Journal of Scientific Research, 2(1&2):165-173.*
28. *Iloba, K. I., Akawo, N. and Anani, C.(2019). Sand dredging impact on macrobenthic invertebrates of a hallowed River in Delta State of Nigeria. Science World Journal. 14(1): 171-176.*
29. *Iloba, K. I. (2021). Algal homogeneity in water and sediment of mid-Ethiope River, Nigeria: a response to severe ecological disturbances. Global NEST Journal, 23(1): 55-64.*
30. *Kay, W.R., Hales, S.A., Scanlon, M.D. and Smith, M.J. (2001). Distribution and environmental tolerance of aquatic macroinvertebrates families in the agricultural zone of Southwestern Australia. Journal of the North American Benthological Society, 20(2): 182-199.*
31. *Nafiu, S.A., Ibrahim, B.A., Maryam, T.A., Habib, R.A. and Inuwa, B. (2017). Water quality assessment in Rimin Gado Dam, Kano - Nigeria using macroinvertebrate fauna. Ewemen Journal of Analytical and Environmental Chemistry, 3(1): 129-136.*
32. *Nnaji, J.C., Uzairu, A., Harrison, G.F.S. and Balarabe, M.L. (2010). Effect of pollution on the physicochemical parameters of water and sediments of River Galma, Zaria, Nigeria. Libyan Agriculture Research Center Journal International, 1(2): 115-1*
33. *Otolo, S.E., Edjere, O., Esemedafe, J.U. and Ejeomo, C. (2017). Determination of some physico-chemical parameters of sediments from Ethiope River, Delta State, Nigeria. Scientia Africana, 16(1): 3-5.*
34. *Rashedul, A., Chowdhury, S. M. and Mohammad, Z. (2018). Physicochemical parameters of water and sediment during spring period in parts off Bay of Bengal, Bangladesh. MOJ Ecology and Environmental Sciences, 3(3): 150-154.*

35. *Seiyaboh, E.I., Inyang, I.R. and Izah, S.C. (2016). Seasonal variation of physico-chemical quality of sediment from Ikoli Creek, Niger Delta. International Journal of Innovative Environmental Studies Research, 4(4): 29-34*
36. *Seiyaboh, E.I., Izah, S.C. and Oweibi, S. (2017). Assessment of water quality from Sagbama Creek, Niger Delta, Nigeria. Biotechnological Research, 3(1): 20-24.*
37. *Sengupta, M. and Dalwani, R. (2008). Benthic invertebrates – A crucial tool in biomonitoring of lakes. Proceedings of Taal 2007: The 12th world lake conference.*
38. *Shah, J.A. and Pandit, A.K. (2013). Application of biodiversity indices to crustacean community of Wular Lake, Kashmir Himalayas. International Journal of Biodiversity and Conservation, 5(6): 311-316.*
39. *Tachet, H., Richoux, P., Bournaud, M. and Usseglio-Polatera, P. (2010). Invertébrés d'eau douce. CNRS éditions, Paris.*
40. *Ubuoh, E.A., Ofpegbu, C.C., Chikezie, P.C., Ota, H.O. and Zhifeng, Y. (2021). Evaluating the spatial distribution of soil physicochemical characteristics and heavy metal toxicity potential in sediment of Nworie River Micro-watershed Imo State, Southeastern Nigeria. Environmental chemistry and Ecotoxicology, 3:261-268. (*
41. *USEPA (2001). Method for Assessing the Chronic Toxicity of Marine and Estuarine Sediment-Associated Contaminants with the Amphipod Leptocheirus plumulosus. US Environmental Protection Agency, Office of Water, Washington DC.*
42. *Vincent-Akpu, I. F., Tyler, C., Wilson, C., and Mackinnon, G. (2015). Assessment of physico-chemical properties and metal contents of water and sediments of Bodo creek, Niger Delta, Nigeria, Toxicological and Environmental Chemistry, 97: 135- 144.*
43. *Wepener, V. and Vermulen, L. A. (2005). Concentrations and bioavailability of selected metals in sediments of Richard Bay Harbour, South Africa. Water SA, 31: 589-595.*
44. *Yirga, K. W. and Hassen, M. M. (2015). Spatial variation of sediment physicochemical characteristics of Lake Tana, Ethiopia. Journal of Environment and Earth Science, 5: 95-109.*
45. *Zubia, M., Hameed, U. R., Baloch, A. B., Noor, U. A., Muhammad, Z., Irum, G., Naila, G., Nelofer, J., Nighat, D., Bibi, A., Irfana, S., Tauqir, A., Tilawat, S., Muhammad, M. and Abdul, H. (2015). Analysis of physicochemical parameters of water and sediment collected from Rawal Dam Islamabad. American-Eurasian Journal of Toxicological Sciences, 7(3): 123- 128.*

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