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Assessment of the Impact of In-Stream Sand Mining on Biodiversity of Macroinvertebrates at Eleme River, Nigeria.

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Abstract: *In-stream sand mining which involve incision of river beds and margins, removal of vegetation resulting in extraction of sand, impacts among others, the river structure and its biodiversity, and cause changes in vegetation structure, loss of macroinvertebrates and decrease in functional diversity of organisms. In the Eleme River, there are two types of in-stream sand mining used; the mechanical, and manual at the Aleto axis, and to ascertain their impacts on the diversity of macroinvertebrates and their habitats, this study was conducted. The River was divided into three stations; mechanical, manual, and unmined, with each station replicated three times in a Completely Randomized Design. Macroinvertebrate sampling was carried out from two substrates in these stations; floating vegetations, logs and stream channels using 500um mesh size pond nets, and 15 to 28m depth sediments using 225cm^3 in a wooden canoe. The samples were sieved through a 0.5mm mesh size sieve net and placed in a 4-L white plastic bucket, preserved with 10% formalin and stained with 0.1% Euson red stain. And taken to the Entomology Research Laboratory, Department of Animal and Environmental Biology, University of Port Harcourt for identification. The identified taxa of microinvertebrates were countered, recorded and data obtained subjected to a set of diversity indices. Dissolved oxygen, turbidity, pH and macrophyte compositions of the stations were determined using standard methods and data obtained analysed to determine the impact of the operatons on the habitat and its suitability for macroinvertebrates habitation. The results showed that macroinvertebrates in the River comprises of three sub-communities of fauna; meiobenthus, Entomofauna and crustaceans. A total of 456 individuals of macroinvertebrates belonging to 18taxa were encountered, out of which 9species (50%) and 12species (66.7%) were lost in manual and mechanical habitat-types respectively. The severity of the impact was in the following descending order; Entomofauna > meiobenthic > crustacean. On the impact of sand mining on habitat structure and quality, it was observed that four taxa of vegetation occurred at the unmined stations, but were absent at the mined stations. This indicates that mechanical operation impacts both habitat and diversity of microinvertebrates with severe impact on entomofauna, therefore the operation should be periodical to allow ecosystem recovery.*

Keywords: *Sand mining, manual, mechanical, Entomofauna, meiobenthus, crustacean.*

1. INTRODUCTION

Extraction of sand from rivers, seas commonly referred as sand mining usually involves digging of open pits in rivers or beaches. The extraction sometimes occurs directly from flowing river beds, channels or margins and this is classified as in-stream sand mining.

In-stream sand mining can cause disturbance of the habitat where macroinvertebrates inhabit and consequently affects the quality of the environment and its indigenous biodiversity of species. A reduction in species diversity will impact the ecological functionality or services of the species affected, resulting to the occurrence of two categories of species; sensitive macroinvertebrates which will die away from the habitat and used as indicators, and resilient group that can be used as monitor species because they can tolerate the impact, and remain in the habitat.

In-stream sand mining impacts the quality of habitat through the removal, or changes in vegetation structure, and decreased or increased in downstream vegetation (Koehnken, 2018). These changes in vegetation also affect the quality of the habitat by reducing the productivity or functionality of the ecosystem because it altered the rate of carbon and nitrogen cycle (Kumar and Kumar, 2014). The impacts on macro-invertebrates includes, temporal change of both the abundance and diversity

(Rempel and Church, 2009), decrease in invertebrate populations resulting from direct removal (Kanehi and Lyons, 1992). Brown *et al*. (1998) found that impacts on macro-invertebrate assemblages varied between invertebrates of different sizes, and the magnitude and frequency of mining. Accordingly, the density of both large invertebrate such as crayfish and mollusk and small invertebrates were significantly higher in unmined sites.

The provision of available conclusive environment for macroinvertebrates are affected by in-stream sand mining that involves widening of river channels. Kondolf (1993) pointed out that this type of sand mining increases both turbidity and temperature of rivers, and cause reduction in shelter and habitat for its indigenous species.

Species richness and abundance of macroinvertebrates are also affected directly by in-stream sand mining as it caused temporal change in both abundance and diversity (Rempel and Church, 2009); changes in microbial community structure (Kumar and Kumar, 2014). It also caused drift in macroinvertebrates communities making the organisms colonize new sections in the river, in escape from suboptimal habitat and in avoidance of intraspecific competition (Brittain and Eikelan, 1998). Sand mining also impact population of species and cause loss of native species with an increase in invasive alien species (Koehnken, 2018).

Another area where in-stream sand mining impact species in a river is the functional diversity of macroinvertebrates in which it has been reported that the abundance of collector gatherers was unchanged between dredged and undredged sites, while the number of collector-filterers decreased between the two sites (Brown et al., 1998). Skaski et al. (2016) showed that the structure of ground bettle assemblages in riparian settings on the lowest elevation caused by river incision were negatively impacted while the beetles on vertically stable river stretches were not impacted.

Eleme River a branch of Imo River, is situated at Aleto and Agbonchia in Eleme Local Government Area of Rivers State, Nigeria. The rivers are stressed by both mechanical and manual operations engaged in sand mining in the river and may cause changes in the habitats and diversity of indigenous macroinvertebrates in the river.

Investigations on the river has been on the physic-chemical properties in which variations in their concentrations, some of which are above intervention limits by Nigeria standard (Gbarakoro et al., 2020) has been reported. Though investigations on the impact of physicochemical changes on macroinvertebrates were not carried out, the authors pointed out that such high level of physicochemical properties were unfit for aquatic inmates. The impact of in-stream sand mining activities on the Eleme River and its inmates are lacking in Literature as there is virtually no available literature on the impacted biodiversity of macroinvertebrates. Therefore, it is our view that sand mining may have caused a reduction in both the status of the habitat and its dependable diversity of aquatic inmates. Changes in species richness and abundance caused by sand mining may have occurred in the Eleme River. It is in response to the gap in information on these that the present study is conducted with an objective to quantify the present status of maroinvertebrates diversity in Eleme river where instream sand mining is occurring. Furthermore, the impact of the sandmining methods employed on the status of the habitats and life support environmental requirements of the macroinvertebrates was determined.

2. MATERIALS AND METHODS

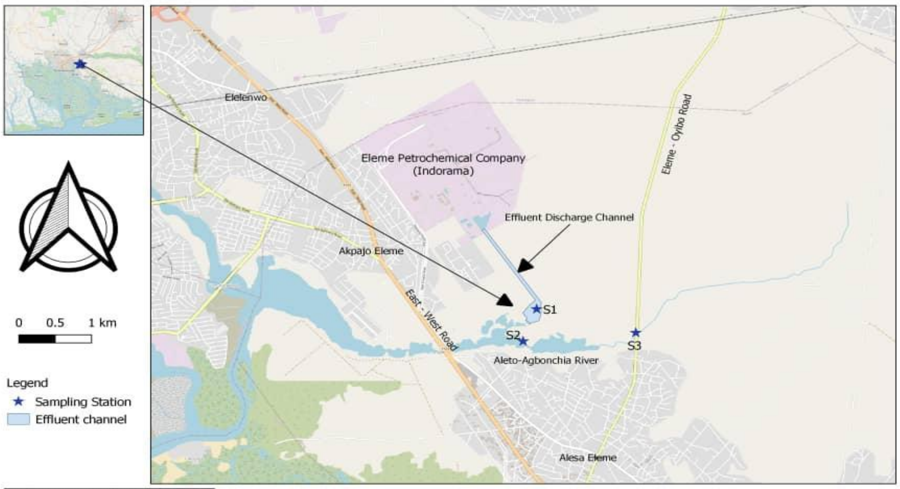
2.1. Description of Study Area

The Eleme study area is one of the oil producing and agro-ecological areas in the Niger Delta, Nigeria. It has two of Nigeria four petroleum refineries. The study river was divided into three sampling stations, mechanically, manually-operated and no operational (unmined) stations. Station I lies at the co-ordinates of elevation 04^{0} 48^{1} 46. 2^{11}N and $07^{0}6^{1}45$. 3 ^{11}E. It is the station where mechanical in-stream sand mining occurs; station 2 lies on 04^{0} 48^{1} 29.8 11 N and $07^{o}06$ 38.6E and it is the site of manual in-stream mining operations. This station is about 1.5 Kilometers from station 1 though station 1 and 2 are located at Aleto River. Station 3 which is about 2 km from station 1 (plates 1,2 & 3) is located on 04^{0} 05^{1} 20.2^{11} N and 06^{0} 53’ 54.4’’E and is the station at Agbonchia river where no mining operation occur. Each station was divided into three sampling points in a Completely Randomized Design. Each sampling points were separated from each other at 15cm apart. At the

Aleto axis of the Eleme river, mechanical sand mining involving the use of machines in the removal of vegetation, incision on river margin and increase in river depths for the excavation of sand characterized Station I. Excavation of sand with the use of basins resulting to slight incision on river margin and river depths, removal of vegetation characterized Station 2.

The major difference between the two stations was observed in magnitude of the mining activities as in both habitat-types, mining was accompanied by the removal of vegetation which was more intensive at the mechanical.

2.2. Map of Study Stations



S/N	SAMPLING STATION	LATITUDE	LONGITUDE
1	Station 1 (S1)	4.812842	7.112383
2	Station 2 (S2)	4.808278	7.110694
3	Station 3 (S3)	4.809483	7.124682

ALETO - AGBONCHIA RIVER
ELEME LOCAL GOVERNMENT AREA OF RIVERS STATE

2.3. Determination of Impact of Instream Sand Mining on Species Richness and Abundance through Macroinvertebrates Sampling.

Macro-invertebrates were collected from the three sampling points in each station using 500µm mesh size pond-nets and Eckman's Grab measuring 225cm^3 in a wooden canoe (Tagliapietra and Sigovini, 2010) from sediment. During collection with the use of nets, floating vegetation and logs found at the stream channels and river margins where incision occurred due to in-stream sand mining were searched and dislodged for the collection of inhabited organisms. Excess materials collected along with the organisms were sieved to remove excess fine sediments with the residue samples emptied into 4-L white plastic bucket.

The Eckman's Grab samples were collected from about 15 to 28 cm depth at mechanical and manual in-stream of 0.5 mm mesh size and immersed into the water to wash off unwanted fine part of the sediments. The unmined sites were not deep enough for the grab and full of sand and gravel such that sediment was not sampled. The residue was preserved in a 4-L bucket with 10% formalin and stained with 0.1% Euson red stain. The samples were transported to the Entomology Research Laboratory, Department of Animal and Environmental Biology, University of Port Harcourt for identification. In the laboratory, the samples were sorted and emptied onto a wide reflective plastic tray with water added sequentially. The stained living organisms were hand-picked with forceps with the aid of a hand lens. The organism picked up were placed in different universal containers and labelled according to taxonomic groups and were later identified, using identification keys under a dissecting microscope(Dudgeon,1999; Wiggins,1996). Macroinvertebrates collected during sampling were placed in their taxonomic groups, counted and recorded according to the respective stations. Species encountered across the three stations, and those that occurred at a particular station were also recorded. Species which occurred at station 3 (control sites) but absent at either stations 1 or 2 were recorded.

Species encountered were grouped into three subcommunities of macroinvertebrates; Entomofauna, meiobenthic and crustacean. Their respective abundances were counted and recorded according to their various groups and habitat-type; mechanical, manual and no method (control). The mostly and less impacted group of macroinvertebrates were recorded.

2.4. Biodiversity Indices

Biodiversity is a function of species richness (number of taxa) and species abundance (number of individual organisms in taxa (Magurran, 2004). The species richness and abundance of macro invertebrate encountered identified, recorded and data obtained were subjected to a set of indices using Margalef richness and Shannon-Weiner indices. This was done in accordance with the fact that single index can lead to erroneous conclusions about biological diversity (Beisel *et al., 2003;* Elias and Limbikani, 2017).

Analysis of variance (ANOVA) was used to analyse the differences in the environmental parameters of the various sampling stations, with the use of Turkey HSD test to determine if the relationship or difference in the mean of parameters between the three stations were statistically significant.

2.5. Determination of Impact of In-Stream Sand Mining on Habitat Structure Through Macrophyte Sampling.

River depths and macrophyte community of the stations were determined and recorded. Eckman's grab was calibrated and inserted into the river from the water surface at various stations.The depth ranges of each station was taken and recorded.

Macrophyte collections were carried out by channel plucking and uprooting of vegetation from the sampling points in the stations. Composite collections of macrophytes from each station were sorted by grouping same species together. The semi-submerged macrophytes were transported to Department of Plant Science and Biotechnology, University of Port Harcourt for identification. Identified species were recorded according to their respective stations. The terms suitable, fairly suitable and not suitable was used to categorized the habitat structure recorded. The term suitable was used for habitat that possess all the macrophyte species collected, fairly suitable where the species were less than the total number collected and not suitable where no macrophyte species was found.

2.6. Determinaton of Impact of In-Stream Sand Mining on Life Support Environmental Parameters

Standard methods used for measurement of dissolved oxygen, turbidity and pH was employed. Calibrated handheld HACH Electronic DO meter and calibrated handheld Hannah pH electronic meter D1-4337 were used to measure the dissolved oxygen and pH, respectively. They were determined in-stiu. Turbidity was determined by nephelometric turbidity meter (NTU). Dissolved oxygen, turbidity, pH values and macrophyte compositions of the stations were determined using standard methods and data obtained analysed to determine the impact of the operational sand mining methods on the habitats and its suitability for macroinvertebrates habitation (Table 2 and 3).

3. Results and Discussion

Impact of In-Stream sand mining on Biodiversity of Macroinvertebrates

3.1. Direct Impact on Species Richness and Abundance.

A total of 456 individual macroinvertebrates belonging to 18 taxa or species in three subcommunities; meiobenthic (oligochaeta), entomofaunal (insect), and crustacea were encountered during the period of study (Table1).

Table1. *Abundance of Macroinvertebrate Community at Eleme River during the Period of Study*

S/N	Species	Family	Mechanical	Manual	Unmined
1.	*Ophidonais sp.*	Naididae	-	22	-
2.	*Nais sp.*	Naididae	7	18	-
3.	*Paranais sp.*	Naididae	3	10	-
4.	*Chaetogaster sp.*	Naididae	-	14	-
5.	*Aeolosoma sp*	Aeolosomatidae	-	27	-
6.	*Elseniella tetrahedral*	Lumbricidae		24	-
	Sub-Total		10	115	-
7.	*Diplonychus rusticus*	Belostomatidae	3	-	1
8.	*Lethocerus indicus (americanus)* (waterbug)	Belostomatidae	-	-	6

9.	*Naucoris sp.* (creeping water bug)	Naucoridae	1	-	4
10.	*Leptonea sp.*	Hydropsychidae	-	-	9
11.	*Aphelocheirus grik*	Aphelocheiridae	-	-	4
12.	D*ytiscus sp.*	Dytiscidae	-	-	5
13.	*Chironomus sp*. (larvae)	Chironomidae	-	-	3
14.	*Dragonfly* nymphs	Libellulidae	-	-	8
	Sub-total		4	-	33
15	Daphina barbata	Brachipoda	6		2
16	Apus sp	Brachipoda			36
17	Macrobrachium sp	Malacostraca	30	152	3
18	Sudanonautus africanus africanus	Malacostraca	29	34	
	Sub-Total		65	188	41
	Grand Total		79	303	74

The encountered species belong to twelve families, with naididae which consists of five taxa (or species) as most dominate family, followed by Belostomatidae, Brachiopoda and Malacostraca which consists of two taxa each (Table 1). The remaining eight families consists of one taxa each (Table 1). The entomofaunal subcommunity which consist of seven families was recorded as the most dominate among the subcommunity-families.

These macroinvertebrates species were differently distributed along mined and unmined river habitat as; mechanical (17.32%), manual (66.45%) and unmined (16.23%). The total percentage abundance distribution among the subcommunities were; 64.47% (crustacean), 27.41% (oligochaeta), and 8.11% (insecta) (Fig.1a&b). Fig. 2 indicates that the manual instream recorded more crustaceans and oligochaetes, though all the three subcommunities occurred at the mechanical, insect and oligochaetes were not encountered at the manual and unmined, respectively, due to the shallow depths of the river and absence of vegetation which would have provided shelter for the organisms.

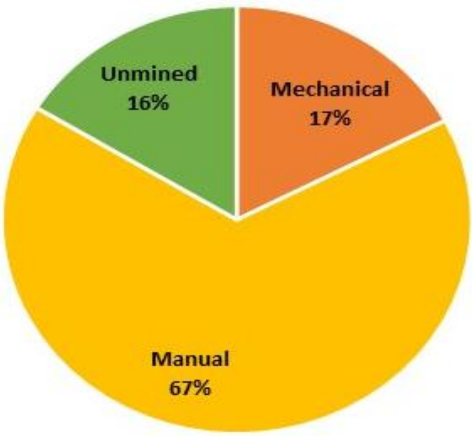


Fig1a. *Distribution of Macroinvertebrates in the three habitat-types at Eleme River, Nigeria.*

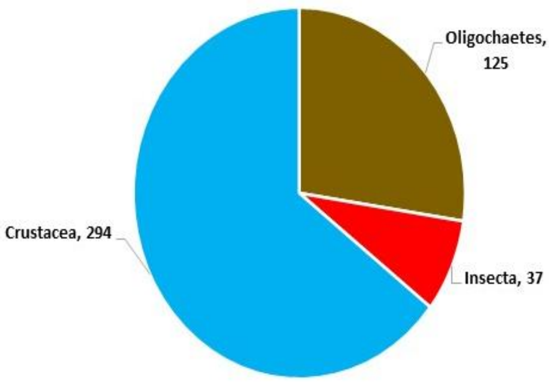


Fig1b. *Percentage Distribution of macroinvertebrates among three subcommunities at Eleme River*.

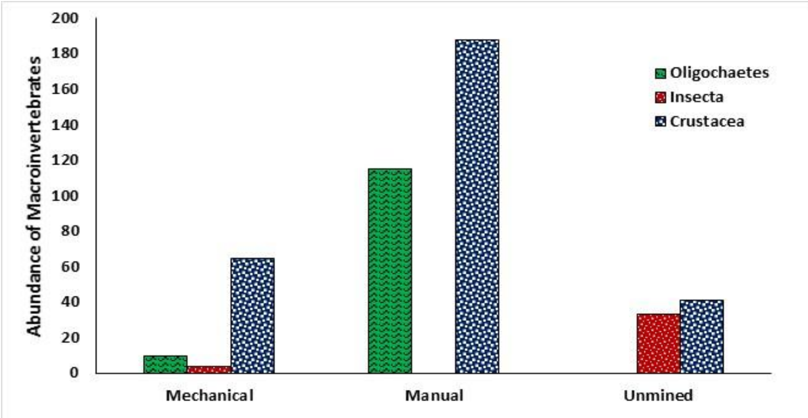


Fig2. *Total abundance of three subcommunities of macroinvertebrates of Eleme River, Nigeria.*

Out of 18 taxa or species encountered, direct impact on the habitat-types caused loss of 9 species (representing 50%) in manual and 12 species (representing 66.7%) in mechanical-habitat-types because only 9 and 8species respectively were encountered during the study. The absence of meiobenthic at the unmined habitat- type was caused by the non-sampling of its sediments as it was shallow, full of sand and gravel and could not permit the use of the grab.

The type or method of In-stream sand mining cause a huge reduction or loss in the biodiversity of macroinvertebrates community in Eleme River.

In- stream sand mining impacts, the sub-communities through direct reduction or loss of species or reduction in their abundances. The impact was more severe in the Entomofaunal sub-community where out of the 8 species encountered, only one; *Diplonychus sp.*, occurred at mechanical habitat-type. Similarly, out of the 6 species collected from the meiobenthic sub-community, only 2species occurred at the mechanical habitat-types indicating that 4species were lost. In the crustacean sub-community, all the 4 species collected except one; *Apus sp.*, was lost in both mined habitat-types, because it was encountered(Table 1).The severity of the impact was recorded in the following descending order in the sub-communities; Entomofaunal>Meiobenthic (Oligochaeta) > Crustacean.

The impact of in-stream mining was not observed on five species of macroinvertebrates as they all occurred in mined habitat-types. These are *Nais sp*; and *paranais sp* (Oligochaeta or meiobenthic subcommunity), *Daphnia sp.*, *Macrobranchium sp.*, and *Sudanonautus sp.*, (crustacean sub-community). The presence of four Naidids; *Ophidonais sp, Nais sp, Paranais* and *Chaetogaster sp.*, in the manual habitat-type also give credence to the fact that sand mining methods impact differently on the oligochaete richness in fresh water body. Moreso, the occurrence of two naidids; Nais sp and Paranais sp in both habitat-types, and absence of two taxa; *ophidonais sp.*, and *chaetogaster sp.*, in mechanical sand mining habitat-types further affirm this fact.

The decrease in species richness in Entomofauna from 8 taxa in unmined to 2taxa in mechanical habitat-types indicates the impact of methods used in sand mining. This agrees with the report that such decrease is caused by the mining (Brown et al., 1998). The decrease in species richness consequently caused a decrease in the abundance (number of individual species in taxa). The numbers of individual species collected from the habitat-types indicated that the impact of sand mining was severe at mechanical. On decrease in abundance among habitat diversity, mechanical habitat-type was more impacted negatively than manual habitat-type. Relative abundance in sub-communities indicated that Entomofaunal sub-community is more affected by sand mining. This is also evidenced by the result of the statistical analyses in which a significant difference in taxa, and abundance between the macroinvertebrate groups, and between habitat-types at 0.05level, indicated the impact of in-stream sand mining types on the organisms, and its habitats (Table 2).

Table2. *Diversity Indices per Stations for Macro-invertebrates*

Index	Mechanical	Manual	Unmined
Taxa-S	4	6	8
N0. Of Individual	14	115	40
Dominance-D	0.347	0.174	0.155

Simpson	0.653	0.788	0.845
Shannon Wiener (H)	1.195	1.65	1.949
Evenness	0.826	0.867	0.878
Margalef	1.137	1.054	1.898
Equitability (J)	0.862	0.921	0.937

Similarly, the physical parameters indicated such significant difference among the habitat-types.

It will be recalled that Koehnken (2018) reported that sand mining have impacts on population such as loss of native species, thus the loss recorded in this study in the mechanical habitat-type is in line with this report. This is because, the indigenous species which are absent in the mechanical-habitat type, are all collected in the unmined habitat-type. This is mostly observed with mined habitat types in entomofauna subcommunity where vegetation was not suitable.

4. Impact on Habitat Structure

In-stream sand mining at Eleme river impact biodiversity of Macroinvertebrate community by changing the structure of the habitat. The common vegetation cover encountered were *Ischaemum rugossum, Acrocerus zizanionides, cummelina erecta*, and *Panicum laxum* (Table 3).

Table3. *Macrophytes Species Collected from Eleme River During the Period of Study*

S/N	Species	Mechanical.	Manual	Unmined
1.	*Ischaemum rugossum*	+	-	+
2.	*Acroceras zizanioides*	-	-	+
3.	*Cummelina erecta*	-	-	+
4.	*Panicum laxus*	-	-	+
	Total	1	-	4

These plant species were all collected from the studied stations except the mined stations, indicating the impact of the mining activities on the habitat structure.

Vegetation cover provides shelter and food for insects, making the habitat suitable for habitation, but this was not the situation in mined stations as the absence of vegetation resulted to the absence of entomofaunal assemblage at the mined stations. This situation consequently created weak habitational relationship between entommofauna and Eleme River at mined stations, which was contrally at the unmined stations.

At unmined stations, the vegetation cover provided suitable habitats for entomofaunal sub-community, resulting to the presence of 8 taxa; D. *rusticus*, L. *indicus*, *Naucoris* sp, *Leptonea* sp, A.*grik*, *Dytiscus* sp, *Chironomus* sp and *Dragonfly* nymphs. The absence of vegetation cover among the mined stations, affected the habitation of macroinvertebrates highly in the mechanical stations, as they were not suitable for the species.

The absence and presence of four types, of vegetation cover at the mined and unmined habitat-types, respectively indicated changes in the structure of habitats and established linkage of habitational relationship with aquatic entomofauna at Eleme river. Such linkage was absent at the highly impacted stations of mechanical and manual habitat-types. This is in consonance with Gumiero *et al.* (2015) report that vegetation types have relationship with assemblage of macro-invertebrate diversities and such relationship diminished in highly impacted river stations.

These changes in habitat structure caused by sand mining however widened water columns and deepened sediments where crustacean and meiobenthic sub-communities inhabit. This was observed with the Eckman's grab which got into deeper depths of 28cm at mined stations. These changes impacted mined stations due to incision that accompanied sand mining, and provided linkage of habitational relationship between the crustacean subcommunities and mined stations. In the crustacean sub-community, the widening of the river column created suitable habitat for free swimmers and caused increase in their population in slightly impacted manual stations, than mechanical stations, because it opened enough spaces for navigation and search for food. This also occurred in the mechanical stations but the incision caused by the use of machines was too sharp to provide such inhabited spaces. This created weak habitational relationship linkage which worsened with oligochaetes assemblage in the sediment samples of highly impacted mechanical stations (Table 1).

5. Changes in Life Support Environmental Parameters

The mean values of life Support Environmental Parameters; Dissolved Oxygen (DO), pH was slightly higher while that of turbidity was slightly lower in the mined impacted stations (Table 4).

Table4. *Physico-chemical parameters of Three Habitat- Types of Eleme River During the Period of Study*

Parameters	WHO	Mechanical	Manual	Unmined
DO (mg/L)	7.5	5.4 – 5.8 5.83 ± 0.12	5.0 – 6.1 5.63 ± 0.33	4.02 – 4.51 4.35 ± 0.17
pH	6.5 – 8.5	6.63 – 6.68 6.65 ± 0.01	6.71 – 6.79 6.75 ± 0.02	6.34 – 6.40 6.37 ± 0.02
Turbidity	15	13.8 – 15.5 14.7 ± 0.49	11.5 – 15.8 14.1 ± 1.32	14.3 – 16.7 15.7 ± 0.72

The mean values of all the three parameters analyzed were within the intervention (permisable) levels of World Health Organization. The concentration of DO mined stations for instance, is slightly above that of unmined station, but both are within the allowable limit. It is 5.83mg/l (mechanical), 5.63mg/l (manual), 4.35mg/l (unmined) and 7.5mg/l (WHO).

The results showed an increase in the pH and Dissolved Oxygen at the mined station above the unmined stations, indicating the impact of in-stream sand mining on such parameters suitable for macroinvertebrate habitation. Gbarakoro *et al* (2020) recorded similar values of turbidity and DO in Eleme River and attributed turbidity values to high dissolved solids and suspended solid particles like colloidal organic matter and silt.

Ajibare (2014) suggested that optimum DO required to support diversity of aquatic life, ranges from 4 to 9mg/L. This may be true in an undisturbed water body as it is in unmined stations in our study, however in water body associated with sand mining and other stressors, support for aquatic life may be hindered. The hindrance which is pointed out in our study is not linked with the slight changes in environmental parameters which is still within the allowable limit, rather it is linked with sand mining activities that accompany widening, deepening of river, disruption and loss of habitats, including loss of macrophytes. This implies that in-stream sand mining though caused slight changes in DO, turbidity and pH which do not exceed allowable limit did not have much impact on diversity of macroinvertebrates at Eleme river, rather its effects on vegetation cover, and habitat loss impact diversity of macroinvertebrates.

6. Conclusion

Sand mining affected biodiversity of macroinvertebrate composition at Eleme River, Nigeria, with that of mechanical method having much impact. The impacts occurred through disturbance on vegetation cover and habitat loss. Three sub-communities of macroinvertebrates were encountered at Elemse River, and Entomofaunal sub-community was the most impacted. There was reduction in species richness and abundance of entomofaunal assemblage due to the severity of the impact of sand mining at the Eleme river. The impact created suitable linkage of habitational relationship between crustacean subcommunity and mined stations, and weak linkage of habitational relationship between oligochaetes assemblage in the sediments and mechanical stations.

Sand mining did not only caused a reduction in macroinvertebrate diversity but also a reduction in macrophytes which provided habitats and food for the animals. At Eleme river, a complete absence of four major macrophytes was observed at the mined stations, but were collected from unmined stations.

The study showed slight changes in life support environmental parameters of dissolved oxygen, turbidity and pH of water in mined stations, but these changes were within the permissible limits recommended by World Health Organization (WHO). This implies that though sand mining accompanied by vegetation removal caused reduction in diversity and abundance of macroinvertebrate at Eleme river, the changes are yet to cause appreciable impacts on life support environmental parameters.

REFERENCES

[1] Beisel, J.N, Polatera, P.U. Bachmann, V. and Moreteau, J.C, (2003). A Comparative Analysis of Evenness Index Sensitivity. *International Review Hydrobiology*, 88 (1): 3-15

[2] Brittain J., and Eikelan, T. (1998). Invertebrate drift – A review. *Hydrobiological*, Vol. 166: 77-93

[3] Brown, A., Lyttle, M. and Brown, K. (1998). Impacts of Gravel mining on Gravel bed streams. *Transactions of the American fisheries Society*, Vol. 2127:979-994

[4] Dudgeon D. (1999). Identification of Fresh Water Invertebrates of the mekong River and Tributaries. Mekong River Publishing Commission, University of Minnesota, USA.276pp.

[5] Elias, R.C, and Limbikani C. (2017) use of benthic macroinvertebrate indices as bio indicators of degraded landscapes in Malawi. *International journal of agriculture forestry and fisheries*; 5(6): 128-134

[6] Gbarakoro, S.L., Gbarakoro, T.N., and Bebu, W.L. (2020). Impact of industrial effluent discharge on the stream, Eleme, properties of Aleto Stream, Eleme, Rivers State, *Nigeria Annual Research and Review in Biology*, 35(1), 79-89

[7] Gumiero, B., Rinaldi, M., Belleti, B., Puppi, G., and Lensi, D.(2015). Riparian vegetation as indicator of channel adjustments and environmental conditions: the case of the Panaro River (Northern Italy). *Aquatic Sciences*, Vol. 77: 563-582

[8] Kanehl, P. and Lyons, J. (1992). Research report 155: impacts of in- stream sand and gravel mining onstream habitat and fish communities Wisconsin department of natural resources

[9] Koehnken, L; and Rintoul, M. (2018). Impacts of sand mining on ecosystem structure, process and biodiversity in rivers. WWF www.panda.org

[10] Kondolf, G. (1993). Geomorphic and Environmental effects of in stream gravel mining. *Land spade and urban planning*, vol – 28: 225-243

[11] Kumar, N., and Kumar, A. (2014). Floristic Diversity Assessment in River Sand Mining near Palri Bhoptan Village, Kisangarh Tehsil, Afmer District, Rajasthan, India. Asian *Journal of Earth sciences*, 7(2): 51-59

[12] Magurran, A.E, (2004). Measuring biological diversity. Blackwell Publishing Company, Science Ltd,USA 132pp.

[13] Obot, I.B, Isreal, A.U, Umorem, S.A. and Mkpeine, V. (2008). Effluents and solid waste analysis in petrochemical company, a case study of Eleme petrochemical Company Ltd, Port Harcourt

[14] Rempel, L. and Church, M. (2009). Physical and ecological response to disturbance by gravel mining in a large alluvial river. *Canadian journal of fisheries and aquatic sciences*, vol. 66: 52 -71

[15] Ajibare. A.O. (2014). Assessment of physic-chemical parameters of water in Ilaje Local Government Area, Ondo state, Nigeria. *International journal of fisheries and aquatic studies* 1(5): 84-92

[16] Skalski, T., Kedzior, R., Wyzga, B., Zawiejska, J., Radecki-P, A., and Plesinski, K. 2016). Impact of incision of gravel bed rivers on ground beetle assemblages. *River research and Applications*, Vol. 32:1968-1977

[17] Tagliapietra, D and Sigo Vini, M (2010). Benthic fauna collection and identification of macrobenthic invertebrates. (www.researchgate.net, publication) or institute of marine sciences CNR-ISMAR; Riva Settle Mantiri 1364/302, Vernice, Italy

[18] Wiggins G.B. (1996). Identification Keys for Tricchotera. 2nd Edition. Larrae of the North America caddisfly Genera (Trichoptera). *Journal of the North America Benthological Society* Vol. 15, No. 3 Pp 403-405. Published by the University of Chicago Press

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