

Assessment of the Impact Artisanal Refinery on the Biodiversity of Macroinvertebrates at Imo-River Oyigbo, Nigeria.

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Abstract: Artisanal refineries which abound the Niger Delta of Nigeria account for a decline in the biodiversity of macro invertebrates and caused changes in the physico-chemical parameters of aquatic ecosystem. In Imo River the impact was investigated using 500um mesh size pond nets and Eckman grab measuring 225cm in a wooden canoe for sampling from two stations. The collected samples were placed in buckets and added with 10% formalin and stained with Euson red stain (0.1%) and taken to the research laboratory, Department of Animal and Environmental Biology, University of Port Harcourt for sorting and identification. Impact of artisanal refineries on the Physico-chemical parameters including Polycyclic Aromatic Hydrocarbons (PAHS) was determined using standard methods. The results showed an increase in PAHs, slight reduction of alkaline pH status, and increase in the abundance of tolerant species of macro-invertebrates to such PAHs values. A total of 206 individual macro invertebrates and ten types of PAHs were encountered and collected from the three study stations. Out of the total individuals, 85 or 41.26% occurred at the artisanal refinery which recorded 14.3 ppm or 47.21% concentration of PAH out of a total of 30.29 ppm. The pH status were acidic in artisanal refinery, and alkaline in boat building/repair stations. The results showed that five types of PAHs that had the highest concentrations all occurred at the artisanal refinery; Acenaphthene (1.98+2.21ppm), Artrracene (1.95+0.86ppm), flourene (1.77+1.24ppm), chryeene (1.96+0.50ppm) and flourancethene (1.44+0.86ppm). The PAHs in this station is almost 3 times higher than the level at boat building/repair station, and the concentration of frengo group of hydrocarbons was also higher in the artisanal refinery station. The presence of micro-invertebrates; Tubifex sp; Dytiscus sp; Gyrinus sp; and Chironomus sp is an apparent exhibition of indifference to pH level and an indication that Imo River, Oyigbo is polluted, as they occur in relative higher abundance in the artisanal station. The relatively high concentration of 5 PAH types is an indication that the Imo River, Oyigbo is dominated by the 5 types, particularly as the detected levels, exceeds the USEPA threshold limit of 0.012µg/l for anthracene. Tubifex sp; with an abundance of 102 species (75.76%) of total macro invertebrates, dominates the Imo Rivers, Oyigbo is polluted, as they occur in relative higher abundance in the artisanal stations. Tubifex sp; with an abundance of 102 species (75.78%) of total macroinvertebrates, dominates the Imo River, Oyigbo. The relatively high concentration of 5 PAH types is an indication that the Imo River, Oyigbo is dominated by the 5 types, particularly as the detected levels, exceeds the US EPA threshold limit of 0.012µg/L for anthracene.

Keywords: Artisanal refinery, macroinvertebrates, Polycyclic Aromatic Hydrocarbons, Tolerant species, biodiversity, Imo River.

1. INTRODUCTION

The Niger-Delta environment of Nigeria is the host to the Nation's Crude oil exploration and exploitation activities which account for over 90% of the country's foreign exchange earnings [1] with attendant degradation of the environment of 13 million tons of spilled oil since its discovery [2].

Following the huge revenue obtained from the oil activities, some unemployed youths of the Niger Delta region become engaged in illegal means of refining Crude oil by obtaining stolen Crude oil and locally refining into petroleum products without professional and requisite technical skills, a process called artisanal refining. They construct artisanal refineries, using metal pipes and drums welded together in which crude oil is boiled and the resultant distillates collected, cooled and condensed in tanks for sale to energy, and transport consumers [3]. Artisanal refinery is a non-standardized refinery site that contain non-treated wastes which contain Polycyclic Aromatic Hydrocarbons as the most abundant hydrocarbons in Crude oil mixture [4] and its surrounding vegetation [5].

The effect on the ecosystem is so devastating such that [6] cautioned that the toxicity on the Niger Delta soil caused alteration of the soil chemical properties and if not checked will potentially devastate the wetland ecosystems. In this region, it has caused among others, mass deaths of refineries, through accidental burning, soot production resulting to atmospheric pollution causing a lot of respiratory illnesses, contamination of the surrounding water bodies through run-offs and effluent discharges. Consequently, impacts on the biodiversity of macro invertebrates; some of which possess potential for use in biological assessment of human impact will be attained particularly as they are the most ubiquitous and diverse component of water bodies [7].

The impact on biodiversity of Macro invertebrates emanates from the soot which form scums that cover the water surface and reduce the navigation space for insects that visit the surface to replenish their gases. Additionally high concentration of hydrocarbon [8]; [9] run-offs and effluent [10] from artisanal refineries reduce dissolved oxygen available to macro invertebrates, leading to a decline in its density.

Macro invertebrates, particularly insects are the group in the aquatic ecosystem most directly affected by any disturbance or pollution because of their high diversity and abundance [11]. In the Niger Delta region of Nigeria, studies on the impact of human activities; bathing/laundry, abattoir and waste dumps on the physico-chemical parameters and biodiversity of arthropods (insects) in water bodies has been reported. Enajero and Gbarakoro [12] reported a reduction in dissolved oxygen, phosphates and increase in the temperature, pH mean values and conductivity in highly human disturbed sites of Isiokpo River. The dominance of *Chironomus* sp and low abundance of species that belong to three orders of insects; Ephemeroptera, Plecoptera and Trichoptera in highly impacted Isiokpo Rivers was also reported, indicating that the river is not ecologically healthy. This is true as [13]; [14] reported that fresh water insect species belonging to the EPT orders are used as indicators of health status of the water bodies due to their response to environmental changes. The severity of the impact of in-stream sand mining on Eleme River macro vertebrate biodiversity in the Niger Delta occurred in the following descending order sub communities; Entomofauna (insects) Meiobenthos (Oligochaeta) and Crustacean [15].

Imo- River, Oyigbo is a fresh water body characterized majorly by three human activities; sand mining, wooden boat building/repairs, and artisanal refineries. It has vegetation and serves as recipient of effluents and deposits from run-offs. The physico-chemical parameters and pollutant status from domestic wastes of the river has been [16]; [17].

There are virtually little or no available literature on the impact of artisanal refineries on the biodiversity of macro invertebrates in Imo River. Therefore, this present study is designed to provide adequate information to fill such gap in literature and the river, with the following aim and objectives;

Aim and Objectives

To assess the impact of artisanal petroleum refinery on the biodiversity of macro invertebrates in Imo-River, Oyigbo.

Objectives:

1. To ascertain the impact of artisanal refinery on some physico-chemical parameters of the Imo River
2. To determine the composition and distribution of macro invertebrates in artisanal refinery impacted section of Imo River.

2. MATERIALS AND METHODS

2.1 Description of Study Area/Sites.

The study area is the Oyigbo axis of the Imo River which is the southern part of the metropolis and was divided based on type of human activity into three study stations (sites); station I (6 34' 24 "N; 3 31 52"E) is located near the bridge where building/repair of wooden boats takes place. In this station, prominent vegetation present includes; ostrich fen (*Matteuccia struthiopteris*), green arrow arum (*Peltandra virgatica*) and decayed giant reed (*A.donax*).

Station 2 is located on 6 47' 36 "N and 3 27' 29"E and is the former loading site for artisanal (illegal) refinery where run-off from the refinery enters the water body, and vegetation present are ostrich fern (*M. struthiopteris*). Station 3 is located slightly adjacent to the refinery with matrix (6 52' 19"N and

3 43' 41"E) and is the site for sand mining. The vegetation in this station includes; *A. donax*, prickly lettuce (*lactuca serriola*) and primrose- willows (*ludwigia palustris*).

Each station was divided into three sampling points which some as replicates a completely randomised Design. Each sampling points was 15cm while each station was 50cm- apart.

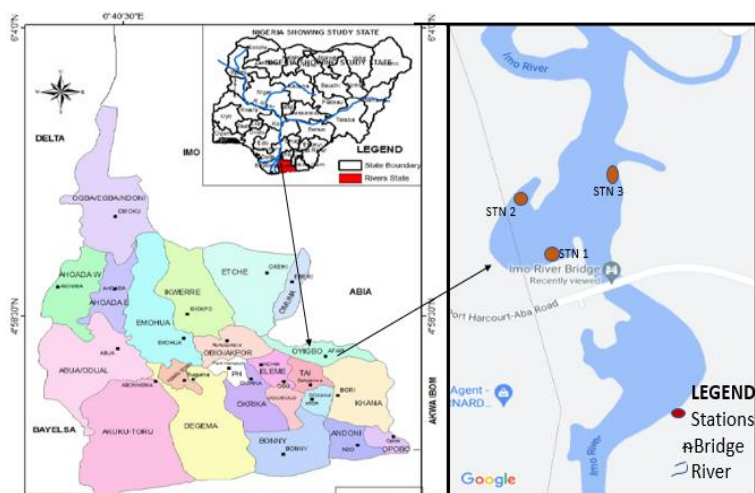


Figure1. Study area

2.2 Determination of Impact of Artisanal Refinery on Physico-Chemical Parameters.

Water samples were collected with 250ml plastic bottles and used for analysis of chemical variables. Calibrated handheld NACH Electronic Do meter for measurement of pH, was engaged and all the measurement were in-situ. Total dissolved solids (TDs) and electrical conductivity of the surface water was also determined in-situ using handheld digital multiple TDs and EC meter (H1-9127) produced by Excelvan Ltd, China. Total Nitrates and phosphates concentrations were determined spectrophotometrically using standard methods (calibrated HACH 3900 DR) spectrometer.

2.3 Determination of Impact of Artisanal Refinery on Macroinvertebrates Sampling

Macroinvertebrate samples were collected from the sampling points using 500um mesh size pond nets and Eckman's Grab measuring 225cm³ in a wooden canoe [18]. During sampling, the net was jabbed under floating vegetation and the vegetation shaken to dislodge organisms from the vegetation and sediments.

Collection with Eckman's grab was also carried out from the sediment and excess materials collected along with the organisms were sieved to remove excess fine sediments with residue emptied into 4-L white plastic bucket. In the bucket 10% formalin was added and stained with Eusson red stain (0.1%). The samples were taken to the Entomology Research Laboratory, Department of Animal and Environmental Biology for sorting, and identification, using identification keys and dissecting microscope. At the end of identification, species were grouped, counted and recorded according to their macroinvertebrate sub-communities, and sampling stations.

2.4 Biodiversity Analysis

Diversity Index: Margalef and Shannon-Weiner indices were used to analyse the data in accordance with the fact that single index can lead to erroneous conclusion about biological diversity [19]; [20]. Analysis of variance (ANOVA) was used to compare the physiochemical parameters of the sampling stations with post-hoc test to separate the means done with Turkey's HSD test.

2.5 Determination of Impact of Artisanal Refinery on Polycyclic Aromatic Hydrocarbon Concentration

Water samples for analysis of PAH were collected from the sampling stations, randomly and manually using 1 litre plastic containers. The samples were analysed using EPA analytical method 8015 modified where hydrocarbons were measured by Gas chromatography flame ionization detector GCFID. The wave length was set at 425nm and the transmitter adjusted to 100% (zero absorption).

3. RESULTS AND DISCUSSION

The result of the study showed an increase in polycyclic aromatic hydrocarbon concentration (PAHs), slight reduction from alkaline to acidic status of the pH, and increase in the abundance of tolerance species of macro-invertebrate in response to the changes in the physio-chemical parameters of the water samples collected from stations of the artisanal refinery.

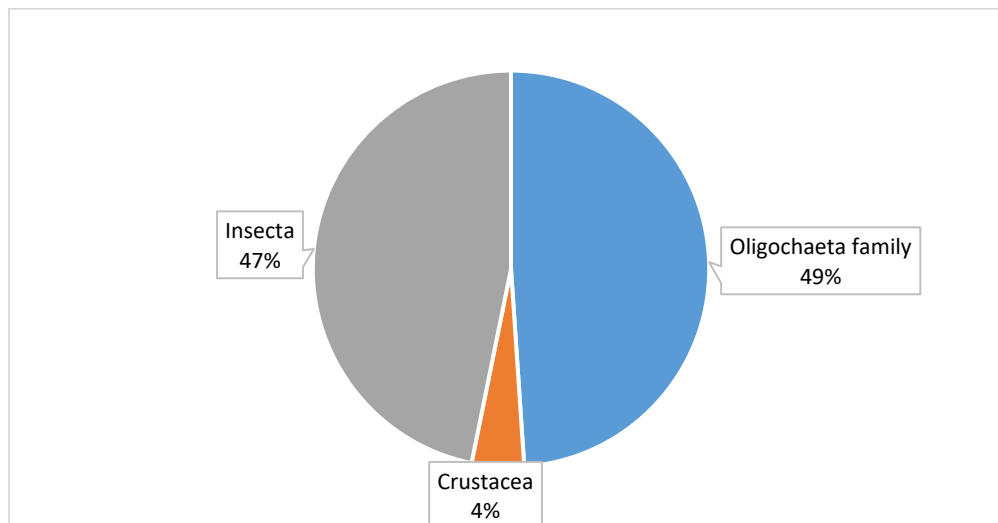


Fig2. Impact of Artisanal refinery on the abundance of groups of macroinvertebrates at the study stations.

A total of 206 individual macroinvertebrate and ten types of polycyclic aromatic hydrocarbon were encountered and collected from all the three stations, during the study. Three groups of macroinvertebrates were encountered; oligochaeta, crustacean and insect, and eighty-five out of the individuals, representing 41.26% occurred at the artisanal refinery station (Fig 2.) which recorded 14.3ppm or 47.21% concentration of PAH (Fig. 3) out of a total 30.29ppm. In this station, the pH was slightly acidic (Table 1) indicating that artisanal refinery changes the pH of water samples in the impacted station against that of boat building/repair station which was alkaline.

Table1. Impact of Artisanal Refinery on the Physiochemical Parameters of Imo River, Oyigbo at the Study Station.

Parameters	Stations			Overall	NESREA (2011) Standard
	BOAT BUILDING/REPAIR	ARTISANAL REFINERY	SAND MINING		
Temp (*C)	31.72 ± 1.70 ^a	30.82 ± 1.49 ^{ab}	30.47 ± 1.55 ^b	31.00 ± 1.61	<40
pH	7.08 ± 1.02 ^a	6.18 ± 1.44 ^b	5.82 ± 1.44 ^b	6.36 ± 1.37	6-9
Salinity (ppt)	9.61 ± 1.08 ^a	9.5 ± 0.83 ^a	9.71 ± 1.19 ^a	9.60 ± 1.00	-
EC (µs/cm)	45.27 ± 28.03 ^a	17.98 ± 3.84 ^b	16.68 ± 3.94 ^b	26.61 ± 20.79	-
TDS (MG/L)	21.78 ± 14.47 ^a	9.26 ± 1.55 ^b	7.47 ± 1.76 ^b	12.84 ± 10.40	<2000
DO (mg/L)	7.14 ± 0.56 ^a	7.35 ± 0.44 ^a	7.15 ± 0.59 ^a	7.21 ± 0.52	>6.0
Nitrate (mg/L)	0.003 ± 0.001 ^a	0.001 ± 0.000 ^b	0.002 ± 0.000 ^c	0.002 ± 0.001	9.1mg/L
Phosphate (mg/L)	0.008 ± 0.005 ^a	0.006 ± 0.001 ^{ab}	0.004 ± 0.002 ^b	0.006 ± 0.003	3.5mg/L
Means within rows with different superscript are significant at p<0.05					
Key: Temp – Temperature, pH – hydrogen ion concentration, EC – electrical conductivity, TDS – total dissolved solid, DO – dissolved oxygen demand.					

The results showed that artisanal refinery station was the most impacted because of the high total concentration of polycyclic aromatic hydrocarbon which was 14.3ppm or 47.21%, while sand mining, and boat building/repair recorded 10.3ppm or 34.0 % and 5.69ppm or 18.79%, respectively (Fig. 2). Furthermore, the five types of hydrocarbon that had the highest concentration, all occurred at the

artisanal refinery; acenaphtane (1.98 ± 2.21 ppm), anthracene (1.95 ± 0.86 ppm), flourene (1.44 ± 0.86 ppm). The PAH in station 2 is almost 3 times higher than the level in station 1(boat building/repairs).

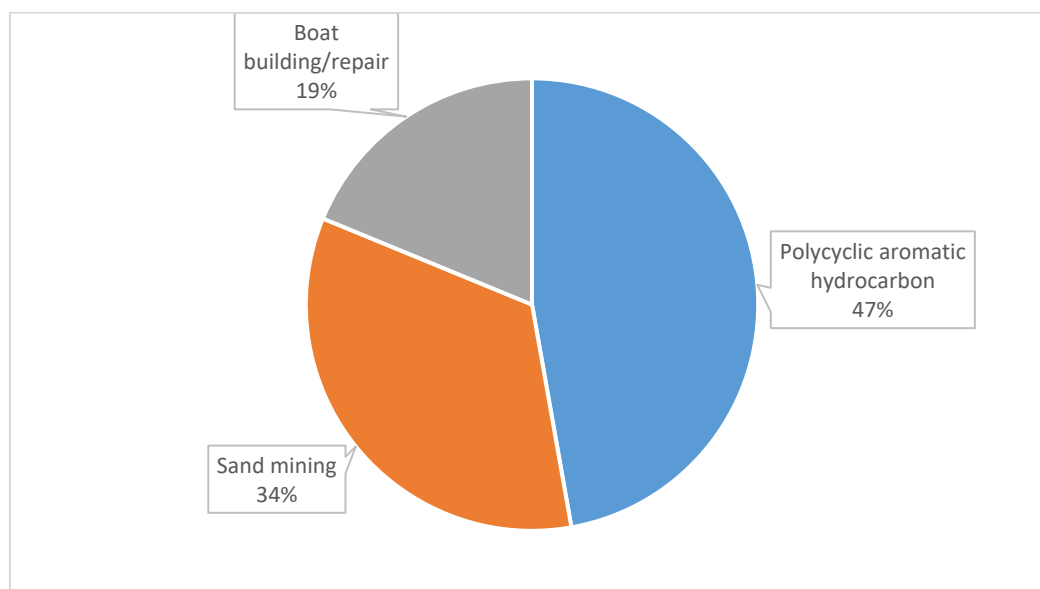


Figure3. Impact of artisanal refinery on the distribution of concentration of PAHs at the study stations

Similarly the Benzo group of hydrocarbons had higher concentrations in the artisanal refinery station than the other two stations (Table 2). The highest concentration of PAHs in this study was in acenaphtene (1.56 ± 1.15 ppm) across the stations, indicating that artisanal refinery of crude petroleum oil increase acenaphtene than any other PAHs in the Imo River, Oyigbo.

Table2. Impact of Artisanal Refinery on the concentration of PAHs in water samples collected from the three Study Stations.

S/N PAHs	Stations			Overall
	BOAT BUILDING/REPAIR	ARTISANAL REFINERY	SAND MINING	
1. Acenaphthylene	0.60 ± 0.32^b	1.39 ± 0.94^a	1.68 ± 0.59^b	0.89 ± 0.74
2. Acenaphthene	1.12 ± 0.85^c	1.98 ± 1.21^a	1.57 ± 1.32^b	1.56 ± 1.15
3. Flourene	1.01 ± 0.78^b	1.77 ± 1.24^a	1.37 ± 1.32^b	1.38 ± 1.14
4. Anthracene	0.47 ± 0.43^c	1.95 ± 0.86^a	1.42 ± 1.17^b	1.28 ± 1.04
5. Flouranthene	0.86 ± 0.67^b	1.44 ± 0.86^a	1.03 ± 1.05^b	1.11 ± 0.88
6. Benzo (a) Anthracene	0.60 ± 0.28^b	1.31 ± 0.67^a	1.82 ± 1.00^b	0.91 ± 0.75
7. Chrysene	0.30 ± 0.13^c	1.96 ± 0.50^a	1.29 ± 1.00^b	1.18 ± 0.93
8. Benzo (b) Flouranthene	0.24 ± 0.35^b	0.77 ± 1.10^a	0.76 ± 1.11^a	0.59 ± 0.92
9. Benzo (k) Flouranthene	0.27 ± 0.18^b	0.75 ± 0.58^a	0.59 ± 1.70^a	0.54 ± 0.55
10. Benzo (a) pyrene	0.22 ± 0.17^b	0.98 ± 0.50^a	0.77 ± 1.67^a	0.65 ± 0.57

Means within rows with different superscript are significant at $p < 0.05$

The relatively high concentration of five types of PAHs recorded in this study indicates that Imo River, Oyigbo is dominated by the five types, particularly as the detected levels, exceeds the threshold limit of $0.0012 \mu\text{g/l}$ for anthracene [21].

The concentrations of the five PAHs detected were significantly different in the artisanal refinery station from the other stations, giving credence to the fact that artisanal refinery increased the level of PAHs in an oil impacted ecosystem. The significant difference in pH values between the artisanal refinery and boat building/repair stations also collaborates this result. Ite and Udo [22]; Eetseh and Ichakpa [23] implicated gas flaring has been responsible for increase in atmospheric CO_2 resulting in the production of acid rain in the Niger Delta due to run-offs. Our study have added to this assertion that artisanal refinery in the Niger Delta also caused a decrease in pH to slightly acidic due to the burning of crude oil resulting in the run-off of rain water into the adjoining water body.

In spite of the changes in pH, and increase in the concentration of PAHs in Imo River, Oyigbo, at the artisanal refinery impacted stations, macroinvertebrate species were relatively higher. The high diversity of species were mainly tolerant species that tolerated the changes. [24] stated that some insect species belonging to the orders; Diptera, Hemiptera and Coleoptera exhibit apparent indifference to pH level. This was the case with our study with exhibition by *Dytiscus* sp; *Gyrinus* sp (Coleopteran), *Gerris* sp (Hemiptera) and *Chironomus* sp (Diptera) (Table 3).

Table3. Impact of Artisanal Refinery on the Physiochemical Parameters of Imo River, Oyigbo at the Study Station.

S/N	Macroinvertebrates	Stations			Total
		1 BOAT BUILDING	2 ARTISANAL REFINERY	3 SAND MINING	
A	Oligochaeta family				
	1. Tubifex tubifex sp (tubificidae)	36	15	51	
	2. Libydriilus sp (eudrilidae) earth worm	3	31	1	
	Sub Total	39	46	52	
B	Crustacea				
	Desmocariss Trispinosa	0	4	2	
C	Insecta				
	1. Pelocoris sp (hemiptera: naucouridae)	6	8	-	
	2. Gerris sp (hemiptera: corixide)	-	4	-	
	3. Dytisnus sp (coleoptera: dytiscidae)	10	6	-	
	4. Gyrinus sp (coleoptera: gyrinidae)	-	7	-	
	5. Culex sp (diptera: culicidae)	6	5	6	
	6. Chironomus sp (diptera: chironomidae)	-	5	-	
	Sub Total	22	44	6	
	Total	61	85	60	206

The abundance of these species, including *Pelocoris* sp (Hemiptera) in the water samples collected from artisanal refinery impacted stations give credence to the fact that such refinery increase some species which are tolerant to high concentration of PAHs and acidic pH values. The presence of the species are indicators of response of insects to changes in water bodies caused by artisanal refinery run-offs (Table 3). Our study also agree with the report that Eleme River in the Niger Delta, Nigeria lacked insect species due to the absence of vegetation caused by sand mining which would have provided shelter for the arthropods [15]. Thus no insect species were encountered at sand mining impacted stations at Imo River, Oyigbo.

The presence of two species of oligochaetes, particularly *Tubifex* sp; at the three study stations indicates that the Imo River, Oyigbo is polluted and it is severe at the artisanal refinery station. The oligochaetes encountered in this study is in consonance with the species described as those that tolerate low and high pH, low dissolved oxygen [25]; [26]; and [27] and are indicators of changes in environmental condition in water body caused by artisanal refinery (Table 3).

4. CONCLUSION

The impact of water samples collected from station receiving run-off from artisanal refinery at Imo River, Oyigbo, showed that *Tubifex tubifex* (Oligochaeta) dominates with an abundance of 102 species (75.76%) of total macroinvertebrates.

The presence and relatively abundance of *Tubifex* sp'. *Gerris* sp'. are indications that artisanal refinery contributes more to the pollution status of Imo River, Oyigbo as they are all tolerant macroinvertebrates. Furthermore, the concentration of PAHS and pH values in the river is impacted by artisanal refinery.

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