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The impact of industrial effluents on the distribution and abundance of macroinvertebrates in River Owo, Lagos, Nigeria

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Abstract

This study investigated the impact of industrial effluents on the distribution and abundance of macroinvertebrates in River Owo, Lagos, Nigeria. Five sampling sites were selected upstream and downstream of an industrial effluent outfall. Macroinvertebrates were collected monthly using D-framed aquatic nets and grabs, identified to family level, and analyzed for abundance, species richness, and diversity. Results indicated that the class Insecta dominated (74.57%) the macroinvertebrate community, with site A (upstream) exhibiting the highest abundance and species richness, while site B (effluent outfall) had the lowest values, indicating heavy pollution. Species such as Tubifex tubifex, Nepa sp., and Eristalis sp. were only found at site B, suggesting their role as pollution indicators. The findings highlight the ecological impact of industrial effluents and emphasize the importance of biomonitoring using benthic macroinvertebrates.

Keywords: Macroinvertebrates, industrial effluents, pollution indicators, River Owo, water quality

Introduction

Assessment of water quality using biological indicators, particularly macroinvertebrates, has increased due to their advantages over chemical methods, which often provide only a temporal snapshot and may fail to detect episodic or non-point source pollution (USEPA, 2004; Albutra *et al*., 2017) [4]. Macroinvertebrates are useful biomonitoring tools because of their sensitivity to local stressors, diversity, longevity, and limited mobility (Edward and Ugwumba, 2011). Integrating biological and chemical monitoring provides a more comprehensive understanding of ecosystem health (Harishman *et al*., 2024). The presence, absence, or abundance of specific taxa can serve as early indicators of environmental degradation (Rosenberg and Reish, 1993; USEPA, 2004) [32]. In Nigeria, such studies are limited, underscoring the need for local water quality criteria to protect biological resources.

Materials and Methods

Study Area

Agbara Industrial Estate, located 31 km west of Lagos on the Badagry Expressway (Lat: 30°00'1"–30°15'1" N; Long: 5°00'1"–10°00'1" E), consists of industrial, commercial, and residential areas. Industrial effluents are treated physically and chemically before being discharged indirectly into River Owo through a swampy forest.

Sampling Sites

Five sites (A–E) were selected: upstream (A), effluent outfall (B), effluent entry (C), and two downstream points (D and E). Water depth varied from 2.6 m to 10.5 m; substrates ranged from clayey-sand to swamp vegetation.

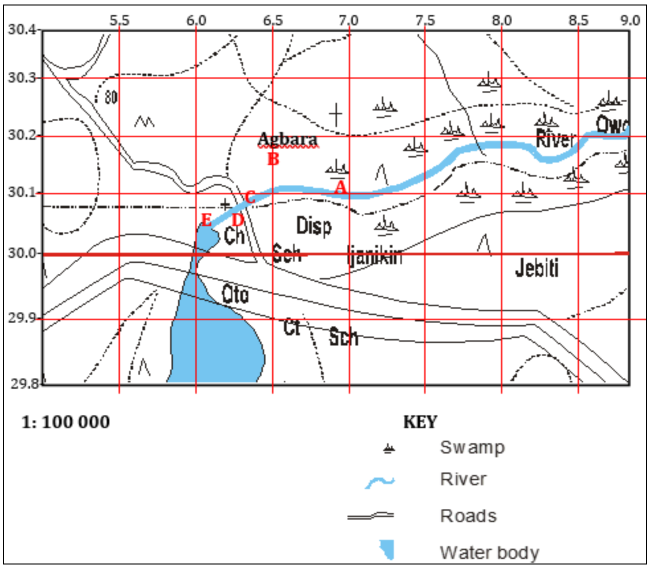
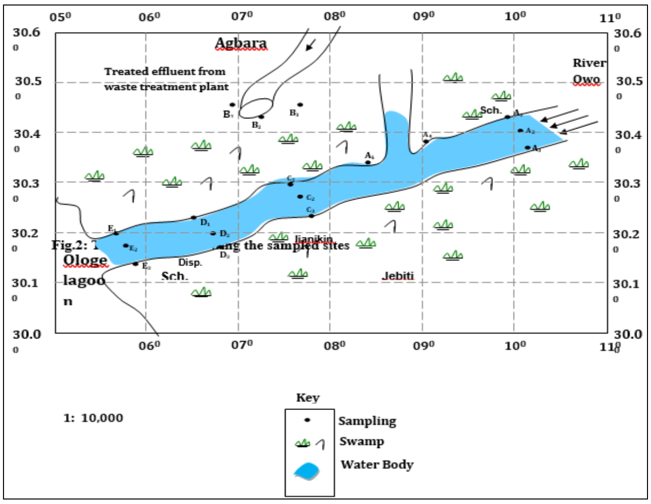


Fig 1: The study area showing the location and geographic features



Sample Collection

Macroinvertebrates were collected monthly using D-framed aquatic nets for shallow waters and grabs for deeper waters. Samples were sieved (0.5–1 mm), preserved in 10% formalin, and sorted using binocular microscopes. Identification used keys from Macan (1960) [21], Needham and Needham (1962) [24], Hynes (1971) [16], Quigley (1977) [31], APHA (1995), and Water Facts (2001) [35].

Sampling site B: This is the effluent outfall B into the swamp (Fig. 2). This site was only accessible through Agbara village. There was no direct link between this site and sites A. The link was an inaccessible swampy forest.

Sampling site C (Fig. 2) was at the point of effluent entry into River Owo after passing through the inaccessible freshwater swamp. It had a depth of between 3.6 at the bank and 9.8metres at the centre.

Sampling Site D: This represented the post-effluent entry point 1 on the River Owo. The water depth varied between 2.8 metres at the bank and 8.9 metres at the centre.

Sampling site E: This represented the second post-effluent entry point 2 on River Owo. The water depth varied between 2.6metres at the banks to 8.9 metre s at the centre.

Collection of water samples and Macroinvertebrates

All macroinvertebrate samplings were carried out in the same areas for water sampling monthly at the sampling sites A, B, C, D, and E. At each sampling site, three (3) sub samples were taken to collect the epifauna and the benthos. The D-framed aquatic net (made with silk material for net and wooden pole), grab (made of iron) was used for the sample collection. The D-framed aquatic net was used for the shallow water of less than four (4) metres deep. Deeper waters were sampled using the grab and D-framed aquatic net. The grab was set in such a way that it would close up on contact with the substratum to be sampled. In the process, the surface bottom sediment is enclosed within the open ends of the grab as it closes. The grab was then lifted out of the water and the sediment sample emptied into a plastic bowl. The vegetation was sampled using the D-framed aquatic net. This sampler was lowered below the vegetation and the vegetation shaken to dislodge any organism present. The organisms so dislodged were retained in the receiving net held below. Each sample collected was screened to remove excess vegetation debris. The rest were emptied into plastic bowls and diluted with water sample from the sites. They were brought to the laboratory where the slurry was poured through standard sieves with mesh size 0.5mm to 1mm mesh openings. The sieved samples were then preserved in 10% formalin pending sorting. Using a 2x-scanning lens and binocular dissecting microscope facilitated sorting. The sorted animals were separated into the major taxonomic categories using the keys in Macan (1960) [21], Needham and Needham (1962) [24], Hynes (1971) [16], Quigley (1977) [31], APHA (1995) and Water Facts (2001). Most sorting was carried out on the day of sample collection, as motile live animals are easier to detect than immobile dead animals. Sorted animals were preserved in 10% formalin. They were later analysed to determine species composition, community structure, species richness and diversity at each site.

Data Analysis

Abundance, species richness (Margalef's index), and diversity were calculated for each site. Species uniquely present at specific sites were considered potential pollution indicators.

Results

Macroinvertebrate Abundance

Insecta was the dominant class (74.57%), followed by Gastropoda (16.66%), Crustacea (4.36%), Oligochaeta (2.46%), and Hirudinea (1.96%). Total abundance by site was highest at site A (32.87%) and lowest at site B (10.57%). Margalef species richness indices were 7.97 (A), 2.20 (B), 8.49 (C), 9.08 (D), and 9.39 (E), indicating site B as heavily polluted.

Table 1: Taxonomic groups of macroinvertebrates in River Owo

Phyllum	Class	Order	Family	Genus	Species	Sites				
						A	B	C	D	E
Annelida	Hirudinea	Gnathobdellida	Hirudidae	*Hirudo*	*medicinasis*	10	19	1	2	3
Annelida	Oligochaeta	Tubificida	Tubificidae	*Tubifex*	*tubifex*	0	44	0	0	0
Mollusca	Gastropoda	Basomnatophora	Physidae	*Physa*	*fontialis*	17	0	10	6	10
Mollusca	Gastropoda	Prosobranchia	Lithorinidae	*Lithorina*	*sp.*	13	0	8	7	6
Mollusca	Gastropoda		Lymnacidae	*Limnae*	*metalonsis*	25	0	15	13	16
Mollusca	Gastropoda	Mesogastropoda	Valvatidae	*Valva*	*sp*	5	0	5	9	8
Mollusca	Gastropoda	Limnophila	Planorbidae	*Planorbis*	*sp*	27	0	17	14	12
Mollusca	Gastropoda		Limnae	*Limnaea*	*pereger*	18	0	13	12	12
Arthropoda	Insecta	Ephemeroptera	Baetidae	*Potamanthus*	*sp*	37	0	19	16	11
Arthropoda	Insecta	Ephemeroptera	Baetidae	*Beatis*	*sp*	30	0	17	13	15
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	*Ephemerella*	*sp*	39	0	27	22	17
Arthropoda	Insecta	Ephemeroptera	Ecdyonuridae	*Heptogenia*	*sp*	16	0	8	8	8
Arthropoda	Insecta	Coleoptera	Hydrophillidae	*Hydrocanthus*	*sp*	23	0	14	14	14
Arthropoda	Insecta	Coleoptera	Helmidae	*Helmis*	*maugei*	10	0	8	8	7
Arthropoda	Insecta	Coleoptera	Haliphidae	*Deronectes*	*sp*	30	0	43	19	14
Arthropoda	Insecta	Coleoptera	Haliphidae	*Haliphus*	*fulvis*	12	0	8	11	8
Arthropoda	Insecta	Coleoptera	Gyrinidae	*Gyrinus*	*sp*	29	0	22	16	12
Arthropoda	Insecta	Coleoptera	Gyrinidae	*Dinealus*	*sp*	20	0	7	5	4
Arthropoda	Insecta	Coleoptera	Dytiscidae	*Platambus*	*sp*	22	0	8	16	10
Arthropoda	Insecta	Coleoptera	Dytiscidae	*Hydropous*	*sp*	12	0	7	12	9
Arthropoda	Insecta	Coleoptera	Dytiscdae	*Hybius*	*sp*	6	0	6	9	3

Arthropoda	Insecta	Odonata	Gomphidae	*Gomphus*	*sp*	29	0	21	20	14
Arthropoda	Insecta	Odonata	Coeangriidae	*Coenogrion*	*sp*	12	0	6	6	6
Arthropoda	Insecta	Odonata	Gomphidae	*Ophiogoinphus*	*sp*	25	0	16	12	9
Arthropoda	Insecta	Odonata	Gomphidae	*Ictinogomphus*	*sp*	7	0	5	3	1
Arthropoda	Insecta	Hemiptera	Bellostomidae	*Bellostoma*	*sp*	14	0	8	8	9
Arthropoda	Insecta	Hemiptera	Nepidae	*Nepa*	*sp*	2	13	0	1	0
Arthropoda	Insecta	Hemiptera	Nepidae	*Ranatra*	*linearis*	0	10	0	0	2
Arthropoda	Insecta	Hemiptera	Gerridae	*Geris*	*sp*	20	0	17	16	14
Arthropoda	Insecta	Diptera	Culicidae	*Culex*	*pipiens*	20	14	9	8	10
Arthropoda	Insecta	Diptera	Chironomidae	*Chironomus*	*sp*	18	36	10	10	8
Arthropoda	Insecta	Diptera	Syrphidae	*Eristalis*	*sp*	0	49	0	0	0
Arthropoda	Insecta	Diptera	Lestidae	*Lestes*	*sp*	11	0	13	11	8
Arthropoda	crustacea	Decapoda	Palaemonidae	*Demoscaris*	*sp*	29	0	23	14	12

Interpretation of Table 1: Taxonomic Groups of Macroinvertebrates in River Owo

Table 1 presents the composition, distribution, and abundance of macroinvertebrates collected across five sampling sites (A–E) along River Owo. The taxa identified belong to three major phyla — Annelida, Mollusca, and Arthropoda — encompassing five classes and multiple families and genera.

General Composition

The phylum Arthropoda (Class *Insecta* and *Crustacea*) constituted the most dominant group, followed by Mollusca and Annelida.

Among Arthropods, the order *Ephemeroptera* (mayflies), *Coleoptera* (beetles), *Odonata* (dragonflies and damselflies), *Hemiptera* (true bugs), and *Diptera* (true flies) were the most represented.

The dominance of insect taxa, particularly Ephemeropterans and Coleopterans, suggests that River Owo still supports a diverse macroinvertebrate community in less polluted stretches.

Site-by-Site Distribution Patterns

Site A (Upstream – Reference Point)

Exhibited the highest species richness and abundance across most taxa.

Sensitive taxa such as *Ephemerella sp.*, *Potamanthus sp.*, *Baetis sp.*, and *Heptogenia sp.* were abundant here.

Indicates relatively unpolluted conditions, serving as a control or reference site.

Site B (Effluent Outfall Point)

Recorded the lowest diversity, but highest abundance of pollution-tolerant species.

Dominated by Tubifex tubifex (44 individuals), Eristalis sp. (49), and Chironomus sp. (36).

Also had *Nepa sp.* and *Ranatra linearis*, which are air-breathing hemipterans tolerant to low dissolved oxygen.

The assemblage indicates high organic and chemical pollution caused by industrial effluents.

Sites C, D, and E (Downstream)

Showed gradual recovery in diversity and abundance compared to site B.

Sensitive groups such as *Ephemeroptera*, *Odonata*, and *Coleoptera* reappeared downstream.

Suggests dilution and self-purification effects downstream of the effluent discharge, though full ecological balance was not restored.

Pollution Indicator Species

Pollution-tolerant taxa:

Tubifex tubifex, *Eristalis sp.*, *Chironomus sp.*, *Nepa sp.*, *Ranatra linearis* — all concentrated at site B.

Their abundance confirms organic enrichment and low oxygen conditions typical of polluted waters.

Sensitive taxa:

Ephemeroptera (e.g., *Ephemerella sp.*, *Baetis sp.*, *Potamanthus sp.*) — abundant at site A and reduced or absent at site B.

Their distribution indicates good water quality upstream and stress downstream of the effluent discharge.

Ecological Implications

The drastic drop in diversity at site B reflects the adverse effect of industrial effluents on aquatic biota.

Recovery downstream (sites C–E) indicates partial self-purification and resilience of the ecosystem.

The predominance of *Insecta* across sites (except at site B) signifies moderate ecological integrity in sections of the river away from the pollution source.

The composition pattern aligns with the Pollution Tolerance Index (PTI) model, where tolerant taxa dominate polluted waters and sensitive taxa dominate cleaner reaches.

5. Summary of Ecological Trends

Site	Dominant Taxa	Water Quality Interpretation
A (Upstream)	Ephemeroptera, Coleoptera, Odonata	Clean / Unpolluted
B (Effluent Outfall)	Tubifex, Eristalis, Chironomus, Nepa	Heavily Polluted
C (Near Effluent Entry)	Mixed taxa (recovery begins)	Moderately Polluted
D (Downstream 1)	Coleoptera, Odonata	Slightly Polluted
E (Downstream 2)	Gastropods, Ephemeroptera	Slightly Polluted to Fair Quality

Discussion

Biological assessment has long been used to monitor surface water quality. Organisms in clean waters differ from those in polluted waters (De Pauw and Vanhooren, 1983; Marneffe *et al*., 1997) [23]. Pollution-sensitive taxa (Ephemeroptera, Plecoptera, Trichoptera) decrease in abundance, while pollution-tolerant taxa (Chironomidae, Oligochaeta) dominate in polluted waters (Korndoerfer and Olson, 2004) [19]. In this study, site B exhibited reduced diversity and abundance, highlighting the impact of industrial effluents. Species such as Tubifex tubifex and Eristalis sp., restricted to site B, served as bioindicators. Findings align with previous studies reporting that macroinvertebrate community structure is influenced by organic and chemical pollutants (Weis and Weis, 1996; Nedeau *et al*., 2003; Adakole and Anunne, 2003) [1, 25, 36]. In tropical freshwater systems, insects often dominate (Ibemenuga and Inyang, 2006) [17]. Comparing upstream and downstream sites is essential to evaluate

The data from Table 1 showed a clear spatial pattern in macroinvertebrate community structure along River Owo that is tightly associated with the effluent outfall from Agbara Industrial Estate. Site A (upstream) exhibited the highest taxonomic richness and abundance of pollution-sensitive taxa (notably several

Ephemeroptera: *Ephemerella*, *Baetis*, *Potamanthus*, *Heptogenia*), whereas Site B (the effluent outfall) displayed markedly reduced richness and was dominated by taxa known to tolerate organic enrichment and low dissolved oxygen (e.g., *Tubifex tubifex*, *Chironomus* spp., *Eristalis* spp., *Nepa* spp.). Downstream sites C–E showed a partial recovery in taxonomic composition and an increasing presence of sensitive and moderately tolerant taxa, indicating spatial attenuation of the effluent's impact. Margalef richness values (A = 7.97; B = 2.20; C = 8.49; D = 9.08; E = 9.39) reinforce this interpretation: the effluent discharge point is biologically impoverished relative to both upstream and downstream locations.

Ecological mechanisms explaining the observed pattern

The distinct assemblage at Site B is best explained by one or more of the following, acting singly or synergistically: high organic loading, oxygen depletion (low DO), elevated biochemical oxygen demand (BOD), increased nutrient loads (promoting eutrophication and microbial respiration), and/or toxic contaminants (heavy metals, solvents, surfactants) typical of industrial discharges. Taxa such as *Tubifex* and *Chironomus* are physiologically adapted to hypoxic or anoxic sediments (haemoglobin or hemoglobin-like pigments, behavioral adaptations) and can exploit organic-rich, fine sediments that accumulate downstream of effluent outfalls. *Eristalis* (rat-tailed maggots) are also characteristic of organically polluted waters because their larvae breathe atmospheric air through a siphon, enabling survival in low-oxygen conditions. In contrast, mayfly nymphs (Ephemeroptera) are typically intolerant of low DO, high turbidity, and toxicants; their abundance upstream and near absence at the outfall is therefore consistent with degraded habitat quality where the effluent enters the river.

Downstream recovery (sites C–E) likely reflects a combination of dilution, reaeration, settling of particulate load, and recolonization from less impacted refugia. The presence of diverse Coleoptera, Odonata and a suite of gastropods and other insect taxa downstream suggests that conditions ameliorate with distance from the outfall but do not necessarily return fully to upstream conditions within the sampled reach. The observed pattern is typical of lotic systems receiving pulse or continuous point-source effluent: a sharply altered community at the discharge point with gradual ecological resilience downstream as physical and biological remediation processes operate.

Community structure and functional implications

The pronounced dominance of Insecta across sites (except where tolerant dipterans and oligochaetes dominate at the outfall) indicates that the river still sustains a functioning aquatic food web over substantial stretches. However, the loss or reduction of sensitive taxa at Site B implies loss of functional groups—especially scrapers and shredders associated with mayflies and certain caddisflies—that contribute to leaf-litter breakdown, primary consumer control, and energy transfer to higher trophic levels. A shift toward tolerant taxa typically corresponds to simplified food webs and altered rates of ecosystem processes (e.g., decomposition and nutrient cycling), which can reduce the resilience of the system to additional stressors.

Seasonality, habitat heterogeneity and sampling considerations

Although Table 1 is presented as pooled counts, seasonal differences were noted in the original manuscript (higher abundances during the rainy season). Seasonal flow and temperature changes influence pollutant dilution, habitat availability (vegetation cover and substrate), and life cycles of macroinvertebrates — factors that can accentuate or mitigate effluent impacts. Habitat heterogeneity (depth gradients, vegetation, substrate particle size) recorded at each site is also an important determinant of local assemblages; for instance, fine organic sediments near the outfall favour tubificids, whereas coarser substrates upstream favour mayfly nymphs and many beetles. Therefore, the spatial pattern observed likely integrates seasonal dynamics and habitat structure in addition to pollutant gradients.

Implications for human uses and fisheries

River Owo provides local fisheries, domestic and irrigation services. Biological impairment at the effluent outfall has direct implications for fisheries productivity, as reduced macroinvertebrate diversity and abundance can decrease food availability for juveniles of many fish species. The presence of pollution-tolerant taxa points to sustained organic pollution that can create risk for human uses (e.g., increased pathogen persistence, accumulation of harmful contaminants in the food web). From a management perspective, these biologically-based indicators provide an early warning that engineered treatment and regulatory enforcement are required to reduce ecosystem and public-health risks.

Limitations of the current study

Several limitations should be acknowledged. First, although macroinvertebrate data are a sensitive integrator of ecological condition, causality about specific stressors cannot be confidently assigned without concurrent physicochemical measurements (DO, BOD, nutrients, conductivity, heavy metals, organic pollutants). Second, the data presented are counts pooled across sampling events; formal statistical testing of temporal and spatial differences (e.g., repeated measures ANOVA, Kruskal–Wallis, multivariate ordination) would strengthen inferences. Third, identification to genus or species was inconsistent for some taxa (e.g., several "sp." entries); higher taxonomic resolution and voucher specimens would improve the robustness of indicator assignments. Finally, replication across seasons and more transects downstream would clarify the spatial scale of impact and recovery.

Concluding statement

The macroinvertebrate assemblages in River Owo showed a clear signal of effluent impact: a biologically impoverished site at the effluent outfall dominated by tolerant taxa, with partial biological recovery downstream and relatively intact communities upstream. These patterns validate the use of benthic macroinvertebrates as practical and sensitive indicators of river health and provide an empirical basis for targeted monitoring and remediation actions to protect both ecosystem integrity and human uses of River Owo.

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