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(RESEARCH ARTICLE)

Determination of microplastics and physicochemical parameters in Nwaorie River, Owerri Municipal, Imo State

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Abstract

Microplastic pollution has emerged as a major environmental concern due to its persistence, ecological toxicity, and potential risks to aquatic organisms and human health. This study investigated the occurrence of microplastics and evaluated the physicochemical properties of water samples obtained from Nwaorie River, Owerri Municipal, Imo State, Nigeria. Water samples were collected from upstream, midstream, and downstream regions of the river using standard environmental sampling procedures. Physicochemical parameters including pH, conductivity, turbidity, temperature, hardness, alkalinity, acidity, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), nitrate, phosphate, chloride, sulphate, and total coliform count were determined using standard analytical methods. Microplastic particles were identified using light microscopy and categorized into microfragments, microfibres, and microbeads. The results showed conductivity (144.01 ± 2.16 µs/cm), hardness (148.36 ± 0.23 mg/L), acidity (43.55 ± 0.64 mg/L), BOD (123.4 ± 1.56 mg/L), COD (123.43 ± 1.59 mg/L), phosphate (8.72 ± 0.42 mg/L), and total coliform count ($(1.43 \pm 0.04) \times 10^2$ cfu/mL), all of which exceeded WHO/EU permissible limits. Conversely, turbidity, temperature, nitrate, chloride, sulphate, and total suspended solids remained within acceptable regulatory standards. Microplastic particles including microfragments, microfibres, and microbeads were detected across upstream, midstream, and downstream regions of the river, indicating widespread plastic contamination within the aquatic ecosystem. The occurrence of microplastics and elevated pollution indicators suggests significant anthropogenic influence arising from sewage discharge, urban runoff, domestic activities, and indiscriminate disposal of plastic wastes around the river environment. The findings from this study highlight the growing environmental burden of microplastic pollution and deteriorating water quality within Nwaorie River, emphasizing the need for improved waste management practices, environmental monitoring, and pollution control measures to protect freshwater ecosystems and public health.

Keywords: Microplastics; Physicochemical; Nwaorie-River; Pollution; Aquatic Ecosystem; Light Microscope

1. Introduction

Plastic pollution has become one of the most critical environmental challenges affecting aquatic ecosystems globally. The increasing production and utilization of plastic materials for industrial, agricultural, medical, and domestic purposes have significantly contributed to environmental contamination due to improper disposal and poor waste management practices. Plastics are highly durable synthetic polymers that resist natural degradation processes, allowing them to persist in the environment for extended periods. Over time, larger plastic materials gradually fragment

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into smaller particles through photodegradation, mechanical abrasion, oxidation, and biological weathering, leading to the formation of microplastics (GESAMP, 2015).

Microplastics are generally defined as plastic particles measuring less than 5 mm in diameter and are currently recognized as emerging contaminants of major environmental concern. These particles may originate from primary or secondary sources. Primary microplastics are intentionally manufactured microscopic particles commonly used in cosmetics, industrial abrasives, pharmaceuticals, and personal care products, while secondary microplastics arise from the breakdown of larger plastic debris such as bottles, plastic bags, fishing materials, food packaging, and household plastics exposed to environmental weathering conditions (Pawar et al., 2016). Due to their small size, persistence, and widespread distribution, microplastics have become increasingly difficult to control within freshwater and marine environments. Microplastics possess unique physicochemical properties that contribute significantly to their environmental persistence and ecological impacts. Due to their hydrophobic nature and large surface area, microplastic particles can adsorb and transport environmental contaminants such as heavy metals, hydrocarbons, pesticides, persistent organic pollutants, and pathogenic microorganisms within aquatic systems (Lithner et al., 2011). These adsorbed contaminants may subsequently be transferred through aquatic food chains following ingestion by aquatic organisms. Studies have shown that fish, mollusks, crustaceans, planktons, and other aquatic organisms often mistake microplastics for food particles, resulting in ingestion, bioaccumulation, intestinal blockage, oxidative stress, tissue damage, and metabolic disorders (Ugwu et al., 2021).

Nwaorie River, located within Owerri Municipal in Imo State, Nigeria, serves as an important freshwater resource utilized for domestic activities, irrigation, fishing, and commercial purposes by surrounding communities. Freshwater systems such as rivers, streams, and lakes play a major role in the transportation and distribution of microplastics within the environment. Rivers particularly serve as important pathways through which plastic wastes originating from terrestrial environments are conveyed into larger aquatic ecosystems including oceans and seas (Yang et al., 2021). Consequently, microplastics have been detected in surface water, groundwater, sediments, drinking water, seafood, table salts, and atmospheric particles in different parts of the world. Their occurrence within freshwater ecosystems has raised growing ecological and toxicological concerns due to their persistence and potential interactions with aquatic organisms. Wastewater treatment plants, domestic sewage, urban runoff, industrial discharges, agricultural runoff, and textile washing activities have been identified as major pathways through which microplastics enter aquatic environments (Mintenig et al., 2017). Microfibres released during the washing of synthetic fabrics constitute one of the most dominant forms of microplastic pollution in freshwater systems.

Apart from ecological impacts, microplastic contamination poses serious public health concerns. The increasing detection of microplastics in drinking water sources and edible aquatic organisms suggests possible human exposure through food and water consumption. Previous toxicological studies have demonstrated that prolonged exposure to microplastics may induce inflammatory responses, oxidative stress, endocrine disruption, and alterations in gut microbiota in experimental organisms (Deng et al., 2017). The ability of microplastics to adsorb toxic chemicals and pathogenic microorganisms further increases concerns regarding their potential effects on human health.

Physicochemical characteristics of freshwater systems remain important indicators used in evaluating water quality, pollution status, and ecological health of aquatic environments. Parameters such as pH, conductivity, turbidity, hardness, acidity, alkalinity, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), nitrate, phosphate, sulphate, chloride, and microbial load provide valuable information regarding the degree of environmental contamination and ecosystem stability (APHA, 2012). Variations in these parameters may arise from industrial discharges, sewage contamination, agricultural runoff, decomposition of organic matter, and other anthropogenic activities within river environments. Therefore, this study was designed to investigate the occurrence of microplastics and evaluate the physicochemical properties of water samples obtained from Nwaorie River, Owerri Municipal, Imo State.

2. Materials and methods

2.1. Study Area

This study was carried out at Nwaorie River located within Owerri Municipal, Imo State, Nigeria. The river serves as an important freshwater resource utilized for domestic, agricultural, fishing, and commercial activities by surrounding communities. Water samples were collected from three designated sampling locations namely upstream, midstream, and downstream sections of the river in order to evaluate variations in microplastic distribution and physicochemical properties across the river course.

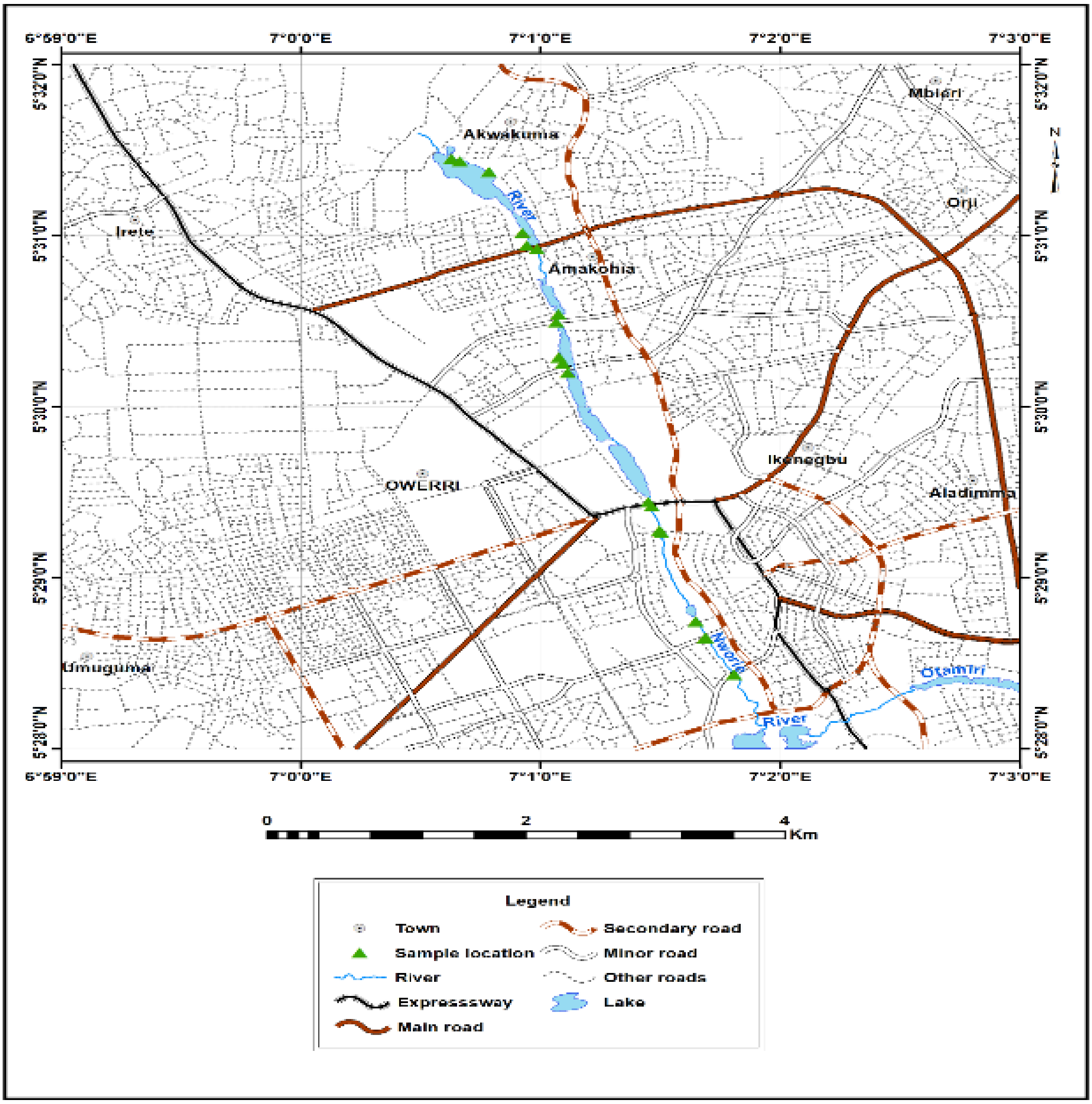

Figure 1 Map of study area

2.2. Collection of Water Samples

Thirty (30) water samples were collected from the stretch of the Nwaorie river (upstream, midstream, and downstream) sections with the coordinates taken at each point of collection to generate the map of the study area. Top and bottom water samples were collected with the aid of niskin water bottle, the samples were then pooled and mixed to obtain a representative sample per collection point for analysis. The water samples were transported to the laboratory for analysis.

2.3. Determination of Microplastics in Water Samples

Microplastic particles present in the water samples were determined using light microscopy and Fourier Transform Infrared Spectroscopy (FTIR) according to methods described by Mintenig et al. (2017). Water samples were filtered through membrane filters to separate suspended particles. The retained particles were examined under an Olympus light microscope for counting, sorting, and classification into microfragments, microfibres, and microbeads based on their morphological characteristics. FTIR analysis was further employed to confirm the functional groups of the identified microplastics.

2.4. Determination of Physicochemical Parameters

Physicochemical parameters including pH, conductivity, turbidity, temperature, hardness, alkalinity, acidity, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), nitrate, phosphate, chloride, sulphate, and total coliform count were determined using standard analytical methods recommended by APHA (2012). Results obtained were compared with WHO/EU permissible standards for freshwater quality assessment.

2.5. Statistical Analysis

All analyses were carried out in duplicates and results were expressed as mean ± standard deviation (SD). Data obtained were subjected to one-way analysis of variance (ANOVA) using GraphPad Prism statistical software. Statistical significance was accepted at $p \leq 0.05$.

3. Results

3.1. Determination of Microplastics in Water Samples

Microplastic particles identified in water samples collected from Nwaorie River consisted predominantly of microfragments, microfibres, and microbeads. To facilitate spatial assessment of microplastic distribution, the results were presented according to the three sampling zones: upstream, midstream, and downstream sections of the river. Variations in the occurrence and abundance of microplastic particles were observed among the sampling zones, reflecting differences in anthropogenic activities and pollutant accumulation within the aquatic ecosystem.

Table 1 Upstream Microplastic Count in Nwaorie River

Sample Name	Microbeads (Particles/L)	Microfibres (Particles/L)	Microfragments (Particles/L)
U1	9	1	51
U2	7	14	57
U3	0	0	16
U4	1	5	59
U5	7	6	50

U=Upstream

Table 2 Midstream Microplastic Count in Nwaorie River

Sample Name	Microbeads (Particles/L)	Microfibres (Particles/L)	Microfragments (Particles/L)
M1	4	0	81
M2	9	7	208
M3	14	3	48
M4	12	0	165
M5	12	0	74

M= Midstream

Table 3 Downstream Microplastic Count in Nwaorie River

Sample Name	Microbeads (Particles/L)	Microfibres (Particles/L)	Microfragments (Particles/L)
D1	8	2	46
D2	6	0	54
D3	1	1	154
D4	12	2	69
D5	5	3	43

D= Downstream

3.2. Physicochemical Parameters of Water Samples

The physicochemical parameters of water samples collected from Nwaorie River are presented in Tables 4 and 5. The parameters were categorized into organic and inorganic physicochemical parameters

Table 4 Organic Physicochemical Parameters of Water Samples from Nwaorie River

Parameters	Composition	WHO/EU Standard
Biological Oxygen Demand (BOD) (mg/L)	123.4 ± 1.56	82
Chemical Oxygen Demand (COD) (mg/L)	123.425 ± 1.59	40
Dissolved Oxygen (DO) (mg/L)	15.425 ± 1.76	10
Total Coliform (cfu/mL)	$(1.43 \pm 0.04) \times 10^2$	10

Values are expressed as mean ± standard deviation (SD) of duplicate determinations.
BOD = Biological Oxygen Demand; COD = Chemical Oxygen Demand; DO = Dissolved Oxygen.

The results revealed elevated BOD, COD, dissolved oxygen, and total coliform counts above WHO/EU permissible limits, indicating significant organic pollution and microbial contamination within the river environment.

Table 5 Inorganic Physicochemical Parameters of Water Samples from Nwaorie River

Parameters	Composition	WHO/EU Standard
pH	6.46 ± 0.06	6.5
Conductivity (µs/cm)	144.005 ± 2.16	100
Turbidity (NTU)	2.95 ± 0.21	35
Temperature (°C)	28.05 ± 0.21	20–30
Hardness (mg/L)	148.36 ± 0.23	60–100
Alkalinity (mg/L)	78.05 ± 0.21	20–200
Acidity (mg/L)	43.55 ± 0.64	8.5
Total Suspended Solids (TSS) (mg/L)	12.265 ± 0.09	50
Nitrate (mg/L)	9.145 ± 0.01	50
Phosphate (mg/L)	8.721 ± 0.42	5.0
Chloride (mg/L)	91.75 ± 0.35	250
Sulphate (mg/L)	134.2 ± 0.14	500

Values are expressed as mean ± standard deviation (SD) of duplicate determinations. TSS = Total Suspended Solids.

The results indicated elevated conductivity, hardness, acidity, and phosphate concentrations above recommended WHO/EU standards, while turbidity, temperature, nitrate, chloride, sulphate, and TSS remained within acceptable regulatory limits.

4. Discussion

The present study evaluated the occurrence of microplastics and assessed the physicochemical parameters of water samples collected from Nwaorie River, Owerri Municipal, Imo State. The findings revealed the presence of microfragments, microfibres, and microbeads across upstream, midstream, and downstream regions of the river, indicating widespread microplastic contamination within the aquatic ecosystem. In addition, several physicochemical parameters exceeded WHO/EU permissible limits, suggesting significant environmental pollution resulting from anthropogenic activities around the river environment.

The occurrence of microplastics in all sampling zones confirms that Nwaorie River is contaminated with plastic-derived pollutants. The detection of microfragments within the river water may be associated with the gradual breakdown of larger plastic materials such as plastic bags, food packaging materials, bottles, and municipal solid wastes discharged into the river. Environmental factors including ultraviolet radiation, oxidation, temperature fluctuations, and mechanical abrasion contribute significantly to the fragmentation of macroplastics into smaller particles known as microplastics (Pawar et al., 2016). Similar observations have been reported in several freshwater systems where degradation of improperly disposed plastic wastes contributes to increasing microplastic contamination.

Microfibres identified in the water samples may have originated primarily from domestic sewage and textile washing activities. Previous studies have demonstrated that washing synthetic fabrics releases substantial quantities of fibre-like microplastics into wastewater systems which eventually enter freshwater environments through sewage discharge (Mintenig et al., 2017). The occurrence of microfibres across upstream, midstream, and downstream regions therefore suggests continuous input of domestic and municipal wastes into the river ecosystem.

Similarly, the presence of microbeads within the river may be associated with personal care products, industrial abrasives, cosmetic products, and household cleaning agents containing intentionally manufactured microscopic plastic particles. The widespread distribution of microbeads across the sampling locations indicates persistent anthropogenic contamination of the river system. Comparable findings have been reported in previous studies where freshwater ecosystems receiving untreated sewage and urban runoff showed significant accumulation of microbeads and other forms of microplastics (Yang et al., 2021).

The occurrence of microplastics throughout the river channel may further be attributed to increasing urbanization, population growth, indiscriminate disposal of plastic wastes, poor drainage systems, and inadequate waste management practices within Owerri Municipal. Rivers serve as major pathways for transporting plastic contaminants from terrestrial environments into larger aquatic ecosystems including lakes and oceans (GESAMP, 2015). Therefore, the continuous deposition and transport of plastic materials within Nwaorie River may contribute significantly to environmental deterioration and ecological imbalance within the aquatic ecosystem.

The physicochemical analysis further revealed important information regarding the pollution status of the river water. The pH value of 6.46 ± 0.06 was slightly below the WHO/EU permissible limit of 6.5, indicating mildly acidic conditions within the river. Although the pH remained close to neutrality, slightly acidic conditions may influence aquatic biochemical reactions, microbial activities, and the mobility of dissolved contaminants within freshwater systems (Ogemdi & Gold, 2018). Similar slightly acidic conditions have been reported in polluted freshwater environments receiving sewage discharge and urban runoff. The conductivity value exceeded the recommended WHO/EU limit of 100 µs/cm, suggesting elevated concentrations of dissolved ionic substances within the river water. Increased conductivity in freshwater systems is commonly associated with sewage contamination, industrial discharge, dissolved salts, and anthropogenic pollutants (APHA, 2012). Elevated conductivity therefore indicates increased environmental contamination and reduced water quality within Nwaorie River. Turbidity and temperature values remained within permissible standards, suggesting relatively stable thermal conditions and moderate levels of suspended particles within the river environment. However, hardness concentration was considerably higher than the recommended WHO/EU range. Elevated hardness values may result from increased concentrations of calcium and magnesium ions derived from geological weathering, sewage contamination, and anthropogenic inputs into the river system. Hardness influences the chemical composition and ecological characteristics of freshwater systems and may affect water suitability for domestic use. Acidity concentration was also significantly elevated above permissible limits, indicating increased acidic pollutants within the river environment. High acidity in freshwater systems may arise from decomposition of organic matter, sewage discharge, and runoff carrying acidic substances into aquatic ecosystems.

Prolonged acidic conditions may alter aquatic ecological balance and negatively affect the survival of sensitive aquatic organisms. Phosphate concentration exceeded the WHO/EU permissible limit, indicating nutrient enrichment within the river system. Elevated phosphate levels are commonly associated with detergent contamination, agricultural runoff, sewage discharge, and municipal wastes (Yang et al., 2021). Excessive phosphate enrichment may promote eutrophication, algal bloom formation, and deterioration of water quality within aquatic ecosystems.

Biological oxygen demand (BOD) and chemical oxygen demand (COD) values recorded in this study were substantially higher than WHO/EU permissible standards. Elevated BOD and COD values are important indicators of organic pollution resulting from microbial decomposition of organic matter within water bodies (Ajayi et al., 2009). High concentrations of BOD and COD observed in this study suggest significant contamination from municipal sewage, domestic wastes, and organic pollutants discharged into the river environment. Similar findings have been reported in freshwater systems impacted by urbanization and human activities.

Despite the elevated BOD and COD values, dissolved oxygen concentration remained relatively high. This may be attributed to atmospheric diffusion and photosynthetic activities occurring within the river ecosystem. However, persistent organic pollution may eventually compromise dissolved oxygen balance and threaten aquatic biodiversity if pollution levels continue to increase.

The total coliform count recorded in this study significantly exceeded the WHO/EU permissible limit, indicating severe microbial contamination of the river water. High coliform counts are often associated with fecal contamination arising from sewage discharge and poor sanitation practices around freshwater systems. This finding raises serious public health concerns, especially where untreated river water is utilized for domestic activities such as washing, bathing, and irrigation.

5. Conclusion

The present study demonstrated the occurrence of microplastic contamination and physicochemical pollution within Nwaorie River, Owerri Municipal, Imo State. Microplastic particles including microfragments, microfibres, and microbeads were detected across upstream, midstream, and downstream regions of the river, indicating widespread plastic contamination within the aquatic ecosystem. The occurrence of these particles suggests continuous input of plastic wastes into the river through anthropogenic activities such as indiscriminate waste disposal, sewage discharge, urban runoff, and domestic activities around the river environment.

The physicochemical assessment further revealed elevated conductivity, hardness, acidity, biological oxygen demand (BOD), chemical oxygen demand (COD), phosphate concentration, and total coliform counts above WHO/EU permissible standards, indicating significant environmental deterioration and organic pollution within the river system. These findings suggest that Nwaorie River is increasingly impacted by human activities capable of altering water quality, ecological stability, and public health safety.

Compliance with ethical standard

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Disclosure of conflict of interest

Authors Declare no conflict of interest

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