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Assessment of Microplastic Pollution in Surface Water and Sediments of Otammiri River, Imo State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study analyzed the physicochemical and heavy metal status and also quantified microplastics from Otammiri River, Imo state, Nigeria. The physicochemical and heavy metal analysis were carried out using procedures of Federal Environmental Protection Agency. The quantification of the microplastics from Otammiri River was carried out according to the National Oceanic and Atmospheric Administration (NOAA) protocol for surface water trawling for microplastics. The microplastics quantified in this study were at the range of 0.3 mm to 5mm that were resistance to wet oxidation and exhibited flotation in a 5M NaCl. The result of the physicochemical parameters

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showed that the parameters were within the Federal Ministry of Environment (FMEV) permissible limits with exception to lead and mercury. The microplastics concentrations at the surface water of Otammiri River was between 0.12 g to 2.50 g and in sediments samples, between 0.01 g to 1.37 g.

Keywords: Microplastic pollution; heavy metal status; plastic particles.

1. INTRODUCTION

Microplatics are commonly defined as plastic particles smaller than 5 mm in at least one external dimension [1,2]. Studies have shown that plastic is abundance in inland freshwater systems in Nigeria [3,4,5,6,7]. Microplastics abundance from shore of Rivers in Nwangele Local Government Area of Imo state, ranged from 440 to 1,556 particles/L, with high accumulation at downstream [8]. [5] showed that 5% of the potential MP particles identified by means of FTIR and pyrolysis GC-MS were polypropylene and polyethylene. The abundance of microplastics ranged from 310–2319 particles/kg in sediment, and 139–303 particles/L in water. Cross River, Qua Iboe River and Jaja Creek in Akwa Ibom, Nigeria, suspended marine litter was reported to be of high quantity of plastic (> 5000 kg/m2). [9] screened and detected MPs in the stomach of commonly consumed fish species from a municipal water supply lake (Eleyele) in Nigeria. The physical effects of MPs on marine organisms include entanglement which may lead to death, injuries and blockage of digestive or intestinal pathways, lowering of energy of productive animals, decrease in food consumption due to ingested MPs [10]. Exposure routes of microplastics to humans include ingestion, inhalation, and dermal penetration [11]. Among all the exposure routes, the ingestion of microplastics was regarded as the primary route. MPs/g 0.44 of nano and microplastics were found in sugar, 0.11 MPs/g were found in salt, 0.03 MPs/g were found in alcohol, and 0.09 MPs/g were found in bottled water [12]. Humans could also assume an estimated intake of 80 g per day of microplastics via plants (fruits and vegetable) that accumulate MPs through uptake from polluted soil [13]. Another study in 2019, showed that microplastics in a human biological sample (feces) 50 items/g and 9 plastic types were found in the fecal sample [11]. Biofilms in drinking water contain loads of microbes which are transported with the water such as tap water causing serious health menace [14]. These plastics with a higher concentration of recent fecal pollution can drift to areas with lower levels of pollution, increasing the total fecal bacteria load in the water [15].

Otammiri River is of great economic importance to those living around them. The river is their major source for fish, irrigation for farming and other domestic activities. To ensure the Sustainable Development Goals (SDGs) which focus to ensure availability and sustainable management of water and sanitation for all, Otammiri River needs to be evaluated for the presence of microplastics. This article focused on the findings of the study regarding the physicochemical, heavy metals and the presence and distribution of microplastics in Otammiri River surface water and sediment samples.

2. METHODOLOGY

2.1 Study Area

The Otammiri River is situated in Imo State, Nigeria. Geographically, its watershed spans between latitudes 5˚17'N and 5˚30'N, and longitudes 6˚58'E and 7˚04'E. Originating from Egbu, Owerri, the river flows southward, passing through significant locations like Nekede, Ihiagwa, Eziobodo, Obowuumuisu, Mgbirichi, and Umuagwo, until it reaches Ozuzu in the Etche Local Government Area of Rivers State. From there, it continues its journey to the Atlantic Ocean [16]. Covering an area of about 10,000 km^2, the Otammiri watershed experiences an annual rainfall ranging between 2250 and 2500 mm. Predominantly, the watershed is characterized by depleted rainforest vegetation, with an average temperature of 27˚C maintained throughout the year [16].

2.2 Collection Points of Samples

The location and accessibility points for samples collection from Otammiri River, Imo State Nigeria are listed below.

a) Ekwuato 464115, Lat 5.334717^0 and Long 6.965682^0 Imo, Nigeria (downstream)
b) Ihiagwa Otammiri Road, Ihiagwa 460113, Lat 5.388439^0 and Long 6.987726^0 (middle stream 1)
c) Nekede 460106, Lat 5.442928^0 and Long 7.022863^0 (middle stream 2)

d) Wetheral, Owerri, 460281, Lat 5.471891^0 and Long 7.0416^0 (upstream).

Collection of physicochemical and heavy metals samples from surface water of Otammiri: This study was carried out during the dry season (January, 2024). Samples were collected using procedures of Federal Environmental Protection Agency [17].

Collection of microplastics from surface water of Otammiri: The collection of surface water microplastic samples was conducted using a surface manta trawl, adhering to the protocol outlined by the National Oceanic and Atmospheric Administration (NOAA) for surface water trawling for microplastics [18]. Samples were gathered against the water current, with the manta trawl equipped with a mesh net size of 0.335 mm and an opening measuring 25 × 60 cm.

Collection of microplastics from sediment samples of Otammiri: The sediment samples were obtained utilizing a grab sampler and deposited into clean glass jars. At each sampling point, five sediment samples were collected, ensuring representation across the area.

2.3 Quantification of Microplastics from Otammiri River

The quantification of microplastics from the Otammiri River followed the protocol established by the National Oceanic and Atmospheric Administration (NOAA) for surface water trawling [18,19,20].

2.4 Statistical Analyses

The data obtained were analyzed with one-way analysis of variance (ANOVA) at 0.05 significant level.

3. RESULTS

3.1 Physicochemical and Heavy Metal Parameters of Otammiri River

From Table 1, it was observed that the surface water at Ekwuato location (464115) was clear; Ihiagwa (460113), sparsely loaded with debris; Nekede (460106), heavily loaded with debris and Wetheral (460281) (the upstream), clear. Their sediment samples at Ekwuato Location (464115) were sparsely loaded with debris, Ihiagwa (460113), loaded with debris, Nekede (460106), and heavily loaded with debris while Wetheral location (460281) was clear.

Table 2, showed that pH for the water sample ranged from 6.57±0.04 (Wetheral 460281) to 7.42±0.05 (Nekede). Temperature of the water ranged from 20.50±0.14 (Wetheral 460281) to 22.70±0.14 (Nekede 460106) while temperature for the sediment samples ranged from 19.70±0.14 (Wetheral) to 20.60±0.28 (Ekwuato). The surface water conductivity had least and highest values at 16.10±0.28 (Ekwuato), 25.10±0.42 (Wetheral) and Nekede (28.50±0.42). There is no significant difference ($P \leq 0.05$) in the pH, temperature and conductivity values of the water and sediment samples across the sampling locations.

The turbidity levels of Otammiri River at various sampling points were assessed, revealing notable variations. Ihiagwa exhibited the highest turbidity levels (17.6±1.41 NTU, followed by Nekede (6.17±0.49 NTU), Ekwuato (2.93±0.32 NTU), Wetheral (1.7±0.17 NTU). Statistical analysis indicated no significant difference ($P \leq 0.05$) in turbidity levels among the sampling locations.

3.2 Hardness, Total Solids, Total Dissolved Solids, Total Suspended Solids, Chemical Oxygen Demand, Biochemical Oxygen Demand

The result from Table 3 showed that Otammiri River had the highest values for "Hardness" (mg/l) at Nekede (60.00±7.07), and least at Ekwuato (40.00±5.66). The sediment samples recorded highest values for "Hardness" at Nekede (80.00±5.66), and least at Wetheral (35.00±4.24) locations. Total Solid, (mg/l) in the water samples revealed to be higher in Nekede (6.10±0.65) and least at Ekwuato (4.56±0.32). The sediment samples showed to have higher total solids at Ihiagwa (12.47±0.92), and least at Wetheral (9.39±0.32) locations. Total Suspended Solid (mg/l) in the water samples reveled to be higher at Ihiagwa, (5.66±0.29) and least at Ekwuato (1.35±0.07) Locations. The sediment samples showed to have higher Total Suspended Solid at Nekede (4.60±0.40), and least at Wetheral (3.19±0.96).

The Table 3 also revealed Chemical Oxygen Demand, COD (mg/l) of the water samples to be higher in Nekede location (178.67±33.94) and least at Ekwwato (165.34±60.34) locations. COD (mg/l) of the sediment samples was higher in Wetheral location (124.00±5.66) and least at Ekwwato (76.00±1.88) locations. The Biochemical Oxygen Demand, BOD (mg/l) result of the water samples showed that Nekede location (165.45±5.44) had higher BOD and least at Wetheral (128.70±18.24).

There is no significant difference (P≤0.05) across the sampling locations for both water and sediment samples.

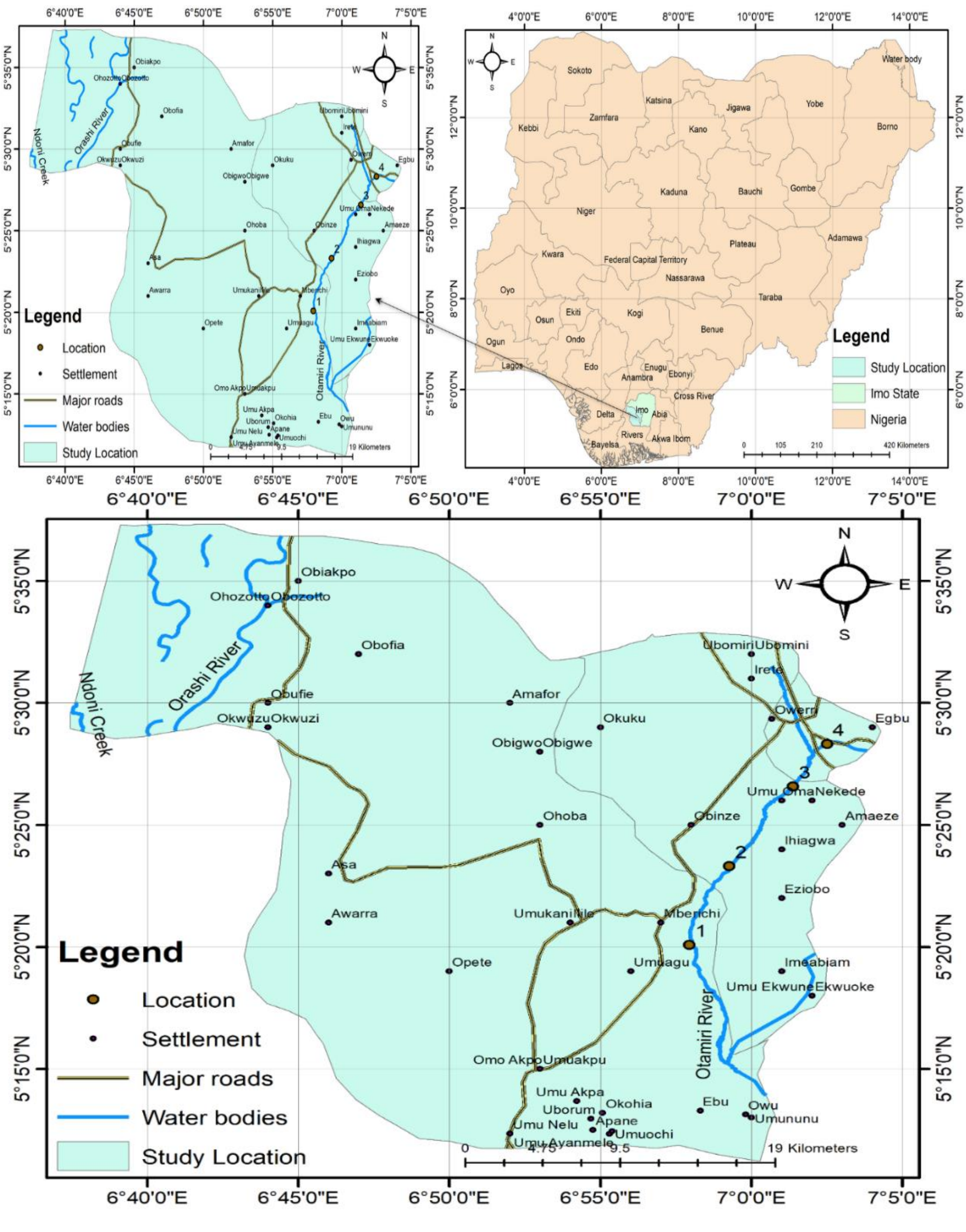

Fig. 1. Location and Accessibility Map of the Study Area (Global Positioning System)

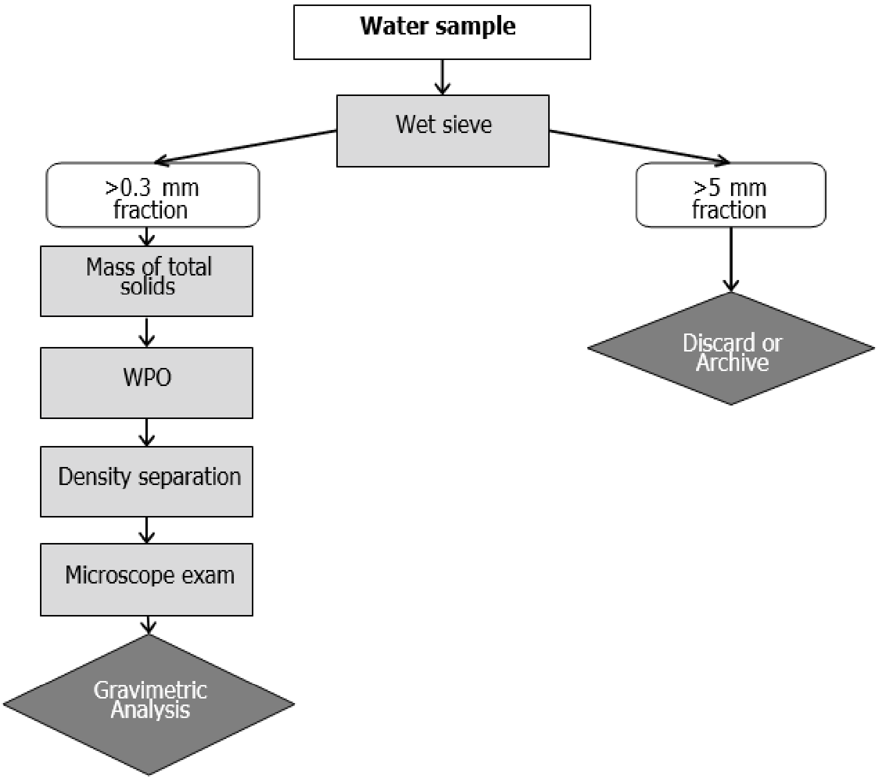

Fig. 2. Flow diagram for the analysis of microplastics in water samples [18]

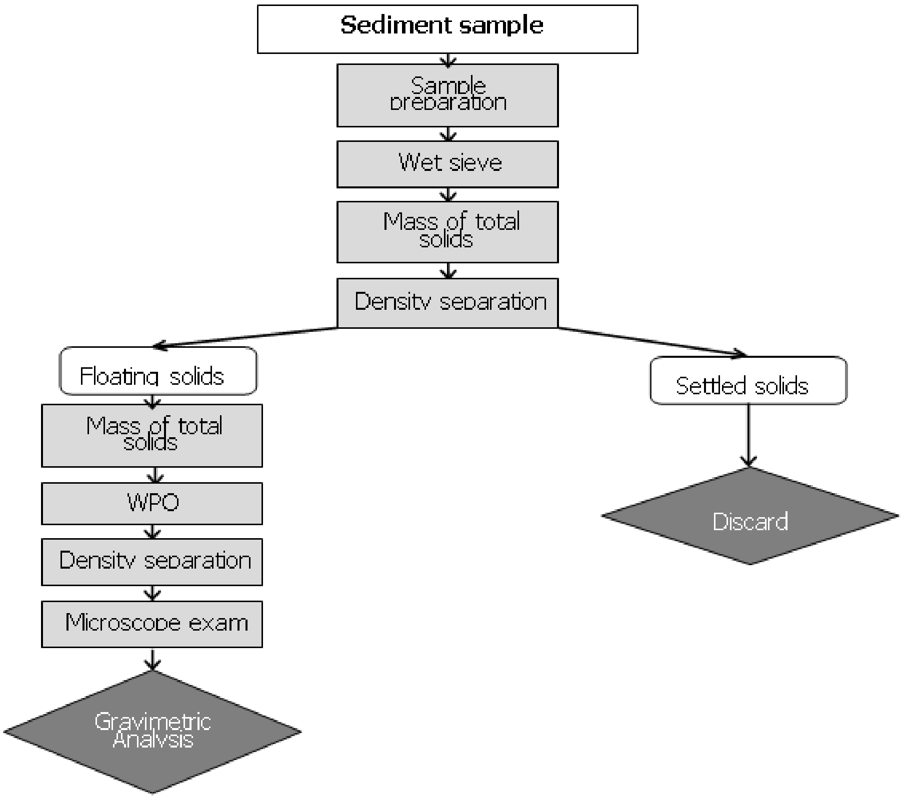

Fig. 3. Flow diagram for the analysis of microplastics in sediment samples [18]

Table 1. Appearance and odour of otammiri surface water and sediment at their sampling locations

	FMEnv Standard	Location	Ekwuato (464115)	Ihiagwa (460113)	Nekede	Wetheral
Appearance	**Clear**	Surface	Clear	sparsely loaded with debris	heavily loaded with debris	Clear
		Sediment	sparsely loaded with debris	loaded with debris	heavily loaded with debris	heavily loaded with debris
Odour	**Unobjectionable**	Surface	Unobjectionable	Objectionable	Objectionable	objectionable
		Sediment	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable

Table 2. pH and temperature conductivity and turbidity of Otammiri River

		FMEnv Standard	Ekwuato (464115)	Ihiagwa (460113)	Nekede	Wetheral
Water	pH	**6.5 – 8.50**	7.15±0.12	7.21±0.13	7.42±0.05	6.57±0.04
	Temperature (^{0}C)	**-**	22.30±0.14	22.35±0.07	22.70±0.14	20.50±0.14
	Conductivity (µS/cm)	**1000**	16.10±0.28	23.75±5.02	28.50±0.42	25.10±0.42
	Turbidity (NTU)	**10.00**	2.93±0.32	17.6±1.42	6.17±0.49	1.70±0.17
Sediment	pH	**6.5 – 8.50**	7.03±0.20	7.18±0.10	7.81±0.45	6.81±0.18
	Temperature (^{0}C)	**-**	20.60±0.28	20.4±0.14	20.35±0.21	19.70±0.14
	Conductivity (µS/cm)	**1000**	10.80±0.14	19.55±1.77	50.10±3.25	24.50±0.57

± Standard deviation; µS/cm- microSiemens per centimeter; NTU- Nephelometric Turbidity Units

Table 3. Hardness, total solids, total dissolved solids, total suspended solids, chemical oxygen demand, biochemical oxygen demand of Otammiri River

	Water					Sediment				
	FMEnv Standard	**Ekwuato**	**Ihiagwa**	**Nekede**	**Wetheral**	**FMEnv Standard**	**Ekwuato**	**Ihiagwa**	**Nekede**	Wetheral
Hardness (mg/l)	200.00	40.00±5.66	54.00±2.83	60.00±7.07	41.00±1.41	-	62.00±4.24	64.50±3.53	80.00±5.66	35.00±4.24
Total Solid, (mg/l)	500.00-1000.00	4.56±0.32	5.62±0.45	6.10±0.65	4.70±0.08	-	9.86±0.42	12.47±0.92	9.58±0.18	9.39±0.32
Total Dissolved Solid (mg/l)	500.00	2.53±0.01	3.99±0.50	4.72±0.09	2.67±0.19	-	5.15±0.81	6.61±0.70	6.67±0.55	7.87±0.52
Total Suspended Solid (mg/l)	<10.00	1.35±0.07	5.66±0.29	4.47±0.60	2.13±0.21	-	3.36±0.35	4.24±1.13	4.60±0.40	3.19±0.96
COD (mg/l)	NS	165.34±60.34	173.14±37.88	178.67±33.94	172.00±35.82	NS	76.00±1.88	91.03±1.94	94.67±16.97	124.00±5.66
BOD (mg/l)	NS	130.15±0.78	155.50±9.69	165.45±5.44	128.70±18.24	NS	126.80±3.96	158.96±40.54	176.00±40.73	127.40±25.74

± Standard deviation; mg/l: milligram /liter; NS- Not Stated

Table 4. Chlorine, nitrate, nitrate, phosphorous, sulphate and fluoride of Otammiri River

	Water					Sediment				
	FMEnv Standard	**Ekwuato**	**Nekede**	**Ihiagwa**	**Wetheral**	**FMEnv Standard**	**Ekwuato**	**Ihiagwa**	**Nekede**	Wetheral
Chlorine (mg/l)	250.00	95.00±2.82	112.00±2.23	104.00±2.83	94.5±4.95	NS	155.00±2.83	142.50±17.67	160.00±1.41	79.00±4.24
Nitrate (mg/l)	50.00	1.49±0.70	3.76±0.28	4.11±0.14	2.24±0.18	20.00	5.96±0.48	6.21±1.06	6.45±0.09	4.78±0.35
Nitrite (mg/l)	0.30	0.33±0.02	0.58±0.01	0.67±0.01	0.24±0.04	NS	3.13±0.59	3.75±0.31	3.53±0.64	2.64±0.33
Phosphorous (mg/l)	5.00	1.78±0.02	2.00±0.07	1.92±0.07	1.54±0.07	>100.00	2.61±0.07	2.29±0.22	2.37±0.14	2.39±0.13
Sulphate (mg/l)	200-400.00	11.32±2.04	13.37±0.87	13.16±0.00	11.92±0.00	100.00	51.44±1.75	71.88±2.38	86.62±1.45	45.68±1.75
Fluoride (mg/l)	NS	0.23±0.07	1.06±1.00	0.60±0.03	0.30±0.08	NS	0.47±0.15	2.23±0.24	2.18±0.06	0.47±0.15

± Standard deviation; mg/l: milligram /liter; NS- Not Stated

Table 5. Heavy metal analysis of Otammiri River

	Water					Sediment				
	FMEnv Standard	**Ekwuato**	**Ihiagwa**	**Nekede**	**Wetheral**	**FMEnv Standard**	**Ekwuato**	**Ihiagwa**	**Nekede**	**Wetheral**
Cadmium (mg/l)	0.01	0.01±0.00	0.01±0.00	0.01±0.01	0.01±0.01	0.01	0.01±0.00	0.01±0.00	0.01±0.01	0.01±0.00
Lead (mg/l)	0.05	0.01±0.00	0.01±0.01	0.03±0.01	7.00±9.90	0.05	0.02±0.00	0.01±0.01	0.01±0.01	0.01±0.01
Mercury (mg/l)	0.01	0.02±0.00	0.03±0.00	0.03±0.00	0.01±0.00	0.001	0.04±0.00	0.03±0.00	0.04±0.01	0.04±0.00
Arsenic (mg/l)	0.2	0.04±0.05	0.03±0.00	0.02±0.00	0.02±0.00	0.05	0.03±0.00	0.03±0.00	0.02±0.00	0.04±0.01

± Standard deviation; mg/l: milligram /liter

3.3 Chlorine, Nitrate, Nitrate, Phosphorous, Sulphate and Fluoride

The result from Table 4 showed that nitrate (mg/l) was found to be higher at Ihiagwa, (4.11±0.14) and least at Ekwuato location (1.49±0.70). The sediment samples recorded highest values for at Nekede (6.45±0.09), and least for Wetheral (4.77±0.35). Nitrite (mg/l) was found in the water samples to be higher at Ihiagwa, (0.67±0.01), and least at Wetheral (0.24±0.04). The sediment samples recorded highest values at Ihiagwa, (3.75±0.31) and least values at Wetheral (2.64±0.33). Phosphorous (mg/l) was found in the water samples to be higher at Nekede (2.00±0.07) and least at Wetheral (1.54±0.07). The sediment samples recorded highest values at Ekwuato (2.61±0.07) and least at Nekede (2.37±0.14). Sulphate (mg/l) was found in the water samples to be higher at Nekede (13.37±0.87), and least at Ekwuato (11.31±2.04). The sediment samples recorded highest values at Nekede (86.62±1.45) and least at Wetheral (45.68±1.75). Fluoride (mg/l) was found in the water samples to be higher at Nekede (1.06±1.00) and least at Ekwuato (0.23±0.07). The sediment samples recorded highest values at Nekede (2.23±0.24).

The heavy metals analysis shown in Table 5 revealed cadmium (mg/l) to be 0.01 for both water and sediment samples across the sampling locations. Lead (mg/l) in the water samples ranged from Ekwuato (0.01±0.00) to Wetheral location (7.00±9.90). The sediment lead concentration was between 0.01±0.01 (Wetheral and Ihiagwa locations) and 0.02±0.00 (Ekwuato location). Mercury (mg/l) in the water samples was between 0.01±0.00 (Wetheral location) and 0.03±0.00 (Nekede and Ihiagwa locations). Arsenic (mg/l) in the water samples had higher values in Ekwuato location (0.04±0.05) while the sediment samples had the highest arsenic values in Wetheral location (0.04±0.01). There is no significant difference (P≤0.05) across the sampling locations for both water and sediment sample.

3.4 Total Solutes of Samples trawled from surface water and sediment of Otammiri River for Microplastics studies

As shown in Fig 1, the total solids for the surface water ranged from Ekwuato, 2.24± 0.28 g to Ihiagwa, 49.27± 1.41 g.

As seen in Fig 2, the sediments total solids ranged from Wetheral, 61.6±18.67 g to Ekwuato, 185.17±15.34 g.

3.5 Concentration of Microplastics in the Surface Water

Examining the concentration of microplastics in surface water across the Otammiri sampling points in Fig 3, followed the order: Nekede > Ihiagwa > Wetheral > Ekwuato. There is no significant difference between the microplastic concentrations found in Otammiri surface water at the different sampling points.

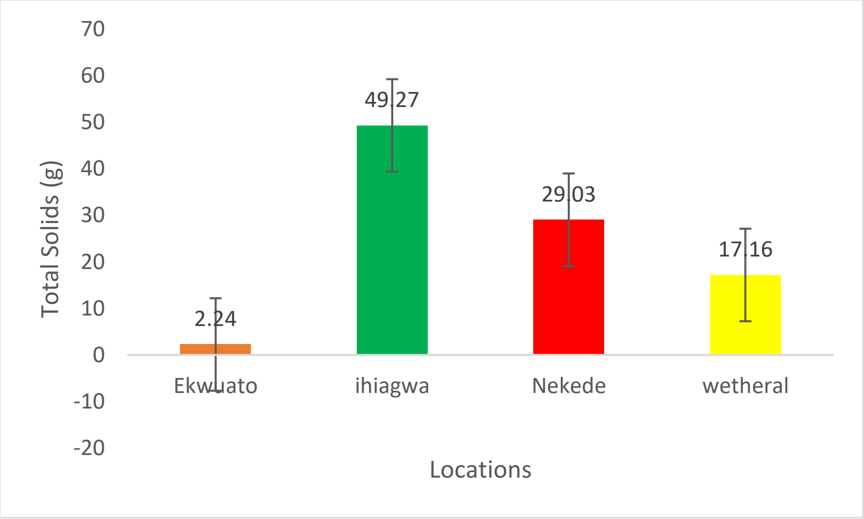

Fig. 4. Total Solids of samples trawled from Otammiri River surface water from different sampling points

g: grams.

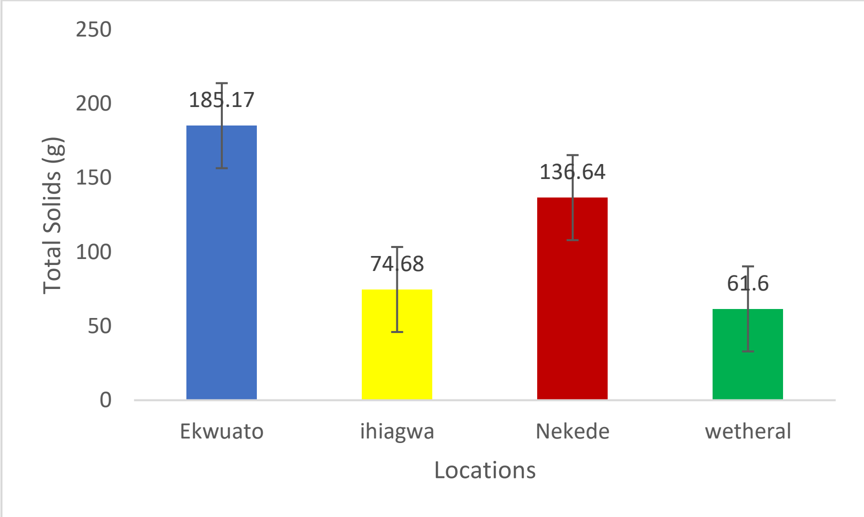

Fig. 5. Total Solids of sediment samples from Otammiri River from different sampling points
g: gram

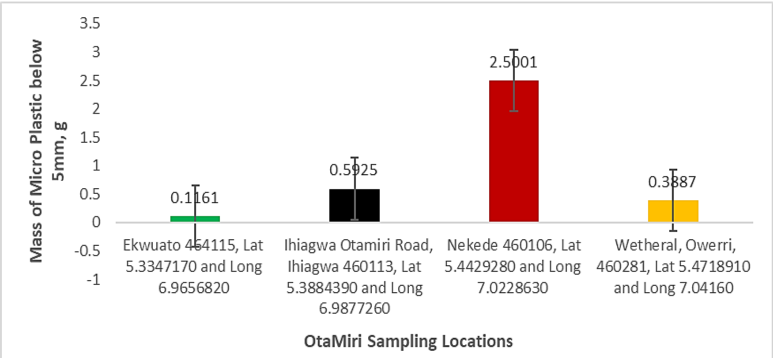

Fig. 6. Concentration of Microplastics in Surface Water across Otammiri River Sampling Points
± Standard error of mean g: grams Lat: Latitude Long: Longitude

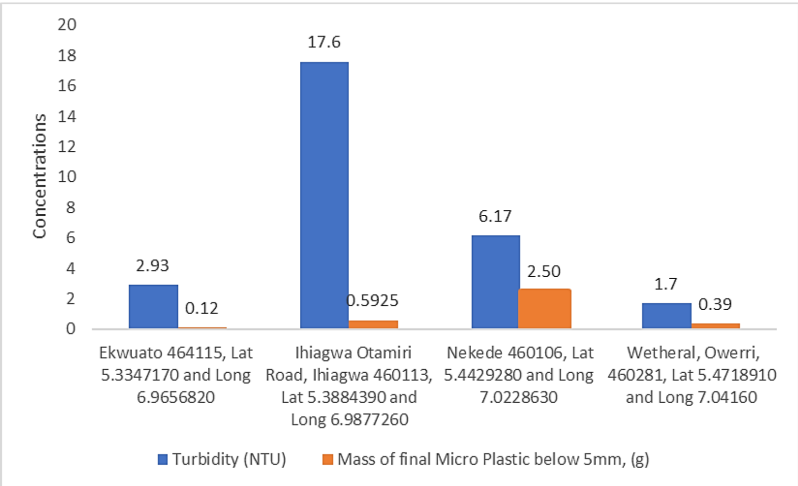

Fig. 7. Correlation between Turbidity of Otammiri River and the microplastics concentration of Otammiri River
NTU: Nephelometric Turbidity Units
g: gram

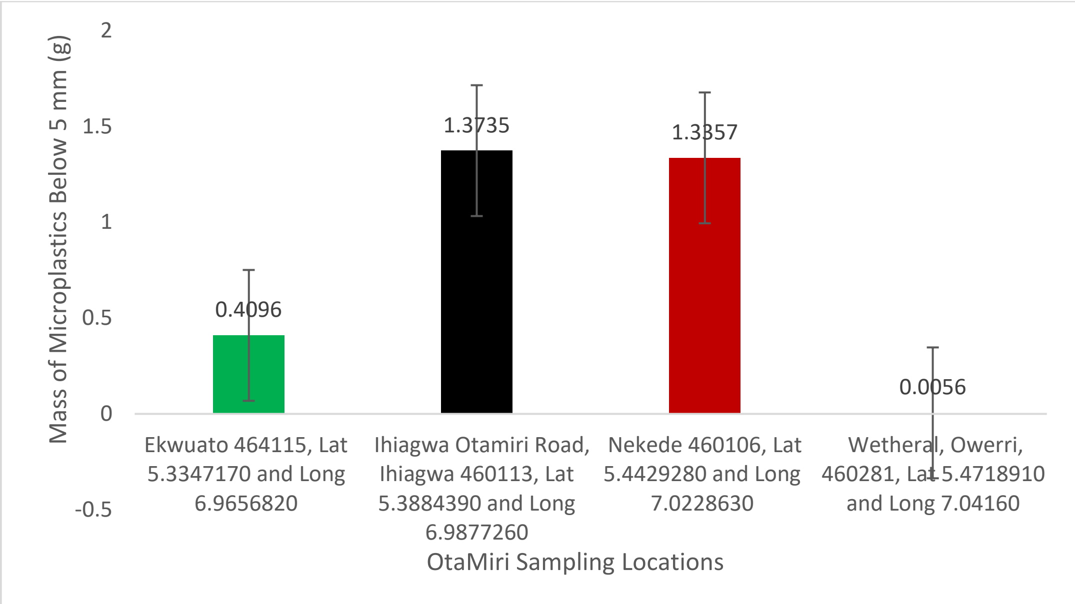

Fig. 8. Concentration of Microplastics in Sediment Samples across Otammiri River Sampling Points

± Standard error of mean g: grams Lat: Latitude Long: Longitude g: gram

3.6 Correlation between Turbidity of Otammiri River and the microplastics concentration

Fig 4, "Correlation between Turbidity of Otammiri River and the microplastics concentration", showed that the microplastics at the surface of the river followed the trend of the turbidity levels. The downstream had the least turbidity and microplastics values (2.93±0.32 NTU and 0.12±0.01 g) while the middle stream had the highest turbidity and microplastics values (17.60±1.42 NTU and 2.50±1.56 g) respectively. At P≥0.05 statistical level, correlation statistical result showed that increment in turbidity levels is directly proportional to the concentrations of the microplastics at the different sampling points as the middle had the highest concentration of the microplastics.

3.7 Concentration of Microplastics in the Sediment Samples

Similarly, the concentration of microplastics in sediment samples across the Otammiri sampling points as shown in Fig 5 followed the order: Ihiagwa > Nekede > Ekwuato > Wetheral.

4. DISCUSSION

Physicochemical parameters including pH, temperature, dissolved oxygen levels, turbidity, conductivity and even nutrient concentration which are influenced by various natural and anthropogenic activities shapes the ecological characteristics of river systems. These factors also influence microplastics abundance in river ecosystem. The appearance of the surface water was clear at the downstream and upstream but was heavily loaded with debris at the middle stream (Ihiagwa and Nekede) with objectable odour as well. This indicates the presence of pollution in this water body at these points which do not confirm to safe drinking water standards [21]. The pH of the Otammiri river and sediments were at acceptable limits of the Federal Ministry of Environment (FMEV) (6.5 – 8.50). The upstream (Wetheral location) surface water and sediment were observed to be slightly acidic while the middle and downstream were observed to be slightly alkaline. In acidic conditions, certain plastics may degrade more rapidly due to hydrolysis or other chemical reactions. Conversely, in alkaline conditions, degradation might be slower. This can influence the rate at which macroplastics break down into microplastics [22].

The temperature values of the surface water and sediments were within the ambient temperature range stipulated by FMEV which is in agreement with the findings of [23,24] in Otammiri River. The temperature values reported were due to the climatic condition of the study area [25,26,27].

Warmer temperatures can accelerate the degradation of plastic materials, leading to increased fragmentation and subsequent release of microplastics into the environment [28]. Temperature influences the metabolic rates and activities of microbial communities responsible for the degradation and decomposition of organic matter, including plastics [29]. Higher temperatures can enhance microbial colonization and enzymatic breakdown of microplastics, potentially affecting their abundance and persistence in aquatic environments [30].

The mean electrical conductivity values of the surface water and sediments were within the acceptable FMEV limit (1000 µscm^{-1}). This infers that there is less impact of dissolve ions in both the surface water and sediment samples. Electrical conductivity can influence the transport and distribution of microplastics. For example, higher conductivity levels may indicate higher concentrations of dissolved salts, which could affect the buoyancy and settling rates of microplastic particles [31]. This can indirectly influence the abundance and distribution of microplastics in aquatic environments by altering their movement and deposition patterns.

The mean total hardness (mg/l) values of the surface water and sediment were below the recommended limit stipulated by FMEV. The middle streams (Nekede and Ihiagwa) were observed to have higher values for total hardness than the upstream and downstream. The hardness in water is due to the presence of cations such as Ca^{2+} and Mg^{2+}, anions such as HCO_3^-, Cl^- and SO_4^{2-} in surface water. Studies [32,33] in Njaba River, Imo State, Nigeria, reported a similar finding. Hard water contains higher concentrations of these ions, which can interact with microplastic surfaces through electrostatic attractions and facilitate the aggregation of microplastic particles with suspended solids and organic matter [34]. This aggregation process may affect the transport and settling of microplastics in aquatic environments, potentially influencing their overall abundance.

The mean suspended solids values in both the surface water and sediment were lower than the permissible limit in the upstream and downstream locations but marginally increased in the middle stream. This informs the high microplastics concentration observed in middle stream. The effect of consuming water with high solids has been reported [33]. Total suspended solids in water can serve as carriers for microplastic particles, facilitating their transport and aggregation. Microplastics can adsorb onto suspended solids through physical interactions and surface properties, leading to the formation of larger aggregates that settle out of the water column [35].

The level of chemical oxygen demand (COD) in the sampling points exceeds the 10 mg/l COD of the maximum permissible limit for drinking water and aquatic life. COD determines the amount of oxygen required for chemical oxidation of organic compounds. High levels of COD can lead to death of fishes and can cause dysentery in humans who use the polluted water. The findings are in tandem with the work of [36] in their quality assessment of Otammiri River. High COD levels can impact the composition and activity of microbial communities in water bodies. Variations in COD levels may alter microbial processes involved in the breakdown of organic matter and plastics, indirectly influencing the persistence and fate of microplastics in aquatic ecosystems [37].

The result obtained from this study showed biochemical oxygen demand (BOD) values to exceed the recommended maximum allowable concentration of the European Union for good quality water for aquaculture (3.0 – 6.0 / 3-5 (pmm). Unpolluted water usually has values 2 or less whereas those receiving waste water/discharge may have values up to 10 mg/l or more [36]. The BOD values are high probably due to the discharge of municipal wastes and poorly executed agricultural activities near the river banks which was observed during the survey of the study site. [24] observed similar values in their study. Elevated BOD levels may enhance microbial activity and organic matter availability, potentially affecting the sorption and degradation rates of microplastics in aquatic ecosystems [38]. Microorganisms play a crucial role in the degradation and biotransformation of organic pollutants and microplastics in water bodies [39]. Changes in BOD levels can alter the composition and activity of microbial communities, indirectly influencing the degradation and fate of microplastics in aquatic environments [40].

The nitrate mean values were also observed to be below permissible levels of FMEV. This shows that there is no much runoffs from the uplands into the river due to the dry season. This study is at variance with the study conducted in wet season [41] where high concentration of nitrate was observed. Nitrite pollution can also affect the composition and activity of microbial communities in aquatic environments [42]. Changes in nitrite levels may therefore influence microbial processes involved in the breakdown and fate of microplastics, potentially affecting their abundance and persistence in water bodies. High concentrate of nitrate in water can cause the development of methemoglobinemia (blue baby syndrome) in infants [41]. Increased nutrient availability due to nitrate pollution may stimulate algal growth and primary productivity, leading to the formation of biofilms and organic aggregates in which microplastics can become entrapped or sorbed [43].

Phosphate mean values were below the permissible standards. Changes in phosphate levels may influence microbial processes involved in the breakdown and fate of microplastics, potentially affecting their abundance and persistence in water bodies [39].

Sulphate mean values are lower than the permissible limits by FMEV Standard, although the river sediment had higher values for sulphate than the surface water. Drinking water containing higher amounts of magnesium sulphate or sodium sulphate may lead to intestinal discomfort, diarrhea and consequent dehydration especially in drinking water containing >500 mg/l of sulphate [44]. Sulfate ions can participate in chemical reactions and interactions with microplastic surfaces. Changes in sulfate concentrations may affect the availability and speciation of metal ions and other contaminants that can adsorb onto microplastic particles [45]. These chemical interactions may influence the fate and bioavailability of microplastics in aquatic ecosystems, potentially impacting their abundance and ecological effects.

The mean values of the studied heavy metals were within the permissible limits in the upstream (Wetheral) that recorded 7.00±9.90 mg/l and mercury that had values that exceeded the permissible limits in all sampled locations. This could result from weathering of parent rocks or anthropogenic activities [27]. It is important to note that these heavy metals may be part of the leachate from waste dumps and landfills around the sampling points which were later washed down the Otammiri River. The heavy metals also owe their sources mainly from discharged electronic wastes (e-wastes) [27]. Heavy metals can adsorb onto the surface of microplastic particles in aquatic environments due to electrostatic attractions and surface properties [46]. This sorption process can lead to the accumulation of heavy metals on microplastics, potentially altering their distribution and behavior in water bodies. Conversely, microplastics can also serve as carriers for heavy metals, facilitating their transport and bioaccumulation in aquatic organisms [47]. Heavy metals sorbed onto microplastics may undergo remobilization under changing environmental conditions, leading to the release of heavy metals back into the water column [48]. This remobilization process can contribute to the redistribution of heavy metals and microplastics in aquatic ecosystems, potentially increasing their exposure and ecological impacts on aquatic organisms [45]. Heavy metals adsorbed onto microplastic surfaces may become more bioavailable to aquatic organisms, leading to potential toxicity and ecological risks [49]. The presence of heavy metals on microplastics can affect their interactions with biota and influence physiological responses in exposed organisms [50].

The turbidity of the Otammiri River was between 1.7±0.17 NTU and 17.6±1.41 NTU. Ihiagwa and Nekede locations (middle streams) had higher turbidity levels. This could be attributed to the heavy anthropogenic activities (sanding mining and waste dumping) in the Ihiagwa and Nekede axis of Otammiri River. This is in consonance with the report of [51] that the turbidity of freshwaters around busy metropolis tends to increase due to high anthropogenic activities. The increment in turbidity levels directly proportional to the concentrations of the microplastics the different sampling points as the middle had the highest concentration of the microplastics. Research has shown that higher turbidity levels are associated with increased microplastics abundance [52,53]. Microplastics concentrations of Otammiri River surface water was between 0.12 g to 2.50 g. Nekede and Ihiagwa locations (middle streams) had the highest concentration of microplastic sampled (2.50 g and 0.59 g respectively). This may be attributed to the industrial and domestic wastewater discharged into the Otammiri River at that point. The upstream sampling point at which less microplastic concentration was seen, was located at Wetheral station. This is to show that anthropogenic activities are far below the levels obtainable in the middle streams. The upstream had higher microplastics concentrations than the downstream (upstream, 0.39 g; downstream, 0.39 g), denoting that the microplastics did not travel long distances as the heavy concentration seen in the middle was far less in the downstream. This can be attributed to the self-filtration system of water bodies [54] The lack of long-distance carriage of the microplastics may be due to the low flow velocity of the river. High water velocity was required to transport more microplastics along a river course. The lack of long-distance carriage observed in the current research may also be due to the general pollution of the river with many large-sized items, which may be absorbing microplastics onto their surfaces, thereby limiting their transport along the river. The spatial variations of the microplastics abundance in the water samples vividly reveals the influence of anthropogenic activities around the sampling areas. Microplastics load in rivers are governed by their proximity to urban areas and human activities [5]. In terms of flowing systems in Nigeria, studies [55,56,57,58,59,60] have reported microplastics abundances in river water samples.

In particular, the levels of microplastics found in Otammiri is cause to worry. Not only does this water serve for domestic and agricultural purposes, most community dwellers depend on the fish for its protein needs. It may therefore be inferred that local people in the area are directly and in advertently exposed to microplastics through domestic use and consumption of the aquatic animals. The high-level microplastic pollution of Otammiri River may not be unconnected with the wide use and indiscriminate disposal of plastic materials, particularly the single-use ones [61]. This situation is exacerbated by the lack of specific laws and policies prohibiting single-use plastics in Nigeria and non-enforcement of already established environmental protection laws.

The sampled sediments of Otammiri had microplastics concentration at the range of (0.01 g to 1.37 g). Microplastics concentrations in the Otammiri sediments were generally lower than the water samples. However, the spatial distribution pattern is similar to that observed for the water samples. Concentration of the microplastics increased from the upstream to the middle stream, and thereafter decreased at the downstream. This finding supports the fact that sediments are a sink for MPs [5]. [62] noted that turbidity currents potentially distribute and bury large quantities of microplastics in seafloor sediments. Overall, the spatial variation of the microplastics in the sediments reflects the impact of Owerri city's poor plastic waste management on the sediments microplastics contents. Due to available space along Otammiri Riverbank, the Owerri Municipal Council in 2000 approved the site as the official dumpsite for most of the solid waste collected from the municipality [63]. Consequently, solid waste has been dumped at this site for more than ten years, on a surface area approximately 11 hectares in size, 6 meters high and not compacted and capped. Nearly 30 tons of commingled wastes are dumped here daily. Vast majority of Nigeria people also dispose plastics indiscriminately in the environment, where they degrade gradually over time, to release plastic fragments of various sizes. Such wastes are carried by run-off into streams and rivers, where they also breakdown to release small plastic particles. Microplastics abundance in waterbodies is closely related to urbanization, human industrial activities, and wastewater impacts [64].

5. CONCLUSION

The physicochemical status of the Otammiri River is within the acceptable limits but high presence of lead and mercury is a cause for public health concern. The microplastics results revealed varying quantities of microplastics in Otammiri River surface water (ranging from 0.12 g to 2.50 g) and sediment (ranging from 0.01 g to 1.37 g). This information underscores the significant issue of plastic pollution, particularly the presence of microplastics, which pose substantial threats to aquatic ecosystems and human health due to their persistent, bioaccumulate nature and ability to adsorb harmful pollutants. Nigeria, especially Imo State should implement comprehensive measures to mitigate municipal, agricultural and plastic pollution at its source, including stricter regulations on plastic production, usage, and disposal.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Appendix 1. Physicochemical parameters

SAMPLES	PH					TEMPERATURE						CONDUCTIVITY			
	R1	R2	mean	std		R1	R2	mean	std			R1	R2	mean	std
Wetheral	6.54	6.59	6.565	0.035355		20.4	20.6	20.5	0.141421		Wetheral	25.4	24.8	25.1	0.424264
Ekwuato	7.06	7.23	7.145	0.120208		22.2	22.4	22.3	0.141421		Ekwuato	15.9	16.3	16.1	0.282843
Nekede	7.45	7.38	7.415	0.049497		22.8	22.6	22.7	0.141421		Nekede	28.2	28.8	28.5	0.424264
Ihiagwa	7.3	7.12	7.21	0.127279		22.3	22.4	22.35	0.070711		Ihiagwa	27.3	20.2	23.75	5.020458
SEDIMENT	R1	R2	#DIV/0!	#DIV/0!		R1	R2	#DIV/0!	#DIV/0!		SEDIMENT	R1	R2	#DIV/0!	#DIV/0!
Wetheral	6.68	6.93	6.805	0.176777		19.8	19.6	19.7	0.141421		Wetheral	24.1	24.9	24.5	0.565685
Ekwuato	6.89	7.17	7.03	0.19799		20.4	20.8	20.6	0.282843		Ekwuato	10.9	10.7	10.8	0.141421
Nekede	7.49	8.12	7.805	0.445477		20.2	20.5	20.35	0.212132		Nekede	52.4	47.8	50.1	3.252691
Ihiagwa	7.11	7.25	7.18	0.098995		20.3	20.5	20.4	0.141421		Ihiagwa	20.8	18.3	19.55	1.767767
				1	2	3	AVE	STD DEV							
			Ekwuato 4	2.7	3.3	2.8	2.933333	0.321455							
			Ihiagwa (	16	18.7	18.1	17.6	1.417745							
			Nekede 4	6.5	5.6	6.4	6.166667	0.493288							
			Wetheral	1.8	1.5	1.8	1.7	0.173205							

		Ekwuato (	Ihiagwa (4	Nekede	Wetheral		Anova: Single Factor						
Water	Ph	7.15	7.21	7.42	6.57								
	Temperat	22.3	22.35	22.7	20.5		SUMMARY						
	Conductiv	16.1	23.75	28.5	25.1		*Groups*	*Count*	*Sum*	*Average*	*Variance*		
	Turbidity (	2.93	17.6	6.17	1.7		Ekwuato (	7	86.91	12.41571	54.59643		
Sediment	pH	7.03	7.18	7.81	6.81		Ihiagwa (4	7	109.49	15.64143	50.88358		
	Temperat	20.6	20.6	20.35	19.7		Nekede	7	143.05	20.43571	247.0775		
	Conductiv	10.8	10.8	50.1	24.5		Wetheral	7	104.88	14.98286	93.27149		
							ANOVA						
							Source of Varia	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
							Between (	235.3197	3	78.4399	0.703767	0.559089	3.008787
							Within Gr	2674.974	24	111.4572			
							Total	2910.294	27				

Appendix 2. Physicochemical parameters CONTD

TDS			
run 1	run 2	mean	std
2.53	2.8	2.665	0.190919
2.53	2.52	2.525	0.007071
4.78	4.65	4.715	0.091924
4.34	3.63	3.985	0.502046
7.5	8.24	7.87	0.523259
4.58	5.72	5.15	0.806102
6.28	7.06	6.67	0.551543
6.11	7.1	6.605	0.700036

TSS			
run 1	run 2	mean	std
2.3	1.96	2.13	0.240416
1.3	1.4	1.35	0.070711
4.89	4.04	4.465	0.601041
5.86	5.45	5.655	0.289914
3.88	2.5	3.19	0.975807
3.11	3.6	3.355	0.346482
4.32	4.88	4.6	0.39598
5.04	3.44	4.24	1.131371

COD			
run 1	run 2	mean	std
197.33	146.67	172	35.82203
208	122.67	165.335	60.33742
202.67	154.67	178.67	33.94113
199.92	146.35	173.135	37.87971
128	120	124	5.656854
74.67	77.33	76	1.880904
106.67	82.67	94.67	16.97056
89.65	92.4	91.025	1.944544

NITRATE			
run 1	run 2	mean	std
2.116	2.365	2.2405	0.17607
0.995	1.992	1.4935	0.704985
3.56	3.96	3.76	0.282843
4.01	4.21	4.11	0.141421
4.522	5.021	4.7715	0.352846
5.622	6.307	5.9645	0.484368
6.514	6.39	6.452	0.087681
5.46	6.96	6.21	1.06066

NITRITE			
run 1	run 2	mean	std
0.208	0.265	0.2365	0.040305
0.345	0.321	0.333	0.016971
0.573	0.594	0.5835	0.014849
0.674	0.654	0.664	0.014142
2.409	2.876	2.6425	0.330219
3.542	2.708	3.125	0.589727
3.985	3.073	3.529	0.644881
3.54	3.975	3.7575	0.307591

PHOSPHOROUS			
run 1	run 2	mean	std
1.591	1.49	1.5405	0.071418
1.761	1.795	1.778	0.024042
1.955	2.049	2.002	0.066468
1.87	1.97	1.92	0.070711
2.303	2.481	2.392	0.125865
2.557	2.658	2.6075	0.071418
2.269	2.472	2.3705	0.143543
2.44	2.13	2.285	0.219203

SULPHATE			
run 1	run 2	mean	std
11.92	11.92	11.92	0
9.876	12.757	11.3165	2.037175
12.757	13.991	13.374	0.87257
13.168	13.168	13.168	0
44.442	46.911	45.6765	1.745847
50.203	52.672	51.4375	1.745847
85.592	87.649	86.6205	1.454519
73.56	70.19	71.875	2.38295

FLUORIDE			
run 1	run 2	mean	std
0.238	0.357	0.2975	0.084146
0.178	0.278	0.228	0.070711
0.347	1.765	1.056	1.002677
0.62	0.58	0.6	0.028284
0.357	0.575	0.466	0.154149
0.357	0.575	0.466	0.154149
2.401	2.063	2.232	0.239002
2.143	2.222	2.1825	0.055861

BOD			
run 1	run 2	mean	std
115.8	141.6	128.7	18.24335
129.6	130.7	130.15	0.777817
169.3	161.6	165.45	5.444722
153.6	157.4	155.5	2.687006
109.2	145.6	127.4	25.73869
129.6	124	126.8	3.959798
204.8	147.2	176	40.72935
187.63	130.3	158.965	40.53843

		HARDNESS mg/l				CHLORINE				TS			
		run 1	run 2	mean	std	run 1	run 2	mean	std	run 1	run 2	mean	std
	Wetheral	40	42	41	1.414214	91	98	94.5	4.949747	4.64	4.76	4.7	0.084853
water	Ekwuato	44	36	40	5.656854	93	97	95	2.828427	4.33	4.78	4.555	0.318198
	Nekede	55	65	60	7.071068	110	114	112	2.828427	5.64	6.56	6.1	0.650538
	Ihiagwa	56	52	54	2.828427	106	102	104	2.828427	5.94	5.3	5.62	0.452548
sediment	Wetheral	32	38	35	4.242641	76	82	79	4.242641	9.62	9.16	9.39	0.325269
	Ekwuato	58	66	62	5.656854	157	153	155	2.828427	10.16	9.56	9.86	0.424264
	Nekede	84	76	80	5.656854	159	161	160	1.414214	9.45	9.71	9.58	0.183848
	Ihiagwa	67	62	64.5	3.535534	155	130	142.5	17.67767	11.82	13.12	12.47	0.919239

Appendix 3. Physicochemical parameters CONTD

		HARDNES	CHLORINE	TS	TDS	TSS	COD	NITRATE	NITRITE	PHOSPHO	SULPHATE	FLUORIDE	BOD
	Wetheral	41	94.5	4.7	2.665	2.13	172	2.2405	0.2365	1.5405	11.92	0.2975	128.7
water	Ekwuato	40	95	4.555	2.525	1.35	165.335	1.4935	0.333	1.778	11.3165	0.228	130.15
	Nekede	60	112	6.1	4.715	4.465	178.67	3.76	0.5835	2.002	13.374	1.056	165.45
	Ihiagwa	54	104	5.62	3.985	5.655	173.135	4.11	0.664	1.92	13.168	0.6	155.5
sediment	Wetheral	35	79	9.39	7.87	3.19	124	4.7715	2.6425	2.392	45.6765	0.466	127.4
	Ekwuato	62	155	9.86	5.15	3.355	76	5.9645	3.125	2.6075	51.4375	0.466	126.8
	Nekede	80	160	9.58	6.67	4.6	94.67	6.452	3.529	2.3705	86.6205	2.232	176
	Ihiagwa	64.5	142.5	12.47	6.605	4.24	91.025	6.21	3.7575	2.285	71.875	2.1825	158.965

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Wetheral	12	461.93	38.49417	3560.062
Ekwuato	12	454.064	37.83867	3443.734
Nekede	12	552.1755	46.01463	4573.67
Ihiagwa	12	522.357	43.52975	4129.466
Wetheral	12	441.7985	36.81654	2280.871
Ekwuato	12	501.7655	41.81379	2870.518
Nekede	12	632.724	52.727	4209.272
Ihiagwa	12	566.615	47.21792	3337.575

ANOVA

Source of Varia	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between (	2499.99	7	357.1414	0.100585	0.998169	2.115472
Within Gr	312456.8	88	3550.646			
Total	314956.8	95				

Appendix 4. Heavy metals

	Mercury (mg/l)					Arsenic (mg/l)			
	Run 1	Run 2	average	std		Run 1	Run 2	average	std
Water:We	0.011	0.012	0.0115	0.000707		0.024	0.021	0.0225	0.002121
Ekwuato S	0.023	0.021	0.022	0.001414		0.008	0.076	0.042	0.048083
Nekede m	0.027	0.032	0.0295	0.003536		0.019	0.016	0.0175	0.002121
Ihiagwa	0.035	0.031	0.033	0.002828		0.032	0.033	0.0325	0.000707
Sediment	0.046	0.039	0.0425	0.00495		0.051	0.037	0.044	0.009899
Ekwuato	0.038	0.04	0.039	0.001414		0.032	0.027	0.0295	0.003536
Nekede	0.033	0.048	0.0405	0.010607		0.024	0.022	0.023	0.001414
Ihiagwa	0.031	0.026	0.0285	0.003536		0.027	0.032	0.0295	0.003536

Sample	Cadmium (mg/l)					Lead (mg/l)			
	Run 1	Run 2	average	std		Run 1	Run 2	average	std
Water:We	0.014	0.002	0.008	0.008485		0.002	14	7.001	4.94904
Ekwuato S	0.009	0.011	0.01	0.001414		0.013	0.01	0.0115	0.001061
Nekede m	0.018	0.003	0.0105	0.010607		0.041	0.026	0.0335	0.005303
Ihiagwa	0.015	0.013	0.014	0.001414		0.002	0.03	0.016	0.009899
Sediment	0.01	0.011	0.0105	0.000707		0.016	0.003	0.0095	0.004596
Ekwuato	0.011	0.007	0.009	0.002828		0.021	0.019	0.02	0.000707
Nekede	0.003	0.023	0.013	0.014142		0.004	0.016	0.01	0.004243
Ihiagwa	0.013	0.009	0.011	0.002828		0.03	0.002	0.016	0.009899

	cadmium	Lead	Mercury	Arsenic
Water:We	0.008	7.001	0.0115	0.0225
Ekwuato S	0.01	0.0115	0.022	0.042
Nekede m	0.0105	0.0335	0.0295	0.0175
Ihiagwa	0.014	0.016	0.033	0.0325
Sediment	0.0105	0.0095	0.0425	0.044
Ekwuato	0.009	0.02	0.039	0.0295
Nekede	0.013	0.01	0.0405	0.023
Ihiagwa	0.011	0.016	0.0285	0.0295

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Water:We	4	7.043	1.76075	12.20458
Ekwuato S	4	0.0855	0.021375	0.000218
Nekede m	4	0.091	0.02275	0.000113
Ihiagwa	4	0.0955	0.023875	0.000106
Sediment	4	0.1065	0.026625	0.000369
Ekwuato	4	0.0975	0.024375	0.000165
Nekede	4	0.0865	0.021625	0.000189
Ihiagwa	4	0.085	0.02125	8.44E-05

ANOVA

Source of Varia	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between (	10.56779	7	1.509684	0.989484	0.462086	2.422629
Within Gr	36.61747	24	1.525728			
Total	47.18526	31				

Appendix 5. Otammiri microplastics studies CONTD

Ekwuato 4	0.1241	0.1081	0.2322	0.1161	0.011314		
Ihiagwa (	0.6254	0.5596	1.185	0.5925	0.046528		
Nekede 4	3.6	1.4002	5.0002	2.5001	1.555493		
Wetheral	0.4877	0.2897	0.7774	0.3887	0.140007		
	Anova: Single Factor						
	SUMMARY						
	Groups	*Count*	*Sum*	*Average*	*Variance*		
	Ekwuato 4	2	0.2322	0.1161	0.000128		
	Ihiagwa (	2	1.185	0.5925	0.002165		
	Nekede 4	2	5.0002	2.5001	2.41956		
	Wetheral	2	0.7774	0.3887	0.019602		
	ANOVA						
	Source of Varia	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
	Between (	7.061603	3	2.353868	3.8565	0.112588	6.591382
	Within Gr	2.441455	4	0.610364			
	Total	9.503058	7				

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