Quantification of Microplastics in Otammiri River, Imo State, Nigeria

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 paraters showed that the parameters were within the Federal Mimistry of Enivronment (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.

1.0 Introduction

Microplatics are commonly defined as plastic particles smaller than 5 mm in at least one external dimension (Miller *et al.*, 2021; United States Environmental Protection Agency, EPA, 2021).Studies have shown that plastic is abundance in inland freshwater systems in Nigeria (Nwakanma, Blessed & Hanson, 2021; Williams &Osahon, 2021;Olarinmoye*et al.*, 2021; Enyoh, Verla, Ohiagu, &Enyoh, 2021; Babatunde & Arinze, 2018).Enyoh, Verla, Verla, &Ihenetu (2019) reported that 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. Olarinmoye*et al.*, (2021) 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).Adeogun,Ibor, Khan, Chukwuka, Omogbemi1 &Arukwe(2022), 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 (Li, Sun, Li, Tang, Miu & Ma, 2021).Exposure routes of microplastics to humans include ingestion, inhalation, and dermal penetration (Anqi & Wen-Xiong, 2023). 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 (Lusher, McHugh, & Thompson, 2013). 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 (Van Franeker, J& Law, 2015). 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 (Anqi & Wen-Xiong, 2023).Biofilms in drinking water contain loads of microbes which are transported with the water such as tap water causing serious health menace (Nworie, 2021). Liang, de Haan, Cerd`a-Dom`enech, M´endez, Lucena, García-Aljaro, Sanchez-Vidal &Ballest´e (2023) noted that 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.This article focused on the findings of the study regarding the presence, distribution, and composition of microplastics in Otammiri River surface water and sediment samples.

2.0 Methodology

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(Fagorite, Ahiarakwem, Okeke, &Onyekuru2019).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 (Fagorite*et al.*, 2019).

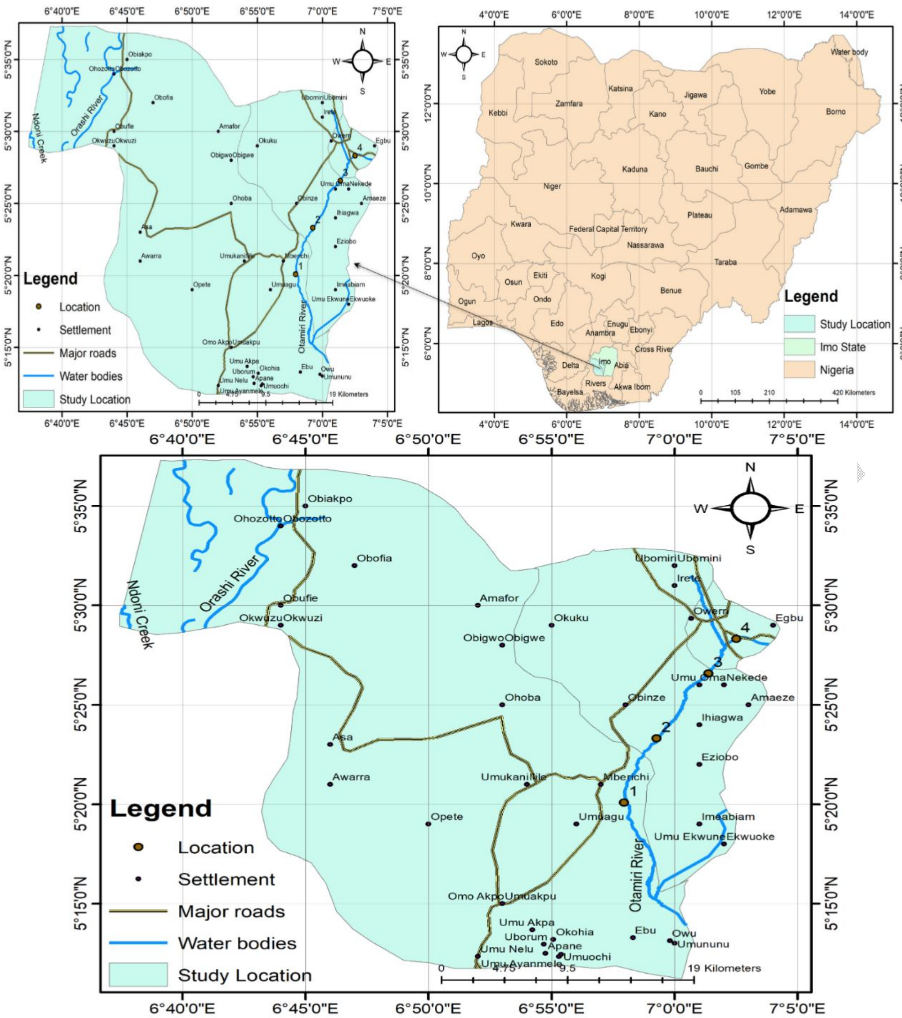

Fig 1: Location and Accessibility Map of the Study Area

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) IhiagwaOtammiri 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 (FEPA 2003).

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 (Bikker, Lawson, Wilson &Rochman, 2020; Kerubo, Muthumbi, Onyari, Kimani & Robertson-Andersson, 2020). 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, as described by Miller *et al.* (2021)and deposited into clean glass jars. At each sampling point, five sediment samples were collected, ensuring representation across the area.

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 (Bikker *et al*., 2020; Kerubo *et al*., 2020).

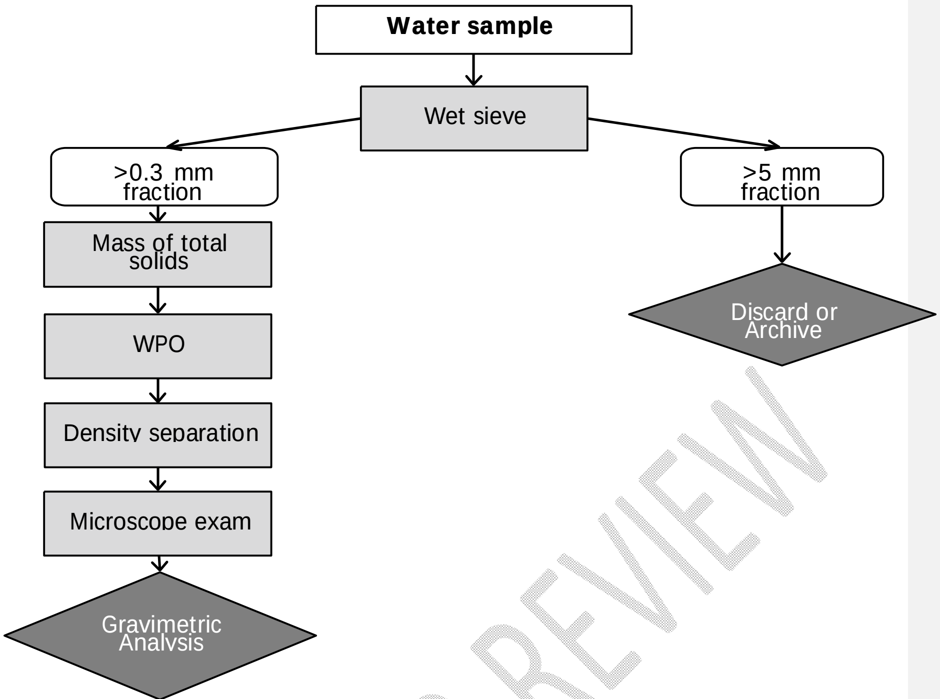

Fig 2: Flow diagram for the analysis of microplastics in water samples (Miller *et al.*, 2021).

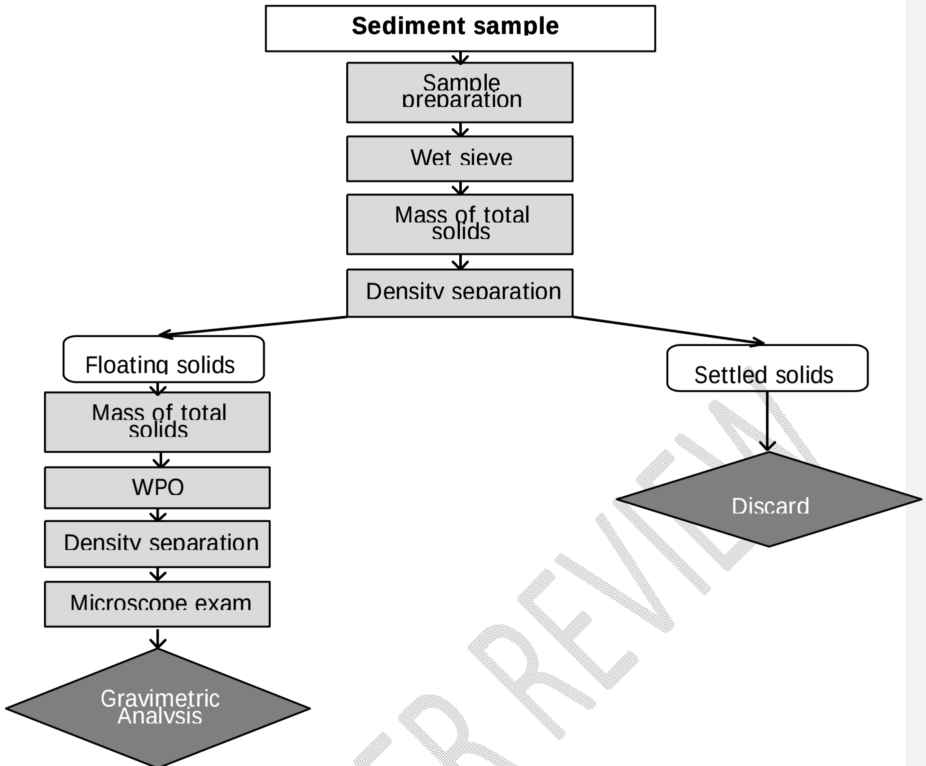

Fig 3: Flow diagram for the analysis of microplastics in sediment samples (Miller *et al.*, 2021).

3.0 Result

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. Odour was unobjectionable across the sampling points.

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.

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

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 atEkwuato (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 atEkwwato (165.34±60.34) locations. COD (mg/l) of the sediment samples was higher in Wetheral location (124.00±5.66) and least atEkwwato (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 ($P \leq 0.05$) across the sampling locations for both water and sediment samples.

Table 3: Hardness, Total Solids, Total Dissolved Solids, Total Suspended Solids, Chemical Oxygen Demand, Biochemical Oxygen Demand

	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

Comment [MM1]: State is required

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 atWetheral (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 atNekede (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) toWetheral 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.

Table 4: Chlorine, Nitrate, Nitrate, Phosphorous, Sulphate and Fluoride

Comment [MM2]: State is required

	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

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± 0.28g to Ihiagwa, 49.27± 1.41g.

As seen in fig 2, the sediments total solids ranged from Wetheral, 61.6±18.67 g toEkwuato, 185.17±15.34 g.

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.

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.

Concentration of Microplastics in the Sediment Samples

Similarly, the concentration of microplastics in sediment samples across the Otammiri sampling points as shown in fig 5followed the order: Ihiagwa>Nekede>Ekwuato>Wetheral. There is a significant difference (P≥0.05) in the microplastics concentration at the different sampling points.

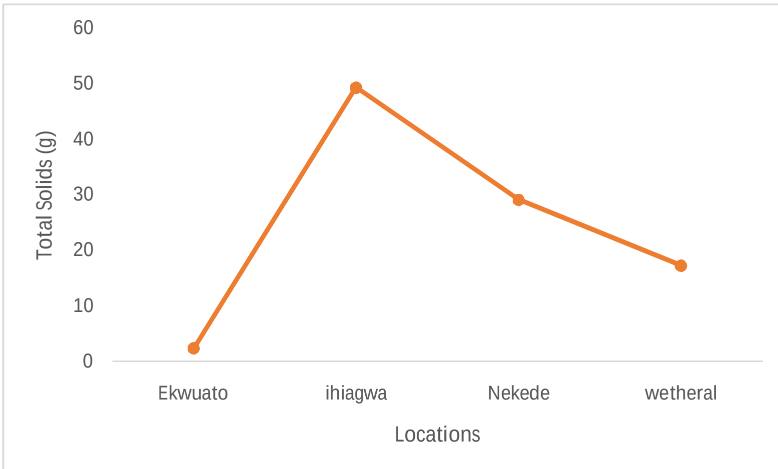

Fig 4: Total Solids of samples trawled from Otammiri River surface water from different sampling points

g: grams.

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

g: gram

Comment [MM3]: Stata including SE bars with significant difference

Comment [MM4]: As above mentioned

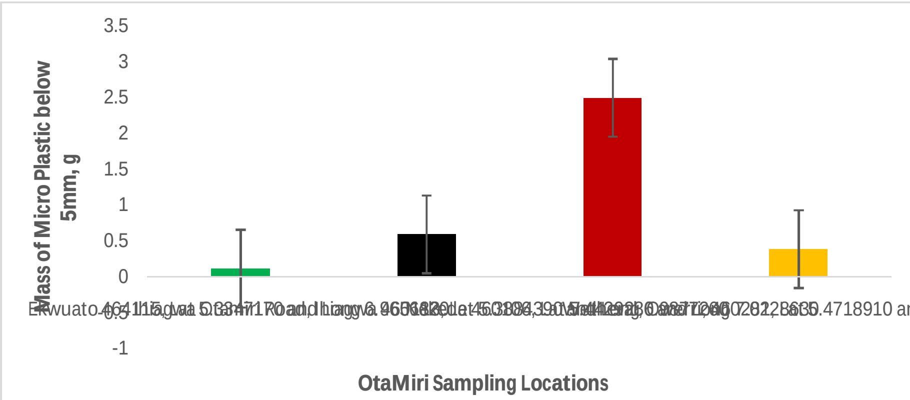

Fig 6: Concentration of Microplastics in Surface Water across Otammiri River Sampling Points

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

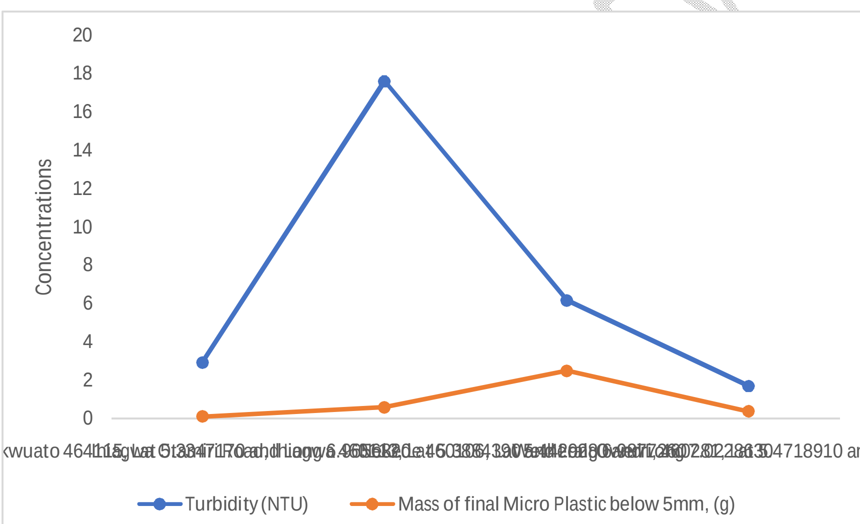

Fig 7: Correlation between Turbidity of Otammiri River and the microplastics concentration

NTU: Nephelometric Turbidity Units

g: gram

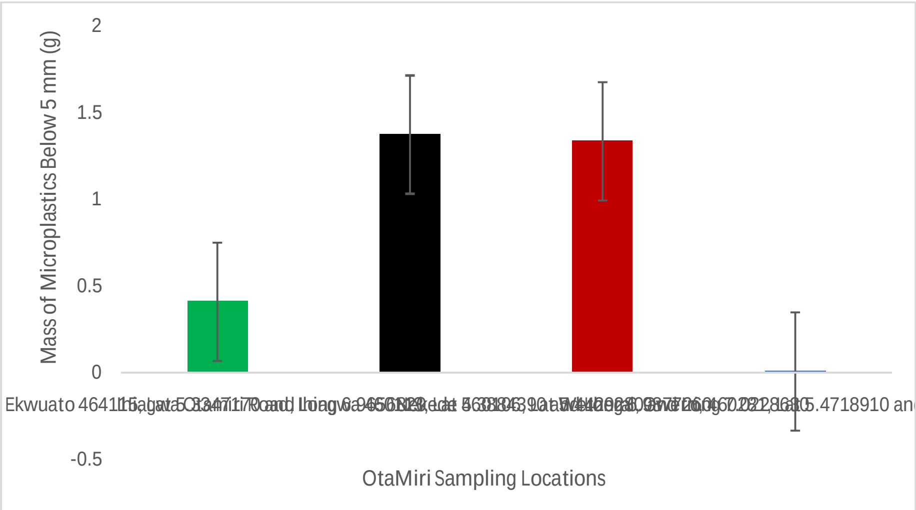

Fig 8: Concentration of Microplastics in Sediment Samples across Otammiri River Sampling Points

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

Discussion

Comment [MM5]: Add summarize diagram

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 objectableodour as well. This indicates the presence of pollution in this water body at these points which do not confirm to safe drinking water standards (WHO, 2011).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 (Andrady, 2011).

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 Cosmas, Ahamefula&Ahiarakwem (2015) and Okeke &Adinna (2013) in Otammiri River. The temperature values reported were due to the climatic condition of the study area (Eze, Onwukeme, Ogbuagu, Aralu, Aduaka& Okoro, 2024; Ubaka, Ekwonu&Ogah 2019; Okechi&Chukwura, 2020).Warmer temperatures can accelerate the degradation of plastic materials, leading to increased fragmentation and subsequent release of microplastics into the environment (Moore, 2008). Temperature influences the metabolic rates and activities of microbial communities responsible for the degradation and decomposition of organic matter, including plastics (Zettler, Mincer & Amaral-Zettler, 2013). Higher temperatures can enhance microbial colonization and enzymatic breakdown of microplastics, potentially affecting their abundance and persistence in aquatic environments (Wright, Erni-Cassola, Zadjelovic& Gibson, 2020).

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 (Enders, Lenz, Stedmon & Nielsen, 2015). 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 conducted by Akubugwo, Nwachukwu &Odika (2013) and Eze *et al.* (2021) 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 (Hüffer, Hofmann &Griebler, 2017). 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 by Akubugwo, Nwachukwu &Odika (2013).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 (Nizzetto, Futter &Langaas, 2016).

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 Amadi, Olasehinde, Okosun, &Yisa (2010) in his 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 (Pittura, Avio, Giuliani, d'Errico, Keiter, Cormier... Regoli, 2020).

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 (Amadi, Olasehinde, Okosun, &Yisa 2010). 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. Okeke & Adinna (2013) 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 (Su, Xue, Li, Yang, Kolandhasamy, Li & Shi, 2019). Microorganisms play a crucial role in the degradation and biotransformation of organic pollutants and microplastics in water bodies (Zhang, Zhang, Qian & Jiang, 2019). Changes in BOD levels can alter the composition and activity of microbial communities, indirectly influencing the degradation and fate of microplastics in aquatic environments (Tian, Jiang, Liu, Chen, Shen, & Zhu, 2021).

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 by Joseph *et al.* (2019) where high concentration of nitrate was observed. Nitrite pollution can also affect the composition and activity of microbial communities in aquatic environments (Wang, Xie, Zhao & Liu, 2018). 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 methaemoglobinaemia (blue baby syndrome) in infants (Joseph, Majesty, Friday, 2019). 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 (Lares, Ncibi, Sillanpää&Sillanpää, 2018).

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 (Zhang *et al*., 2019).

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 (Al-Wabel, Usman, El-Saeid, 2016). 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 (Sun, Wang, Han, Jin, Yu, Zhao & Shi, 2021). 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 (Okechi&Chukwura, 2020). 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)(Okechi&Chukwura, 2020). Heavy metals can adsorb onto the surface of microplastic particles in aquatic environments due to electrostatic attractions and surface properties (Xue *et al*., 2020). 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 (Song *et al*., 2021).Heavy metals sorbed onto microplastics may undergo remobilization under changing environmental conditions, leading to the release of heavy metals back into the water column (Hüffer, Hofmann & von der Kammer, 2017). 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 (Sun *et al*., 2021). Heavy metals adsorbed onto microplastic surfaces may become more bioavailable to aquatic organisms, leading to potential toxicity and ecological risks (Li *et al*., 2019). The presence of heavy metals on microplastics can affect their interactions with biota and influence physiological responses in exposed organisms (Luís, Ferreira, Fonte, Torres & Soares, 2020).

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 Bashir, Kimiko, Mak, Fag & Goncalves (2021) who stated 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 (He, Han, Zheng, Yue, Li, Wu & Li, 2021; Ziajahromi, Kumar & Neale, 2020).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 as noted by Toumi, Abidli&Bejaoni, (2019). The lack of long-distance carriage of the microplastics may be due to the low flow velocity of the river. He, Smith, Egodawalta, Ayoko, Rimtoul&Goonetileke (2021) had stated that 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. This finding is in line with the study of Olarinmoye, Stock, Scherf, Whenu, Asenime&Ganzallo (2021) who noted that the microplastics load in rivers are governed by their proximity to urban areas and human activities. In terms of flowing systems in Nigeria, studies (Gideon, Adewumi, Kehinde, Michael, Temitop, Oluwatoyin, Oluwatosin, & Ademola, 2024 – Osun River; Ogbomida, Obazele, Aganmwonyi, Chukwuka, Emeribe&Omoigberale, 2023 - Ikpoba Rivers, Edo State; Aliyu, Okunola, Awe & Musa., 2023 - Kaduna; Nwonumara, Okoro, &Okogwu, 2021 – Ndibe, Cross River; EbereWirnkor, Verla &Ihenetu, 2019) 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 (Yalwaji, John-Nwagwu&Sogbanmu, 2022). 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 (Olarinmoye, Stock, Scherf, Whenu, Asenime&Ganzallo, 2021). Florian, Joris, Ian & Michael (2020) 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. Eze, Anaebonam, Nweze, Onyemeka, Frank–Ogu, Justice-Alucho&Chiroma (2021) reported that 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. 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. Ting, Haiqing, Fang, Fuhong, Youjun, Hao, Dongxia, Xingxuan, & Qianqian, 2023) noted that microplastics abundance in waterbodies is closely related to urbanization, human industrial activities, and wastewater impacts.

4.0 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, bioaccumulative nature and ability to adsorb harmful pollutants.

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