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Research Article

Characterization of Macro Litter and Microplastics Abundance in the Ogunpa River, Ibadan: Intimation for Solid Waste Management and Environmental Policy

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Abstract

This study characterized macro litter and microplastics abundance in the Ogunpa River with the intimation for solid waste management and environmental policy. Types of plastics and anthropogenic activities around the sampling points were observed using an observational checklist. Water samples were collected from five sampling locations along Ogunpa River for eight weeks during the wet season while particulate fractions of plastic litter and water quality were determined using standard procedures. Water quality was compared with the limits recommended by World Health Organization (WHO) and National Environmental Standards and Regulations Enforcement Agency (NESREA). Data were analysed using descriptive statistics and Pearson Correlation at $p<0.05$. Field observations revealed that indiscriminate disposal of solid wastes including plastics led to the high rate of plastic pollution in the river. A total of 3,569 macro litter and plastics were identified and categorized as: plastics (70%), metal (7%), paper/cardboard (5%), rags (4%), rubber (3%), glass/ceramics (4%), medical and agro-based waste (4%) and wood (3%). The mean microplastic was 45.0±0.8 particles/L (range = 32 to 60 particles/L) while the most common shapes found were fibers and fragments. The major polymer identified were polyethylene, polystyrene, polyester, nylon, and polypropylene. Total Suspended Solids (mg/L) and Nitrate (mg/L) values were higher than the recommended limit by NESREA and WHO. A significant positive correlation existed between microplastic concentration in water and Total Suspended Solids. Microplastics were found in high concentration along Ogunpa River and human activities along the river could serve as a source of microplastic pollution. It is essential to raise public awareness of waste disposal and implement stricter waste management policies at the local communities.

Keywords

Microplastics, Ogunpa River, Wastewater Pollution, Fourier Transform Infrared Spectroscopy

1. Introduction

Plastic pollution has emerged as a critical public health challenge globally, with urban rivers bearing a significant burden. Most of the developing countries experience the problem of plastic pollution and this has greatly impacted

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ecosystem health and services. The challenge posed by plastic pollution is of great significance and exhibits a complex nature, presenting substantial threats to both public health and the essential integrity of the natural environment [1]. Plastics are commercially used materials that are polymeric in nature and present in various shapes, colors, types, and sizes [2]. They include synthetic organic polymers that are derived from the polymerization of monomers extracted from fossil fuels and comprise a cocktail of different additive chemicals, including polymers, dyes, antioxidants, flame-retardants, and plasticizers, all of which may be toxic to the environment [3, 4]. A global increase in plastic production in the middle of the 20th Century has led to an increased accumulation of refuse including litters of plastic in the aquatic environment such as rivers, oceans, lakes, and estuaries [5, 6].

Macro litter, which includes visible waste items such as plastic bottles, packaging materials, and other human-made debris, often leads to microplastic pollution—small plastic particles measuring less than 5 mm that result from degradation or are directly introduced into the environment. These pollutants negatively impact aquatic ecosystems, water quality, and present dangers to both human and animal health [7] (Blettler et al., 2018). The proliferation of microplastics is mainly attributed to poor waste management, stormwater runoff, and the release of untreated wastewater [8] (Wagner et al., 2014). In low- and middle-income countries, the problem worsens due to insufficient waste collection systems and careless dumping practices, resulting in significant amounts of both macro and microplastic pollution in urban water bodies [9] (Akdogan & Guven, 2019). Studies in Africa and Asia have highlighted the lack of effective solid waste management systems, which contributes to the direct dumping of waste into rivers and lakes [10, 12] (Ntagisanimana et al., 2021; Nguyen et al., 2023; Gebrekidan et al., 2024). These circumstances not only endanger aquatic ecosystems but also emphasize the critical need for evidence-based regulations and enhanced solid waste management practices.

In Nigeria, annual production and usage of plastics have really spiralled up [13, 11]. For instance, a study had documented that Nigeria contributes 0.13-0.34 tons in millions of plastic wastes ranking it (Nigeria) the 9th country globally in pollution of waterways [14, 12]. It is noteworthy that such indiscriminate disposal of microplastics tells on human health. Microplastics ingested by aquatic animals most of which are later consumed through the food chain thus becoming an emerging food safety issue and risk [14-16].

However, the UN Sustainable Development Goal 14 (Life Below Water) emphasizes the importance of controlling pollution in marine and freshwater environments [17, 18] (Molony et al., 2022; Hansen et al., 2023). Also, the European Union's Single-Use Plastics Directive seeks to mitigate plastic waste through regulatory measures and responsibility from producers [19] (EU, 2019). Research conducted in Africa, specifically in Rwanda, has explored the growing environmental problems caused by inappropriate waste management and disposal, especially of electronic waste (e-waste), and the resulting negative effects on soil and water quality [20, 21] (Twagirayezu et al., 2022; Twagirayezu et al., 2023). This underscores the need for efficient waste management techniques. In Nigeria, the National Environmental (Sanitation and Waste Control) Regulations (2009) offers some legal framework but suffers from inadequate enforcement [22] (Okechukwu, 2024). Although Lagos has implemented a plastic buy-back program, cities like Ibadan are still behind in developing structured waste management strategies. Despite the existence of multiple policies, their execution is uneven, and the incorporation of data on river pollution into urban planning and waste management policies is still limited. Furthermore, a key requirement for informing policy choices and creating effective waste management systems is to assess the quantity, types, and origins of macro litter and microplastics present in surface waters. Most of the studies on plastics pollution have focused on the detrimental effects in aquatic environments which can act as a vector for pollutants, and transport them long distances to affect aquatic environments. Nevertheless, Ogunpa River, the Ibadan's most significant urban waterway, is a crucial component of the city's hydrological system, yet it has become heavily polluted with plastic waste. The river and its tributaries have been polluted through indiscriminate disposal of solid waste [23, 21]. Despite the above revelation, there is paucity of information on macro litter and microplastics in the river water and little or no policies in place to control plastic pollution within Ibadan metropolis. Such information can guide mitigation strategies, such as implementing plastic restrictions, launching public awareness initiatives, and investing in waste management infrastructure, ultimately leading to cleaner aquatic ecosystems and more resilient urban frameworks. Therefore, this study was conducted to document the abundance and distribution of microplastics in the Ogunpa River with the intimation for solid waste management and environmental policy.

2. Materials and Methods

2.1. Study Area

This study was conducted along the Ogunpa River and its tributaries (Figure 1), in Ibadan at a latitude of $3^{0}35'$ and $4^{0}10'$N, and a longitude of $7^{0}2'$ and $7^{0}4'$E. Ibadan is the capital of Oyo State, Nigeria, in West Africa. It is 128 km north of Lagos and 345 km southwest of Abuja, the Federal Capital Territory. The city of Ibadan is spread over the strongly undulating plains and the quartzite hills and ridges of the Ogunpa River basin. The city has a tropical wet and dry climate with a lengthy wet season and relatively constant temperatures throughout the year. The city experiences an annual rainfall of about 1230 mm and a temperature of 26.46°C [24, 22]. Ibadan is naturally drained by four rivers with many tributaries: Ona River in the North and West; Ogbere River towards the East; Kudeti River in the central part of the metropolis, and Ogunpa River flowing through the city. Ogunpa River is a third-order stream with a channel length of 21.5 km (13.4 mi) and a catchment area of 54.92 km [24]. The city is highly urbanized in terms of residential development, industrial concentration, recreational groups, and educational establishments [25, 23]. Thus, the heterogeneous characteristics of the Ibadan population and the influx of people into the city are transforming steadily the predominantly indigenous city into a multicultural, multi-ethnic urban settlement. This urbanization pressure is expected to lead to an increasing run of chemical and waste pollution. However, the poor waste disposal habits within Ibadan are directly linked to the frequent flooding of the river, especially at downstream reaches.

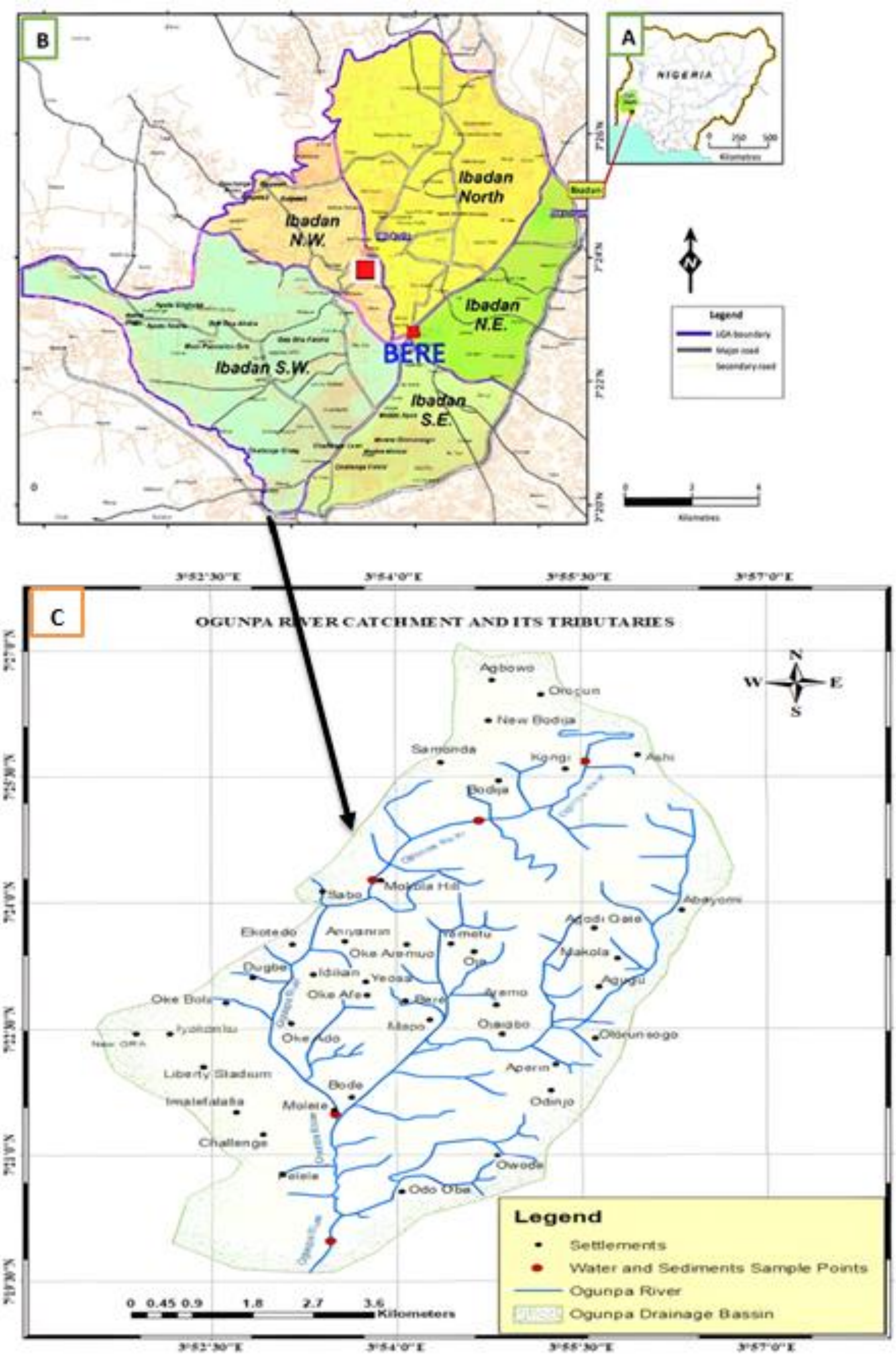


Figure 1. *Map of the study area [A=Nigeria; B= Ibadan metropolis; C= Ogunpa River Drainage Basin and its Tributaries].*

2.2. Sample Collection

Five sampling locations were purposively selected along the mapped-out area (10 by 10m) of the Ogunpa River drainage basin. The locations were Ashi (Location I), New-Bodija (Location II), Dandaru (Location III), Molete (Location IV) and Soka (Location V). Field observation was carried out using a checklist to determine the anthropogenic activities at each location. The macro litter and plastic (>5mm) analysis of this study utilized and modified the operational guidelines on the monitoring and survey of marine litter [13, 26]. Water samples were collected using 1Litre glass bottles [25-28]. Polypropylene bottles (1Litre) were used to collect water samples from each sampling location for physico-chemical analysis. The sample bottles (with sieves and glass funnel) were washed, cleaned, and rinsed with distilled water before sample collection. Duplicate samples were collected fortnightly from each sampling location for two months during the rainy season and a total of 40 water samples were collected according to recommended standard methods described by the American Public Health Association [29]. The sample bottles were tightly stoppered after each collection, transported under 4°C to the laboratory and analysed for Physicochemical characteristics such as pH, Alkalinity, Turbidity, dissolved Oxygen (DO), Total Solids (TS), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Electrical Conductivity (EC), Nitrate, Sulphate and Phosphate.

2.3. Laboratory Analysis

2.3.1. Physicochemical Parameters

The pH of the samples was measured using a calibrated pH meter while turbidity (expressed as NTU) was determined using HACH DR/2000 spectrophotometer at wavelength of 450 nm. Jenway 470 TDS-Conductivity meter (UK) was used to measure Conductivity and total dissolved solids. Titrimetic method (Winkler titration with sodium thiosulfate) was used to determine Dissolved Oxygen while alkalinity was determined using titrimetric method. Total suspended solid (TSS) was determined using gravimetric method. Nitrate, Sulphate and Phosphate were determined using UV/Visible spectrophotometer. All reagents used for analysis were prepared from Analar grade chemicals. Appropriate reagent blanks were prepared for each analysis to ensure Quality Control and Quality Assurance. All analyses were carried out in triplicates [29]. The result was compared with permissible limits of the World Health Organization (WHO) and the National Environmental Standards and Regulations Enforcement Agency (NESREA).

2.3.2. Extraction, Identification, and Quantification of Macro Litter and Microplastics (MPs)

Water samples were filtered through a cellulose filter paper with a pore size of 11μm (Whatman No. 1, Catalog No. 1001 110, UK) with the aid of a glass funnel [13]. The cellulose filter paper was placed in a covered petri dish and transferred to the oven at 40°C to enable visual inspection and quantification. MPs identified were recorded based on the filtered water volume (particles per Liter) while plastic particles were directly observed through visual inspection based on physical characterization and microscopy [30]. MPs were isolated, counted, and examined under a stereomicroscope (Search Tech, Japan; Model: S/ST Series-10x WF10X). The microscope at 10X magnification was used to differentiate between the visually inspected MPs and photographed. Microplastics were identified as particles or substances with an unusual shape or color [31]. The shapes and colors of the MP types identified were also recorded [32].

2.3.3. Fourier Transform Infrared Spectroscopy (FTIR) Analysis of Water Samples

FTIR analysis was done to determine the polymer origin and composition of the small plastic particles in the samples [33]. All equipment items including the die set and spatula were cleaned with methanol to avoid contamination. A quantity of 0.02 g from the isolated plastic particles realized from water samples, was mixed with potassium bromide (100 mg) using a mortar and pestle. The mixture was poured into a metal die set to form pellets. The round-shaped pellets were placed into the FTIR spectrometer (Perkin Elmer Spectrum 2) for analysis. The results of the FTIR were compared to an FTIR fluka library and other studies, to identify the most common types of polymers [34].

2.4. Quality Control and Assurance

Quality control and assurance were done throughout the processing and analysis of water samples, to prevent airborne microplastic contaminants. This was achieved throughout the extraction process and visual sorting in the laboratory. One processing blank was run by filtering 800 ml of distilled water in the same way as the water samples during the extraction process. Work surfaces were thoroughly cleaned and all glassware and utensils were thoroughly rinsed with filtered deionized water and properly kept in a clean metal box before use and covered with aluminium foil when not in use.

2.5. Data Management and Analysis

Data recorded on a spreadsheet were sorted, checked for completeness, and entered using Statistical Package for Social Science (SPSS) version 23.0. Descriptive data was summarised using mean and standard deviations, frequencies, and percentages. Kurtosis was used to perform the normality test on clean, suitably formatted data. Prior to doing a Pearson correlation analysis, a kurtosis coefficient of 2.978 was acquired. Pearson's correlation was used to determine the relationship between the physico-chemical parameters of samples and the concentration of microplastics at 5% level of significance.

3. Results

3.1. Plastic Pollution at Selected Sampling Locations of the Ogunpa River

The extent of plastic pollution is shown in Figure 2. Field observation revealed that there is indiscriminate disposal of plastic materials along the river. Most of the plastic materials were observed to be emanated from human activities such as road or building construction, car wash, markets, shops, and so on. These materials are responsible for the high rate of plastic pollution along the flow of the river. Indiscriminate disposal of waste (nylon, nets, microbeads, agricultural wastes) was found at its peak at Ashi, Soka and Dandaru areas of the study location.

Figure 2. Plastic Pollution at Selected Sampling Locations of the Ogunpa River.

3.2. Abundance and Composition of Macro Litter and Plastic Pollution in the Ogunpa River

This study recorded a total of 3,569 macro litter and plastics across the five sampling locations. The macro litter and plastics were categorized into eight major groups: plastic (PL), rubber (RB), cloth (CL), glass/ceramics (GC), paper/cardboard (PC), metal (ME), wood (WD), and others (OT) as shown in Figure 3. The compositions were Plastics (70%), metal (7%), paper/cardboard (5%), rags (4%), rubber (3%), glass/ceramics (4%), medical and agro-based waste (4%) and wood (3%). The macroplastics (>5mm) particle count gives a high range of value for plastics as found in Molete (Location IV) followed by Soka (Location V), Ashi (Location I), Dandaru (Location III), and New-Bodija (Location II).

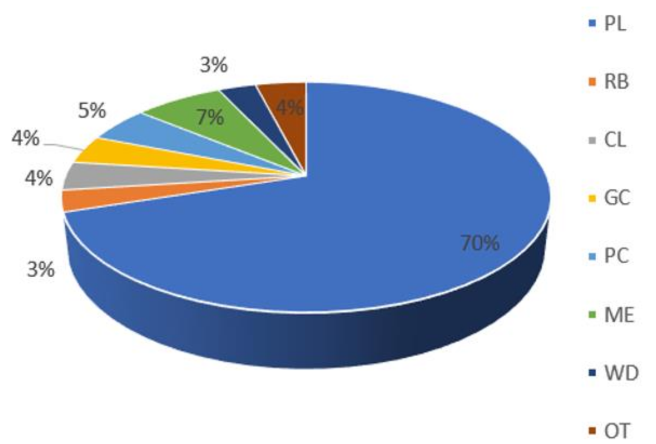


Figure 3. Abundance of macro litter and plastic pollution at Ogunpa River.

[NB: Plastic (PL), rubber (RB), cloth (CL), glass/ceramics (GC), paper/cardboard (PC), metal (ME), wood (WD), and others (OT)]

3.3. Identification and Morphological Characterization of Microplastics

Microplastics of different shapes such as fibers, fragments, films, pellets, and beads were identified in water samples along the five selected locations of Ogunpa River as shown in Figure 4. The most common shapes found were fibers and fragments. The morphological characteristics of microplastics include the shape and colour of plastics found in the water samples of Ogunpa River as shown in Table 1. The shapes include fibers, fragments, pellets, films, and beads as found within the five locations of Ogunpa River. Only fibers were found in the water sample at Molete. The colours found across the five locations of Ogunpa River were green, transparent, black, red, and yellow. (Table 1). The Fourier Transform Infrared (FTIR) spectra of the microplastics from Ogunpa River water sample were analysed in the fingerprint region from 4000-500cm^{-1} (Figure 5). This result reveals the presence of polyethylene, polystyrene, polyester, nylon, and polypropylene in Ogunpa River water as seen in Table 1.

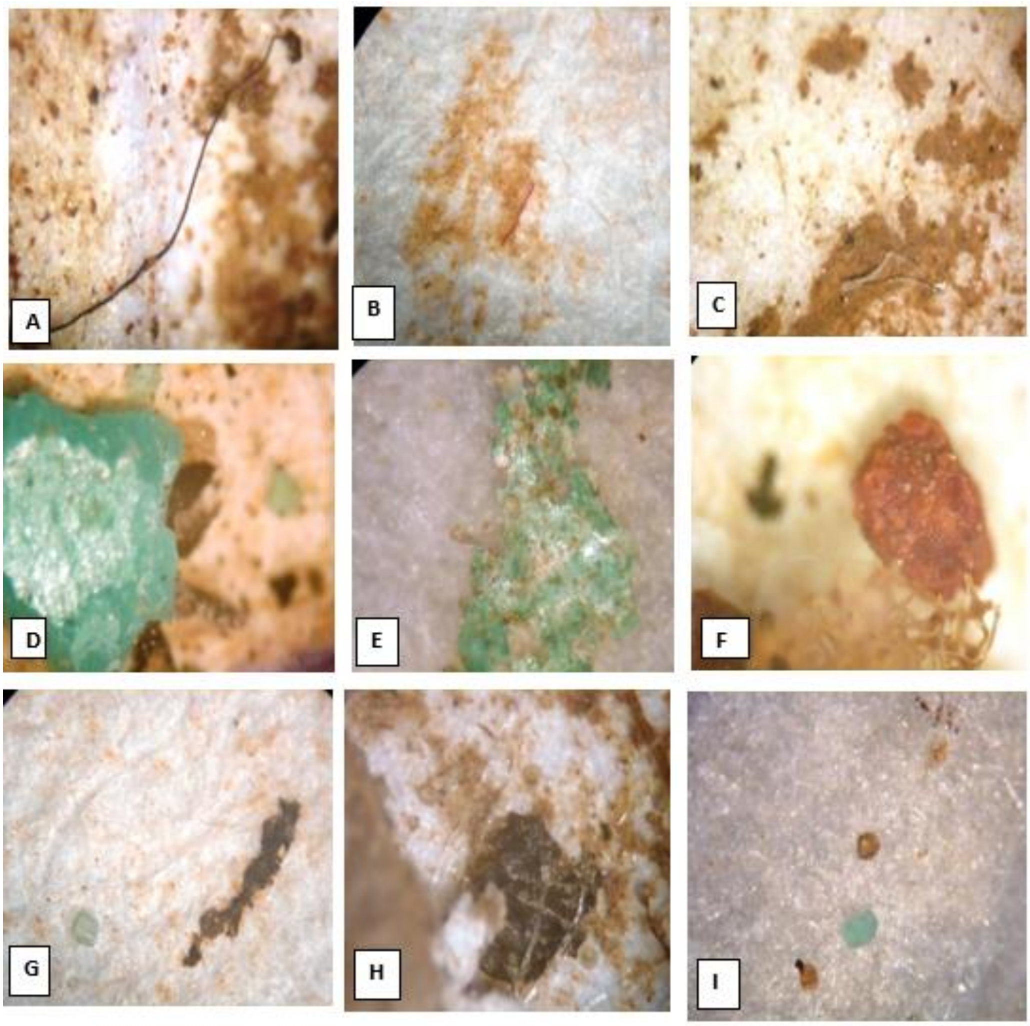


Figure 4. *Microplastic shapes [(A-C) as fibers, (D-F) as fragments, (G&H) as films, and (I) as spheres with a size range of 1mm].*

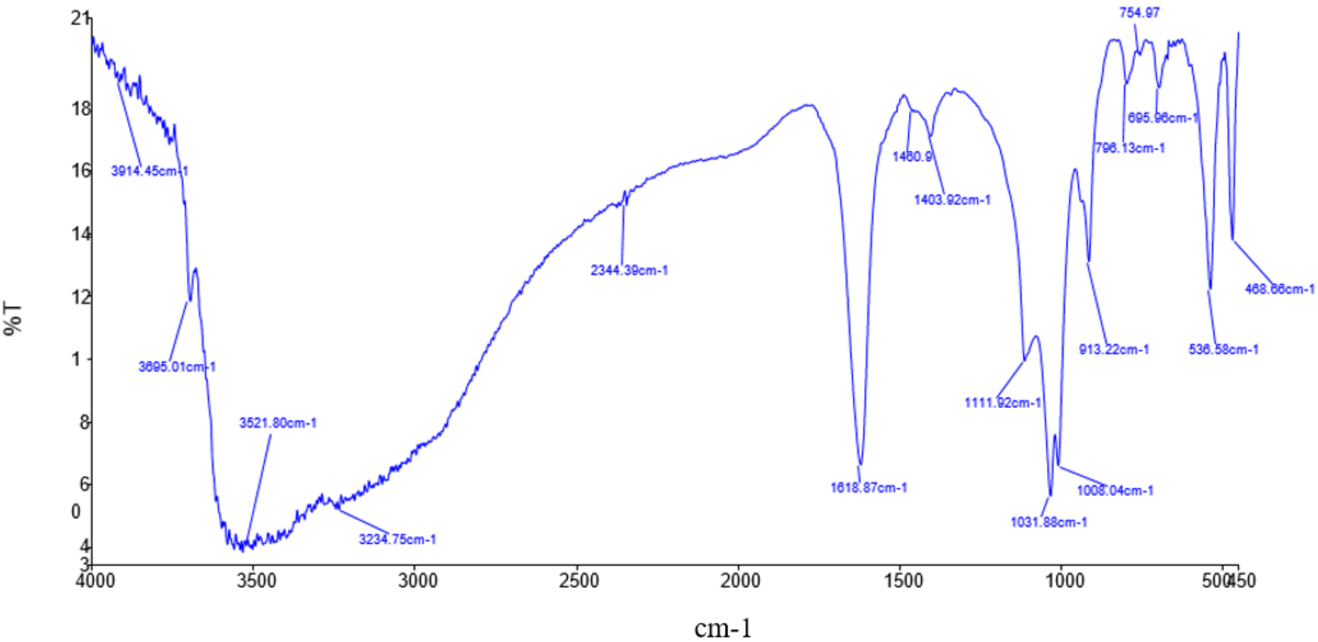


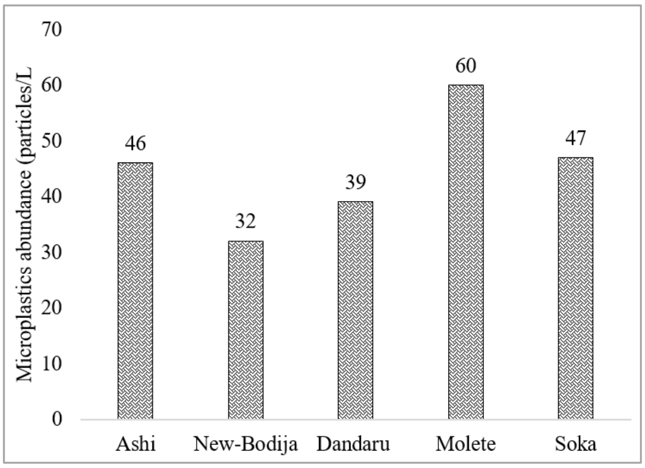
Figure 5. *FTIR spectra for microplastic particles in water samples of Ogunpa River.*

Table 1. Morphological characteristics, Identification of MPs and specific polymer in water samples.

Sample Locations	Water		Specific Polymer
	Shapes	Color	
Ashi	Fibers, Fragments	Red, black, transparent	Polyethylene (PE), Polypropylene (PP), Nylon (NL), Polystyrene (PS), Polyester (PL)
New-Bodija	Fibers, Fragments	Black, green, transparent, brown	
Dandaru	Fiber, Fragments	Blue, transparent, Black	
Molete	Fibers	Black, red and transparent	
Soka	Fibers, fragments	Brown, green, black, and transparent	

3.4. Abundance of Microplastics in Ogunpa River

Microplastics (MPs) abundance in water samples from Ogunpa River ranged from 32 to 60 particles/L with an average of 45.0±0.8 particles/L. Microplastics abundance was higher in Molete (60 particles/L) and Soka (47 particles/L), which can be attributed to high indiscriminate disposal of poorly managed plastic waste along the river bank (Figure 6).



Mean±SD = 45.0±0.8 particles/L

Figure 6. Microplastics Abundance in water samples along Ogunpa River.

3.5. Physico-chemical Characteristics of Water Samples and Their Correlation with Microplastics

Table 2 presents the results for the physico-chemical characterization of water samples along the sampling locations, compared with permissible limits by the WHO and NESREA. The mean pH values of the water samples across the five locations are as follows: Ashi (7.26±0.37), New-Bodija (6.79±0.24), Dandaru (7.25±0.3), Molete (7.31±0.42), and Soka (7.19±0.37). These values fall within the range of the WHO and NESREA standards. Significantly, Dissolved Oxygen (mg/L) was higher at New-Bodija (8.63±0.11) and Dandaru (7.47±0.04) compared to other sampling points. DO values at New-Bodija and Dandaru were higher than the recommended limit by WHO and NESREA. Total Suspended Solids (mg/L) were 16.3±2.5 (Ashi), 143.0±11.56 (New-Bodija), 65.0±3.62 (Dandaru), 115.0±15.0 (Molete), and 82.08±10.0 (Soka), respectively, with significant differences. Significantly, turbidity (NTU) was higher at Ashi (29.26±4.86) and Dandaru (30.98±4.14) compared to other sampling locations. The mean nitrate (mg/L) at Ashi, Dandaru and Molete were 78.54±49.83, 69.85±62.0 and 71.46±50.22, respectively. These were above the permissible limit recommended by WHO and NESREA. Phosphate (mg/L) value was significantly higher at Ashi (39.17±5.0) compared to other sampling locations along the river. Other parameters such as Alkalinity, TS, TDS, and EC were within the permissible limit by WHO and NESREA.

Table 2. Results of physico-chemical characteristics of the water samples.

Parameters (Unit)	Ashi	New-Bodija	Dandaru	Molete	Soka	F Statistics	P value	Standards	
								WHO*	NESREA**
pH	7.26±0.37	6.79±0.24	7.25±0.3	7.31±0.42	7.19±0.37	1.770	0.149	6.5-8.5	6.5-9

Parameters (Unit)	Ashi	New-Bodija	Dandaru	Molete	Soka	F Statistics	P value	Standards	
								WHO*	NESREA**
Temperature (°C)	29.0±0.57	25.0±1.73	27.0±1.53	26.0±0.57	26.0±0.76	13.460	<0.001	<25°C	40
Alkalinity (mg/L)	122.0±12.58	128.0±12.14	115.0±10.0	173.0±9.23	192.0±7.52	9.080	<0.001	200	120
Turbidity (NTU)	29.26±4.86	7.05±3.31	30.98±4.14	6.45±3.79	15.0±2.86	34.280	<0.001	5-7	41.1
DO (mg/L)	6.09±0.06	8.63±0.11	7.47±0.04	0.58±0.07	0.58±0.22	14.860	<0.001	6.0	4.0
TS (mg/L)	242.0±9.17	397.0±16.53	276.0±4.59	423.0±16.95	450.0±8.11	7.750	<0.001	1000	500-1500
TDS (mg/L)	230.0±8.79	258.0±7.83	215.0±5.66	317.0±6.73	367.0±3.16	26.460	0.031	500	1000
TSS (mg/L)	16.3±2.5	143.0±11.56	65.0±3.62	115.0±15.0	82.08±10.0	2.800	<0.001	50	30
EC (µs/cm)	464.0±20.20	513.0±14.0	430.0±5.16	625.0±9.09	734.0±7.59	25.370	<0.001	750	1000
Nitrate (mg/L)	78.54±9.83	26.33±1.77	69.85±6.0	71.46±5.22	33.35±4.04	3.820	0.008	50	40
Sulphate (mg/L)	202.0±4.68	261.0±16.89	108.0±8.84	166.0±8.28	158.0±9.36	3.850	0.008	250	500
Phosphate (mg/L)	39.17±5.0	8.35±0.89	5.55±1.14	11.90±7.43	11.59±7.92	4.190	0.005	15	10

Source: *World Health Organization (WHO), [35]; **National Environmental Standards and Regulations Enforcement Agency (NESREA), [36]

Significantly, there is a positive correlation between microplastic concentration in water and TSS and EC. However, a significant negative correlation existed between microplastic concentration in water and Dissolved Oxygen of the water as presented in Table 3.

Table 3. *Correlation results of the physico-chemical parameters and microplastic concentration of the water samples.*

Parameters (Units)	pH	TDS	TS	EC	Temp	Alkalinity	Turbidity	TSS	DO	Nitrate	Sulphate	Phosphate	MCw
pH	1												
TDS (mg/L)	-0.041	1											
TS (mg/L)	-0.038	0.671**	1										
EC (µS/cm)	-0.018	0.995**	0.687**	1									
Temp (°C)	0.260*	-0.450**	-0.466**	-0.435**	1								
Alkalinity (mg/L)	0.072	0.872**	0.451**	0.876**	-0.195	1							
Turbidity (NTU)	0.288*	-0.313*	-0.293*	-0.284*	0.340**	-0.211	1						
TSS (mg/L)	-0.036	0.214	0.865**	0.233	-0.313*	0.012	-0.191	1					
DO (mg/L)	-0.098	-0.707**	-0.373**	-0.699**	0.301*	-0.601**	0.279*	-0.019	1				
Nitrate (mg/L)	-0.140	-0.143	-0.267*	-0.147	0.219	0.067	0.101	-0.257*	-0.021	1			

Parameters (Units)	pH	TDS	TS	EC	Temp	Alkalinity	Turbidity	TSS	DO	Nitrate	Sulphate	Phosphate	MCw
Sulphate (mg/L)	-0.446*.*	0.230	0.081	0.216	-0.184	0.074	-0.188	-0.031	0.147	-0.064	1		
Phosphate (mg/L)	-0.045	-0.079	-0.167	-0.070	0.280*	0.018	0.477**	-0.180	0.017	-0.131	-0.032	1	
MCw (par/L)	-0.559	0.422	0.536	0.785**	-0.617	0.508	0.001	0. 795*	-0.841**	0.161	-0.178	0.457	1

*. Correlation is significant at the 0.05 level (2-tailed). MCw (Microplastic concentration in water)
**. Correlation is significant at the 0.01 level (2-tailed).

4. Discussion

This study reveals that the presence of large plastic materials such as pet bottles and nylon bags in the Ogunpa River was resulted from indiscriminate waste disposal. This has led to the destruction of the drainage basin and channelization. Previous study has documented that macro litter and microplastic pollution are particularly common in places where there are high anthropogenic pressures such as harbours and marinas [37]. The plastic waste can impact the aquatic environments through urban runoff, settling from the air, and effluent discharge from wastewater treatment plants [38-40]. In this study, it was observed that packaging materials and human activities such as road or building construction, car wash, markets, shops, and so on, are responsible for the high rate of plastic pollution along the flow of the Ogunpa River. Studies have documented similar findings [41, 42]. Furthermore, it was revealed that indiscriminate disposal of waste (nylon, nets, microbeads, agricultural wastes etc.) which poses a major public health challenge, was found at its peak at Ashi, Molete, and Soka areas of the study location. Flooding may result from the obstruction of drainage and river channels caused by macro litter, particularly plastics, particularly during the wettest rainy seasons. Because of this, the water becomes stagnant, which encourages algae blooms and upsets the natural equilibrium. The presence of plastic litter accumulation in the drainage system, including single-use plastics, serves as potential sources of specific contamination and can impact living organisms in the surrounding environment. Similar finding has been earlier reported in a study [40].

This study recorded a total of 3,569 macro litter and plastics across the sampling locations. This finding total is lower compared to some previous studies conducted during the rainy season in South Korea [43] and Northern Taiwan [44], respectively. However, a previous study conducted in Nigeria had reported a slightly lower value (3,487 items/m) than that value obtained in this study [13]. Higher number of macro litter and plastics in the river samples could be attributed to increased industrialization and urbanization around the Ogunpa River channel. The accumulation of plastic waste can disrupt the physical environment of the river by blocking the riverbed and diminishing water flow, which in turn impacts the natural habitat of aquatic life. Additionally, aquatic species, including fish and amphibians, might consume plastic particles or get caught in larger debris, resulting in injuries or fatalities. While there is limited data on the fauna of Ogunpa River, similar effects have been noted in other tropical rivers [5, 6]. Microplastics of different shapes and colors were identified in water samples from five selected locations of the Ogunpa River. Microplastics have the ability to absorb and transport harmful chemical pollutants such as heavy metals and persistent organic pollutants (POPs), which may then be released into the river's food chain, affecting biodiversity and posing risks to humans. Microplastics identified using a stereomicroscope showed different shapes such as fibers, fragments, pellets, and films [42, 45]. The most common colors found across the five locations of the Ogunpa River were green, transparent, and black. Other colors were red, transparent, and black while the fragments were green and red. The transparent colors found in this study could have been from plastic shopping bags and wrappings as well as fishing lines and ropes, whereas the black MPs may have been discharged into the environment through the breakdown of plastic pipes. This finding is similar to that of a previous one [46].

The polymers found through FTIR analysis of microplastics discovered along the Ogunpa River, were polyethylene, polystyrene, polyester, nylon, and polypropylene. The fingerprint of the spectrum of each sample was compared with previous findings [47, 48]. This study observed a similar trend in the abundance of polyethylene and polypropylene from the samples analysed. This was consistent with global trends of polymers indicating an increase in global production and use of plastics in Nigeria [49]. These polymeric materials are found to be responsible for the pollution of waterways, sewage drains, and open landfills in terms of increased tonnage. Thus, the results of the study with the dominance of PP and PE were similar to other studies' [41, 50, 51].

Microplastics (MPs) abundance in water samples of Ogunpa River ranged from 32-60 particles/L with an average of 45.0±0.8 particles/L. This result was higher when compared to studies from other countries [41, 52, 53], but lower to other studies conducted in Nigerian rivers [13, 54]. Furthermore, this study observed that Molete is a mid-point for two rivers and Soka is connected with waste from nearby industries. Molete and Soka are known to have highly intensive anthropogenic activities, due to high industrialization and urbanization that experience wind and rainy events leading to high levels of contamination [55]. Nonetheless, WHO [56] states that two of the main inputs of microplastics into the aquatic environment are surface run-off and wastewater effluent.

Findings from the study reveal that the pH of (Ogunpa) water was within the recommended limits by WHO and NESREA. Moreover, the mean values recorded were not statistically different between the sampled locations. Temperature and turbidity were above the WHO's and NESREA's permissible limits. However, the mean values for turbidity recorded in Ogunpa River exhibited significant differences between the sampling locations. The highest turbidity levels recorded at some sampling points (Dandaru and New-Bodija) along the river can be attributed to washing of cars and other cloth materials at the river bank. High turbidity results could be attributed to increased turbidity concentrations during rainfall especially in developed water sheds [29]. Moreover, wastewater from carwash contributes to high turbidity in the receiving water body [57]. Elevated turbidity levels suggest possible pollution sources, such as agricultural runoff, urban effluents, or land-use changes, which could lead to sedimentation and hinder light penetration, adversely affecting aquatic flora and fauna. Electric conductivity (E.C) was within the permissible limit of WHO and NESREA. This result was similar to the findings of a previous study [58].

Data from this study revealed a significantly high nitrate concentrations at some sampling locations, which were greater than the recommended value stated by WHO and NESREA. This could have resulted from improper disposal of waste from humans and animals or runoff leakage from fertilized soil. Concentrations of TS and TDS were below permissible limits by the WHO and NESREA. This finding is similar to the report of a previous study [42]. The findings of Total Dissolved Solids (TDS) reflect a favorable environment for aquatic organisms, as all measured values remained significantly below the harmful thresholds established by WHO and NESREA. Furthermore, this study observed a significant positive correlation between microplastic concentration in water and, TSS and EC of the water. This indicates that an increase in the concentration of microplastics could lead to an increase in the Total Dissolved Solids and Electrical Conductivity of the water sources and vice versa. Similar findings have been reported in a study [59]. Data from this study also revealed a significant negative correlation between microplastic concentration in water and Dissolved Oxygen of the water. This finding indicates that an increase in microplastic concentration could result to decrease in Dissolved Oxygen of the water source. However, previous studies have reported contrary findings [60, 61].

5. Conclusion

The widespread presence of microplastics in the rivers not only highlights the inefficiencies in waste disposal systems but also signals a growing environmental crisis with far-reaching implications for both aquatic life and human health. This study has revealed that large plastic materials such as pet bottles and nylon bags were present in the river. Furthermore, the presence of various polymers, predominantly fibers and fragments, underscores the urgent need to address the sources of plastic waste in the region. Additionally, some of the water quality parameters exceeded the WHO's and NESREA's permissible limit. Also, there is a significant negative correlation between microplastic concentration in water and Dissolved Oxygen of the water. The poor water quality raises major concerns about the potential health risk to the local communities. Establishing a River Basin Pollution Control Act is crucial to create a legal structure for managing pollution in urban river ecosystems like the Ogunpa River. The main elements of this act should involve designating urban rivers as "Environmental Protection Zones," limiting waste discharge into these rivers, and conducting regular environmental audits of industries and residential areas near the rivers. Additionally, there should be a regulation for Plastic Waste Audit Reporting, requiring every local government in the Ibadan metropolis to submit time-specific reports on plastic waste audits. This will ensure effective monitoring of the progress of mitigation strategies and aid in policy evaluations.

Abbreviations

LGA	Local Government Area
WHO	World Health Organization
NESREA	National Environmental Standards and Regulations Enforcement Agency
NTU	Nephelometric Turbidity Unit
DO	Dissolved Oxygen
TSS	Total Suspended Solids
TDS	Total Dissolved Solids
TS	Total Solids

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Ethics Declarations

Ethical approval was sought and obtained from the University of Ibadan/University College Hospital ethical community, of the Institute for Advanced Medical Research and Training (IAMRAT) in Ibadan, Nigeria.

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Conflicts of Interest

The authors declare no conflicts of interest.

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