



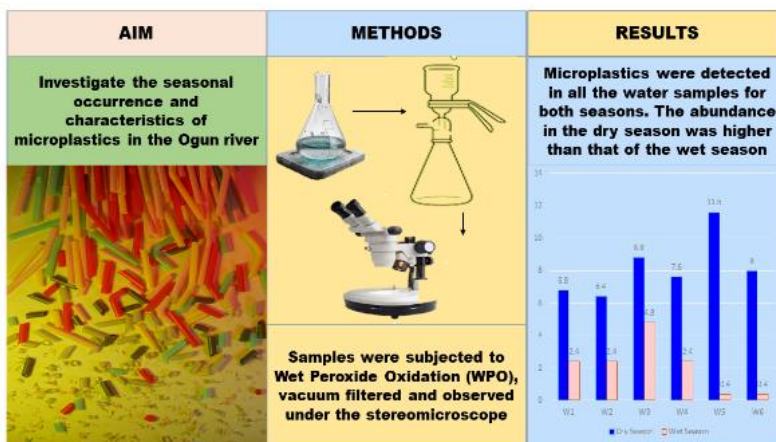
Seasonal variation of microplastics in surface water of the Ogun River, Nigeria

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ABSTRACT

Microplastic pollution has emerged as a critical environmental concern, posing substantial risks to aquatic ecosystems and human health. The high population density in riverine areas underscores the importance of assessing microplastic pollution in rivers, which affects not only aquatic life and human health but also livelihoods. This study investigates the occurrence and characteristics of microplastics in the Ogun River surface water during dry and wet seasons. Grab water samples were collected from six strategic locations and analyzed for microplastics using a combination of extraction, digestion, and filtration methods. Samples were digested for microplastics extraction using the Wet Peroxide Oxidation (WPO) method, vacuum filtered through a 0.45µm membrane filter (47 mm diameter) and categorized according to their shapes and colors. The results reveal widespread microplastic contamination, with abundance ranging from 6.4 to 11.6 particles/litre during the dry season and 0.4 to 4.8 particles/litre during the wet season. Fibers (93.50% dry, 90.63% wet) and white microplastics (71.54% dry, 43.75% wet) were identified as the predominant shape and color. These findings highlight the need to mitigate microplastic pollution in Ogun River. A multi-faceted approach, encompassing plastic waste reduction, improved wastewater treatment, and sustainable practices, is essential for protecting the river's ecosystem and ensuring human well-being.



HIGHLIGHTS

- Microplastics were found in all Ogun River surface water samples in both seasons.
- Microplastic levels were higher in the dry season than during the wet season.
- Fibrous microplastics were most prevalent in water samples.
- White colored microplastics were more dominant in both dry and wet seasons.

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1. Introduction

Plastic products are increasingly being used worldwide because they are indispensable for modern society (Andrady & Neal, 2009). Plastics are very versatile, durable, lightweight and relatively inexpensive to produce, hence their exploitation for a wide range of applications. This has however led to plastic pollution which has been reported everywhere and has become a serious environmental concern (Wicaksono et al. 2021). Environmental factors such as mechanical abrasion, thermal degradation and

photo degradation usually lead to the breakdown of plastics into smaller forms in the environment (Cooper & Corcoran, 2010; Zhang et al., 2021; Kamweru et al., 2011) and these smaller forms are referred to as microplastics.

Microplastics are characterized as fragments of polymeric origin with dimensions smaller than 5mm (FAO, 2017), particularly between the range of 0.1 µm and 5000 µm (Masura et al. 2015). Microplastics can be primary or secondary in nature, based on the nature. While primary microplastics are produced in a micro - size range, which are widely used in cosmetic products and raw materials for production processes that end up contaminating the

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environment during transport and handling (Andrady, 2017; Schnurr et al. 2018), secondary microplastics are particles originating from the fragmentation of larger pieces in the environment (Reisser et al., 2014; Duis & Coors, 2016; Hermabessiere et al., 2017).

Microplastics, once in the environment, can be transported through wind, sewers, agricultural run-offs or storm water run-offs, and are now found in almost every part of the biosphere including wastewater, freshwater, seas and oceans, sediments, soil and air (Carr et al. 2016; Rodrigues et al. 2018; Xiong et al. 2018; Ng & Obbard, 2016; Vianello et al. 2013; Scheurer & Bigalke, 2018; Levermore et al. 2020). They pose great risks to the environment due to their minute size, ubiquitous nature and tendency to be ingested by organisms (Andrady, 2011). According to Della Torre et al. (2014) & Sussarellu et al. (2016), they have also been found to threaten the photosynthesis process in algae and the reproduction and hatching in certain organisms. Some of the toxicological effects reported in several aquatic biota as a result of microplastics pollution includes alterations in tissue morphologies, gene expression, enzyme activity, swimming patterns, and kidney dysfunctions (Saad, 2023).

Microplastics provide habitat for growing microorganisms, due to their size and varying effects (Yang et al. 2020), and also act as pollutant transport media for other toxic elements such as DDT, polybrominated diphenyl ethers and other additives that were incorporated during the manufacturing process. Consequently, these toxic elements find their way into the systems of living organisms through consumption and may result in progression along different food chains, ultimately affecting human health (Jin et al. 2021).

Only few studies have been conducted on microplastics in aquatic ecosystems in Nigeria, even though Nigeria is one of the top twenty countries that produce large masses of plastic waste, which ends up in aquatic environments (Idowu et al. 2024a). Microplastics has been seen to contaminate sediment, water and biota (Idowu et al. 2024a; Akindele et al. 2020; Ololade et al. 2024; Doherty et al. 2024; Ogbomida et al. 2023; Nwonumara et al. 2021) in Nigeria's aquatic environment with the highest reported microplastics abundance for a river water globally (Idowu et al. 2024a).

The Ogun River is a major water body in Southwestern Nigeria with a total area of 23.7km² (Awomeso et al. 2019), but there had only been few investigations and reports on the levels of microplastics in the river.

Akindele et al. (2020) assessed the levels of microplastics in the Ogun and Osun rivers using aquatic insects as bioindicators. Two types of microplastics namely, fibers and fragments were recorded in the species investigated (*Lestes viridis*, *Siphonurus* sp. and *Chironomus* sp.) with fibers dominating the microplastic composition, indicating the presence of microplastics in the rivers. Ololade et al. (2024) assessed five major rivers in south western Nigeria namely Ibese river in Lagos State, Ogbese river in Ondo State, Ona river in Oyo State, Asejire river in Oyo State, Ogun river in Ogun State and one coastal water - the Third Mainland Bridge Ocean in Lagos State for microplastics. Microplastics were recorded in all water and sediment samples from all locations ranging from 67.22 to 171.23 particle/L and 64.10 to 114.52 particle/kg dry weight (dry season) and 124.24 to 227.30 particle/L and 28.45 to 71.90 particle/kg dry weight (wet season), respectively. High microplastic distribution were observed in the Third Mainland Bridge Ocean, Ibese river, Ona river and Ogun river, compared to the Ogbese river and Asejire river, with fiber microplastics being the highest type recorded in all the samples.

Seven inland rivers (Rivers Yauri, Benue, Argungu, Jamare, Ogun, Ethiopie and Orashi) across the six geopolitical zones in

Nigeria were investigated for the presence of microplastics by Doherty et al. (2024). Microplastics were found in all of the sampled fishes, water and sediments across all studied rivers, with the Ogun river having the highest concentration of microplastics in water samples. Fiber, fragment and film were the shapes of microplastics recorded with fibers being more prevalent in water and fish samples, and fragments more in sediment samples. Shokunbi et al. (2024) also examined the abundance and nature of microplastics and potentially toxic elements (PTEs) in the sediments of the Odo-Ona and Ogun Rivers in Southwest Nigeria. Microplastics were detected in every sediment sample, with Ogun and Odo-Ona rivers having abundances of 66.7 – 311 items/kg dry weight and 133 – 433 items/kg dry weight, respectively. The observed shapes across the two rivers were fibers, fragments and films, with fibers being more dominant at all the sampling points.

These studies emphasized the need for further research in monitoring microplastics in water column and riverbeds, as well as their sources and pathways into the environment.

The Ogun river spans through three states in the Southwestern part of Nigeria before discharging into the Lagos lagoon, and is of particular interest to microplastics study due to high anthropogenic pressure.

Hotspots of water pollution lie around urban, agricultural, industrial and forest land uses (Wijesiri et al. 2018; Xu et al. 2019; Camara et al. 2019; Githinji et al. 2019). Microplastics are found in industrial influents from Waste Water Treatment Plants (WWTP's) and textile plants (Browne et al. 2011; Deng et al., 2020) and are capable of adsorbing various pollutants such as heavy metals, acids and hydrocarbons due to their hydrophobic nature and large surface area (Tang, 2021; Yaqoob et al. 2020).

Common agricultural practices such as the use of plastic films for insulation and mulching, plastic water pipes for irrigation and plastic greenhouse covers, or the application of sewage sludge as fertilizer, are some of the potential sources of microplastic contamination in nearby water bodies via wind and surface runoff (Steinmetz et al. 2016; Brodhagen et al. 2017). Domestic waste and sewage disposal, sand mining, logging as well as the presence of abattoirs, also contribute to water pollution and environmental degradation.

The river is also of economic, cultural and social importance as it serves as source of water supply for domestic, commercial, industrial and agricultural purposes, and fishing zone (Awomeso et al. 2019). This study therefore aimed to investigate the seasonal occurrence of microplastics in surface water of the Ogun river, the shape of microplastics present in the surface water during dry and wet seasons, and the color of microplastics present in the surface water during dry and wet seasons.

2. Materials and Methods

2.1. Materials

Iron (II) Sulphate salt (CAS: 7782-63-0) and 30% Hydrogen Peroxide AR grade (CAS: 7722-84-1) were purchased from Molychem chemical company (Mumbai, India). Polytetrafluoroethylene (PTFE) membrane filters (0.45µm pore size, 47mm diameter) were sourced from Merck Life Science Private Limited (Bangalore). A laboratory oven (Surgifield Medical, SM9053A, England) was used to oven dry the samples. VWR hotplate/stirrer was used to heat the samples. Rotary Vane Vacuum Pump (VP115) was used alongside a Buchner funnel to filter the samples, and a digital microscope with an attached camera (Moticam SMZ-171) was used to view and quantify the microplastics.

2.2. Study Area

The Ogun river is a large waterway that rises in the Iganran hills, east of Shaki in the North Western part of Oyo State of Nigeria at coordinates 8°41'0"N and 3°28'0"E and flows southwards through Ogun State into Lagos State over a distance of 480km (Ayoade et al. 2004). Before emptying into the Lagos Lagoon, it passes through Ibarapa, Iseyin, Abeokuta, Owode, Ikorodu, and Ifo local government areas. According to Adeosun et al. (2014), it is characterized by two seasons with the dry season occurring between November and March while the wet season is between April to October, with mean annual rainfall ranging from 900 mm in the north to 2000 mm towards the south, and the estimates of total annual potential evapotranspiration have been put between 1600 and 1900 mm (Bhattacharya and Bolaji, 2010).

The river is a perennial river and is abstracted for domestic water supplies in Ogun and Lagos States. It also holds significant economic values through its role in agriculture and food security, fisheries, animal husbandry, transport services, industrial activities, and tourism (Adekanye et al. 2016). Some of these services it provides, alongside urban runoff and domestic wastewater may serve as entry points for microplastics. Sampling exercise was conducted in the months of January and May 2024 to represent the dry and wet seasons respectively.

2.3. Sample collection

Six locations along the Ogun river were sampled (Figure 1). An improvised water sampler (a 250ml capacity glass bottle with rope tied around its neck) was held in opposite direction to the flow of the river to collect the samples. Samples were collected from four

different sampling points within each location and then composited into 2.5 litres amber bottles that had been pre-cleaned with both filtered distilled water and the river water. Once it was filled up, the bottle was capped.

2.4. Microplastics extraction from water samples

Extraction of microplastics followed the procedure of (Masura et al. 2015) with slight modification. Each water sample (2.5 L) was stack sieved using stainless steel sieves of 4.75 mm and 0.5 mm. Solids retained on the 0.5 mm sieve was rinsed with filtered distilled water into a pre-weighed beaker and dried in an oven at 75°C for 48 hours, after which the dried solids was subjected to Wet Peroxide Oxidation (WPO) using 20ml each of aqueous Fe(II) solution and 30% Hydrogen Peroxide. The resulting mixture was heated to 75°C on a hotplate and was removed as soon as gas bubbles were observed at the surface. After boiling had subsided, the mixture was heated at 75°C for an additional thirty minutes. Where bubbles were observed again, additional 20 ml of Hydrogen Peroxide was added to the sample to fully digest the organic matter. After digestion, the sample was vacuum filtered through a 0.45µm membrane filter (47 mm diameter) with the aid of a Buchner funnel and vacuum pump. The filter was then placed in a pre-cleaned glass petri dish for further examination.

2.5. Microplastics counting by microscopy

All the membrane filters were examined for microplastics under a digital microscope with an attached camera (Moticam SMZ-171). Microplastics were identified based on recommendations according to standard guidelines (Marine and Environmental

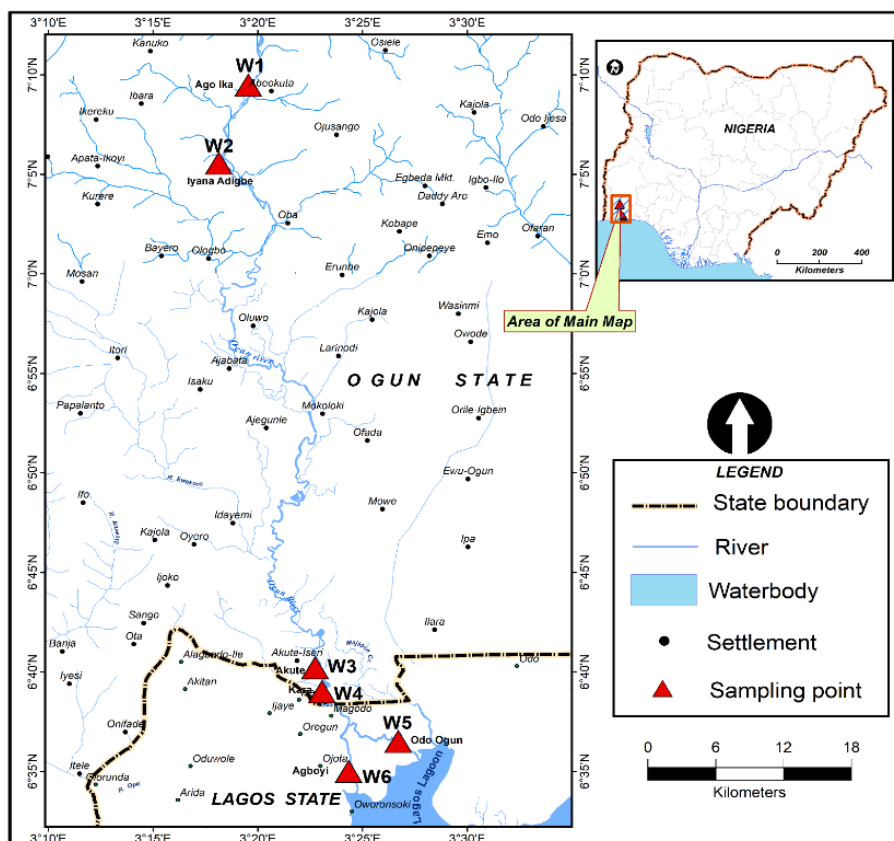


Figure 1. Map of the study location showing the sampling points

Research Institute [MERI], 2017; Norén, 2007). Criteria for microplastics identification included the absence of cellular or organic structures in the plastic particles, clear and homogeneously colored particles, semi flexible or hard particles with uneven edges and fiber particles that are equally thick throughout their entire length, although fraying or splitting is sometimes seen. The identified microplastics were categorized in terms of shapes (fragment, fiber, film and pellet) and color (red, blue, green, brown, yellow, black and white). Pictures of the microplastics were taken using the attached digital camera.

2.6. Quality assurance and control

During the experiment, cotton laboratory coats were always worn, and samples in glass jars were always covered with aluminum foil. All sampling containers and materials used were either glass or aluminium materials, and they were adequately rinsed with filtered distilled water. After each filtration, the filter was immediately kept inside a glass petri dish and covered until further examination. Blank controls with filtered distilled water were used in all experiments following the same procedure used for the samples (Zhu et al. 2021).

2.7. Statistical Analysis

The abundance of the microplastics recorded was determined by dividing the total number of microplastics by the sample volume, with the data expressed as the number of microplastics per 1 litre of water (particles/litre). Microplastics abundance, shape, and color were graphically represented using Microsoft Office Excel and Boxplot statistical analysis was performed in R studio.

3. Results and Discussion

3.1. Occurrence and abundance of microplastics in water samples

Microplastics was detected in all the water samples for both seasons. A total of one hundred and fifty-five (155) microplastics were identified, with an abundance of one hundred and twenty-three (123) and thirty-two (32) for both dry and wet season respectively. The average abundance of microplastics in the dry season ranged from 6.4 particles/litre in W2 to 11.6 particles/litre in W5, and from 0.4 particles/litre in both W5 and W6 to 4.8 particles/litre in W3 for the wet season as illustrated in Figure 2.

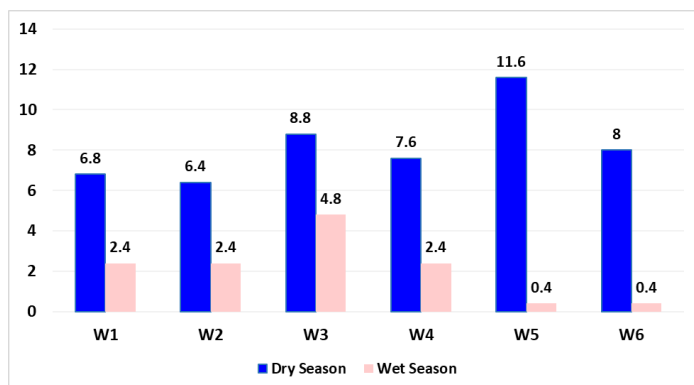


Figure 2. The average abundance of microplastics in water samples during the dry and wet seasons

The abundance of microplastics in both seasons was highest in W3, followed by W5. Point W3 was located in Akute, an area where the river was dammed for providing drinking water, supporting agricultural activities and acting as flood control by regulating water flow. Point W5 was located in Odo Ogun, a downstream area through which the river empties into the lagoon. Sulistiyowati et al. (2021) reports that microplastic abundance in downstream area was higher than midstream; and artificial damming leads to the formation of microplastic hotspots in river waters and sediments due to reduced river mobility (Xia et al. 2025).

Relative abundance was also recorded in points W1, W2, W4 and W6 with point W6 having the least abundance. Fishing activities being carried out at point W1 may account for the significant concentrations of microplastics at this location. Points W2 and W4 were located near local residential houses where people dumped wastes directly into the river as a means of disposing them of, and point W6 was located towards the downstream of the river. All the sampling points have high population, and previous studies have shown that an increase in coastal populations can influence the quantity of microplastic pollution entering waterways (Jambeck et al. 2015; Lebreton et al. 2017).

Microplastics concentrations were lower than those reported in previous studies conducted in the Osun River ($22,079 \pm 134$ particles/litre) and Kaduna River (153 particles/litre) in Nigeria (Idowu et al. 2024a; Aliyu et al. 2023), the Nakdong River (1970 ± 62 particles/litre) in Korea (Eo et al. 2019), and the Thames River (44.3–510 particles/litre) in England (Devereux et al. 2022). However, they were higher than those recorded from the Tallo River (0.74–3.41 particles/litre), Brantas River (0.8–1.25 particles/litre), and Han River (2.32–8.41 particles/litre) (Wicaksono et al. 2021; Ekawati et al. 2024; Chen et al. 2023). Just like in our study, these findings revealed that high microplastics abundance are related to high anthropogenic activities.

Figure 3 shows the distribution of microplastics abundance in the dry and wet seasons. In the dry season, the minimum microplastics abundance is about 6.4 particles/litre, the 25th and 75th percentile are 6.8 and 8.8 particles/litre respectively and the interquartile range is 2.0 particles/litre; while in the wet season, the minimum microplastics abundance is about 0.4 particles/litre, the 25th and 75th percentile are 0.4 and 2.4 particles/litre respectively and the interquartile range is also 2.0 particles/litre. The line across the box represents the median microplastics abundance which is

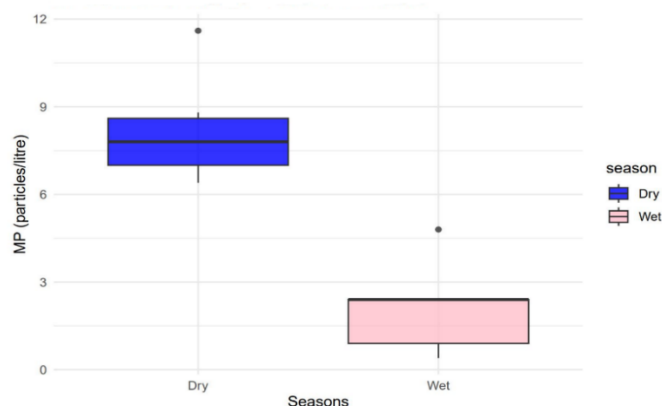


Figure 3. Boxplot diagram of microplastics abundance in water during the dry and wet seasons in Ogun river.

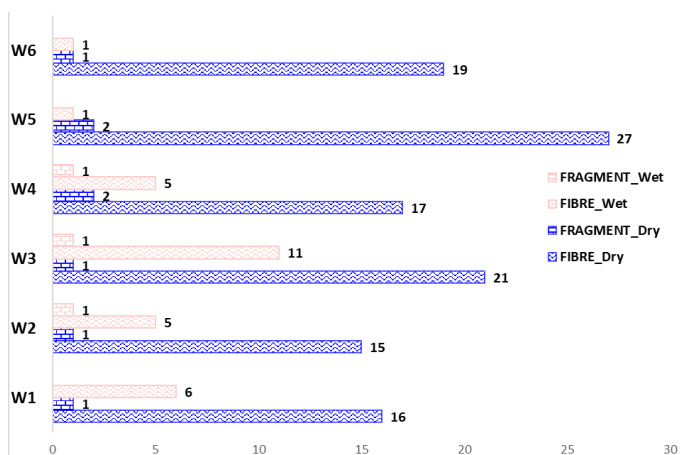


Figure 4. Shapes of microplastics in water samples during the dry and wet season

about 7.8 and 2.4 particles/litre for dry and wet season respectively.

In our study, microplastic pollution was higher during the dry season than in the rainy season (Figure 3) and this is in agreement with some previous studies (Wicaksono et al. 2021; Wei et al. 2022a). Water depth in the Ogun river usually follows a seasonal pattern with an impact of ambient temperature and rain, with records of lower depths in the dry season and higher depth during wet season (Adeosun et al. 2014). The difference in water depth

could cause the ratio of volume to surface-water area of the river to be smaller in the dry season, which leads to a higher amount of microplastics in the surface water (McNeish et al. 2018). Slower water flows in the dry season than during the wet season could also have resulted in the elevated quantities of microplastics recorded (Li et al. 2023). This is in contrast to studies conducted by (Ololade et al. 2024; Idowu et al. 2024b) where surface water samples collected from some rivers and coastal communities in Nigeria had more plastic particles during the wet season than in the dry season. According to Wei et al. (2022a), this could be due to accumulation of microplastics in surface water and surface sediments during the dry season, followed by resuspension in the rainy season with increased rainfall. Rainfall will also reduce the concentration of microplastics in the atmosphere, and erosion can bring terrestrial microplastics into water bodies (Liu et al. 2019; Schmidt et al. 2021; Wei et al. 2022b). These would consequently lead to an increase in the abundance of microplastics in water bodies during the wet season in comparison to the dry season.

3.2. Shape characteristics of microplastics in water

According to Hidalgo - Ruz et al. (2012), fibers, fragments, sheets, beads, foams and pellets were usually recognized as distinct shapes of microplastics. Based on the results of our study, two shapes of microplastics were seen from water samples, namely fibers and fragments (Figures 4 and 5). Fibers and fragments have been frequently reported as the most abundant shapes of microplastics found in freshwater bodies (Chen et al. 2022; Frank et al. 2022; Hossain et al. 2022).

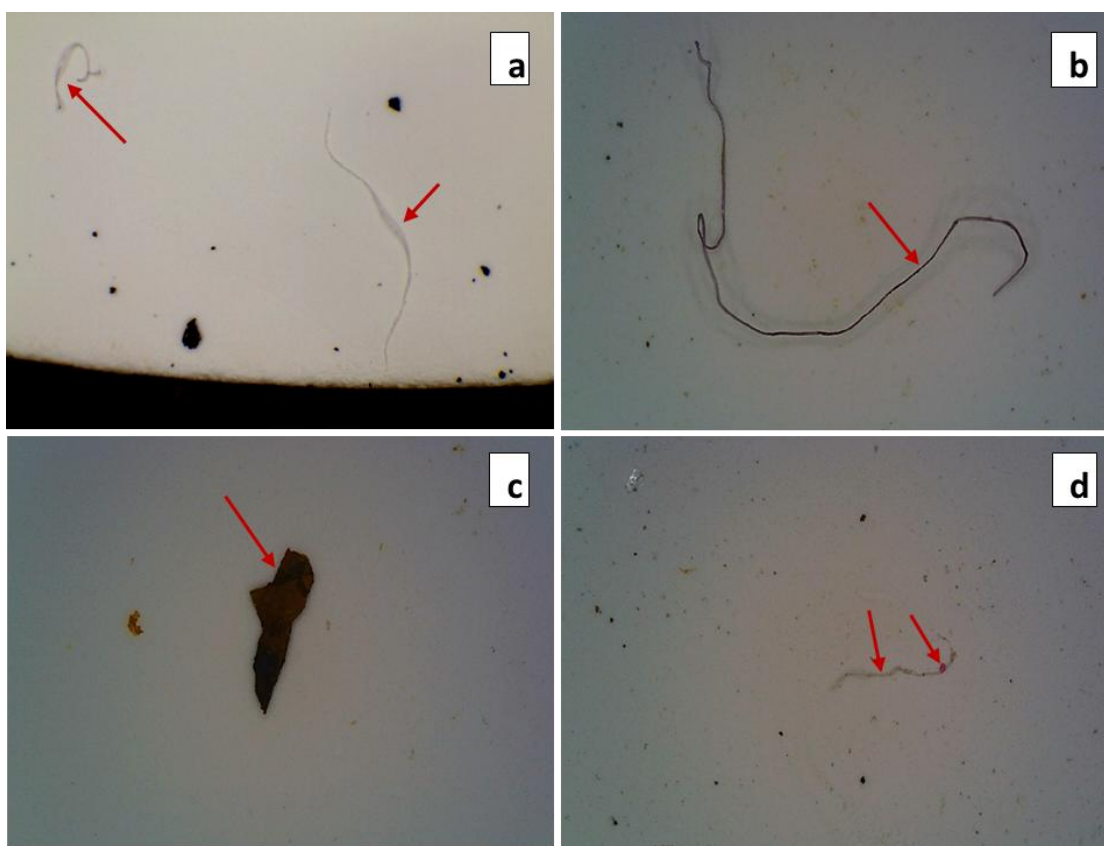


Figure 5. Representative of microplastics found in the samples. White and black fiber (a,b), brown fragment (c), white fiber and red fragment (d)

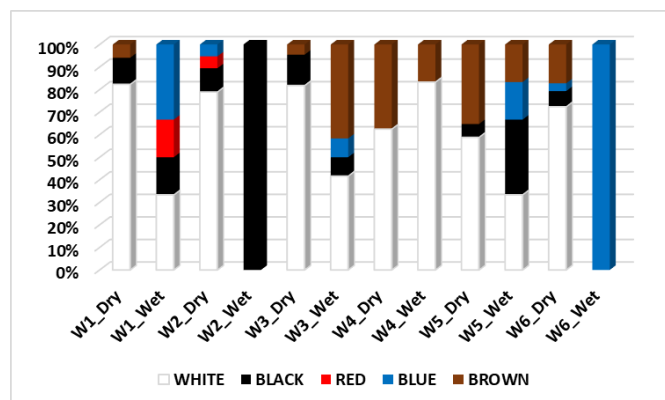


Figure 6. The dominant color of microplastics discovered in water samples during the dry and wet seasons

The microplastics in the Ogun River were dominated by fibers in both the dry season (93.50%) and wet season (90.63%). The shape of microplastics could mimic the natural prey of fish that exist in the environment (Dris et al. 2015; Cole et al. 2011), and can also be an indicator of the microplastic's origin. The Ogun river is a river that is used predominantly for fishing, and also as a laundering site by many locals. Thus, the high prevalence of fibers over fragments is an indication that the source of microplastics into the river is the breakdown of fishing lines and nets and cloth laundering (Zhu et al. 2018; Hernandez et al. 2017). This is in contrast to fragments which mainly originate from the fragmentation of larger-sized plastic materials (da Costa et al. 2017; Ramaremisia et al. 2022).

3.3. Color characteristics of microplastics in water

In general, five colors were observed for microplastic particles, which include white, black, red, blue and brown (Figure 6). White colored microplastics were more dominant in both dry and wet seasons, accounting for 71.54% and 43.75% respectively. This however contrasted with studies conducted by Oni et al. (2020) where red and green were the dominant colors reported during the dry and wet season respectively.

The color of microplastics may indicate its source (Chinfak et al. 2021). White and transparent/translucent plastics have been reported as the most abundant floating plastics in water (Ory et al. 2017). This may be as a result of the exposure of plastic particles to ultraviolet light which first leads to discoloration of plastic particles, after which there is a loss of the pigment due to the length of exposure time so that it changes color to white or transparent Marti et al. (2021), or it could be an indication of the use of white or transparent fishing lines and nets. White or transparent microplastics can also be linked to transparent food containers that mainly consists of polyethylene and polypropylene polymer (Wicaksono et al. 2021).

Many aquatic organisms tend to prefer microplastics with a similar color to their prey. Reports also have it that fish tend to prefer lighter colors of microplastics, such as blue, white, and transparent, because it is easier to distinguish these colors compared to the brownish natural environment color (Wicaksono et al. 2020; Crawford & Quinn, 2017).

4. Conclusion

In this study, microplastics were investigated in the surface water of the Ogun River in southwest Nigeria. All the samples had

microplastics, and the maximum abundance was recorded in point W3. The microplastic abundance in the Ogun River is influenced by seasonal variations, with the dry season having higher abundance than the wet season. Fibers and fragments were the only shapes of microplastics recorded, the majority being fibers, suggesting that they originated from aquaculture and daily life. White colored microplastics were also more dominant in both seasons. Reduction in the microplastics levels in the river may be achieved by raising public awareness on appropriate waste disposal, as well as promoting waste reduction, reuse and recycling. The recent ban on single-use plastics pronounced by the Nigerian government should also be enforced firmly. The water of the Ogun river is used for supplying drinking water and to irrigate agricultural lands, hence, risk assessment studies of microplastics on human health are strongly recommended.

CRedit authorship contribution statement

SAO: Resources, field work, methodology, data collection and entry, data analysis, writing draft. **KAY:** Methodology, data analysis, writing draft, reviewing and editing, supervision, visualization. **SLA:** Methodology, data analysis, writing draft, reviewing and editing, supervision, visualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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