Journal of Global Ecology and Environment

Volume 20, Issue 4, Page 126-135, 2024; Article no.JOGEE.12468
ISSN: 2454-2644

Characterization of Microplastics in the Sediment of Azuabie and Eagle Island Creeks, Rivers State, Niger Delta

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Authors' contributions

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

Article Information

DOI: https://doi.org/10.56557/jogee/2024/v20i48925

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://prh.ikprress.org/review-history/12468

Original Research Article

Received: 17/08/2024
Accepted: 20/10/2024
Published: 31/10/2024

ABSTRACT

Microplastics are dispersed throughout the world's ocean and is often found in shorelines, seabed sediments, beaches, and wastewater effluents. they can accumulate in the tissues, serve as vehicles for transport of pathogens, adsorb and accumulate toxic pollutants. The small size of microplastics makes them easily available for ingestion by different species of fish in the marine

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Cite as: *T.I., Inyang, Ekweozor, I.K.E., Ideriah, T.J.K., Anaero-Nweke, G.N., Gbaa, N.D, and Ubulom, S.R. 2024. "Characterization of Microplastics in the Sediment of Azuabie and Eagle Island Creeks, Rivers State, Niger Delta". Journal of Global Ecology and Environment 20 (4):126-35. https://doi.org/10.56557/jogee/2024/v20i48925.*

environment. This study was undertaken to identify and characterize the microplastic in the sediment of Azuabie and Eagle Island Creek in Rivers State, Nigeria. Microplastic characterization was achieved following standard procedures using micro-Fourier Transform Infra-Red Spectroscopy (Agilent Cary 630 FTIR). The result revealed that microplastic shape in the sediments of Azuabie and Eagle Island Creeks were dominated by microplastic filament followed by fragment in both stations with Eagle Island creek having the highest Percentage while other shapes like Film, bead and foam were not found. Microplastic (>1mm) was the most prevalent size identified. Polypropylene and Polyethylene were the only polymer type detected in both stations with Polypropylene the most prevalent polymer type in both stations. The study further revealed the presence of black and blue coloured microplastics with black colour occurring the most in Azuabie Creek, statistically the values were not significantly different. Therefore, based on the result of this study, there is a need for constant monitoring of wastes discharged into both Azuabie and Eagle Island Creeks by the regulatory bodies in order to reduce their levels in the aquatic ecosystem.

Keywords: Microplastics; polypropylene polymers; plastic pollution; microplastic filaments.

1. INTRODUCTION

"Microplastics have been observed throughout bottom sediments of marine and freshwater environments, including sediments in rivers, estuaries, lagoons, lakes, seas and deep-sea trenches" [1,2,3,4,5,6]. "Microplastics are commonly found in the environment in three forms; fragments which form from mechanical and biological fragmentation of larger plastic items, microbeads which are manufactured as abrasives in cosmetics and air-blasting and microfibers from sources such as synthetic fabrics and ropes" [7,8,9]. "Studies have shown multiple damaging effects of microplastics in the environment, including adsorption of toxic organic contaminants, ingestion by animals with implications for human consumption" [10,11] and "changing the heat transfer and water movement of sediment" [12]. "Accumulating concentrations of suspended plastic particles and heteroaggregates could affect the food sources or the turbidity levels in the habitats of cyanobacteria and phytoplankton communities" [13].

Microplastics have been observed in benthic environments since the late 1970s [14]. A Knowledge of the harmful effects of microplastics on benthic marine species and communities is growing [15,16], however, little is known of past microplastic accumulation in benthic environments. Several studies have examined microplastics in sediments [17]. For example, Claessens et al. [18] quantified the number of microplastics in 16-year-old sediments collected at the intertidal and high-water mark. However, there have been no evaluations of microplastic contamination in deep sediments with known age cores, allowing analysis of deposition rates and concentrations.

Microplastics with density greater than that of sea water sink down in sediments where they accumulate [19], while those with low density float on the sea surfaces [20]. Increase in density can be through biofouling by organisms in the marine environment result in sinking of microplastics. As bio fouling progresses, the density of the plastic material increases and once the density becomes greater than that of sea water, the plastic material sinks to the bottom of the sea [21]. "Marine sediments have potential to accumulate microplastics" [22]. "A very high concentration of microplastics now occur within marine sediments; such plastics making up 3.3% of sediment weight on heavily impacted beaches" [23]. "It is a fact that deep sea areas, submarine canyons, and marine coastal shallow sediments are sinks for microplastics" [24].

As with sediments in other aquatic environments, microplastics similarly accumulate in mangrove sediments. In a study conducted by Nor and Obbard [25] on the prevalence of microplastics in mangrove habitats of Singapore, microplastic particles extracted using the floatation technique were smaller than 20 µm and contained polypropylene, polyvinyl chloride, nylon, and polyethylene. "Also, the concentration of the microplastic ranged from 12.0-62.7 particles per dry sediment. The distribution of microplastics in mangroves located in peninsular Malaysia recorded about 418 items of different microplastic polymers ranging from polystyrene foams to plastic pellets" [26].

Microplastics appear to be more abundant in densely populated areas. In a study analyzing sediments from 18 locations representing 6 continents, Browne et al. [9] demonstrated a positive relationship between microplastic and human population density. Indeed, microplastics are detected in large numbers in highly populated areas, such as at locations in the North Sea [18] and the Mediterranean Sea [27], as well as in Asia [24] and the highly populated coast of Brazil [28].

“On heavily polluted beaches, microplastics (0.25 – 10 mm) can make up 3.3% of the sediment by weight, as opposed to 0.12% plastic by weight on control beaches” [12]. On Hawaiian beaches, plastics ranging in size from 0.25 to 4 mm were most abundant (55.5%), yet proportions of microplastics (1 – 4.75 mm) of up to 90% have been reported as well [29]. The link between microplastic pollution in sediments and human activities has also been demonstrated by Claessens et al. [18], who detected particularly high concentrations of microplastic granules in the sediments of coastal harbours. However, as not all types of microplastics could be linked to sources in the harbours, the importance of rivers as potential sources of microplastics to the marine environment was stressed. This was confirmed by Vianello et al. [3] and Ubulom et al. [13] who detected the highest microplastic concentrations in those areas influenced most by freshwater inputs. The importance of rivers as sources of microplastics to the marine environment was demonstrated by Castañeda et al. [1], who detected high concentrations of microbeads in the sediment of the Saint Lawrence River, Canada. These microbeads were suggested to originate from municipal and industrial sewage effluents. It is therefore the main objective of this study to characterize microplastics present in the sediment of Azuabie and Eagle Island Creeks, Rivers State.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The Azuabie Creek is an estuarine tidal water body, a major creek in Bonny Estuary. The creek connects the land through many river channels and provides settlement to front water dwellers [30]. The creek is characterized by high sea flow and low freshwater input from adjourning swamp forest and municipal sewers within slaughter market area of Port Harcourt. The Azuabie Creek complex is located between latitude 4°28´- 4°40´N and longitude 7°00´ - 7°15´E (Fig. 1). The vegetation of the area is basically mangrove and freshwater swamps with sparse occurrence of Palm and other coastal vegetation. Azuabie Creek is characterized by the presence of several companies mostly oil servicing company on its bank and receives effluents from petroleum and oil servicing companies, market refuse, timber processing activities, abattoir, riverine settlements, transportation, and fishing activities. These effluents and waste from these mentioned sources are likely to contain various categories of plastics and associated pollutants. Additionally, run-offs discharged into the water body are likely accompanied by plastics. The creek has tidal influence from the seas and is in the tropical climate region with a temperature range of 25° C – 30°C.

The Eagle Island (control location) is located along Latitude N4°47’49.08 and Longitude E6°58’31.218 (Fig. 2). It is accessible by road and water through the Eagle Island Road and Iwofe River respectively, which are both adjourning locations of Port Harcourt metropolis, Rivers State, Nigeria. The vegetation is dominated by Nypa palm (*Nypa fruticans*), red mangrove (*Rhizophora racemose*) and white mangrove (*Avicennia germinas*). The major anthropogenic activities going on within and around the Eagle Island Creek include dredging activities, local boat water transportation, using outboard engine and inboard wooden boats, disposal of organic and inorganic wastes [27]. The choice of the study areas was influenced by the presence of industries, markets and residence which allows for the indiscriminate dumping of plastic wastes into the water body. These coupled with the paucity of studies on microplastics in these areas prompted this research.

2.2 Research Design

The descriptive research design was adopted in the sampling and determination of microplastics in the sediment of Azuabie and Eagle Island Creeks. Samples were collected and analysed in a three-month period and results obtained were presented in barcharts and tables.

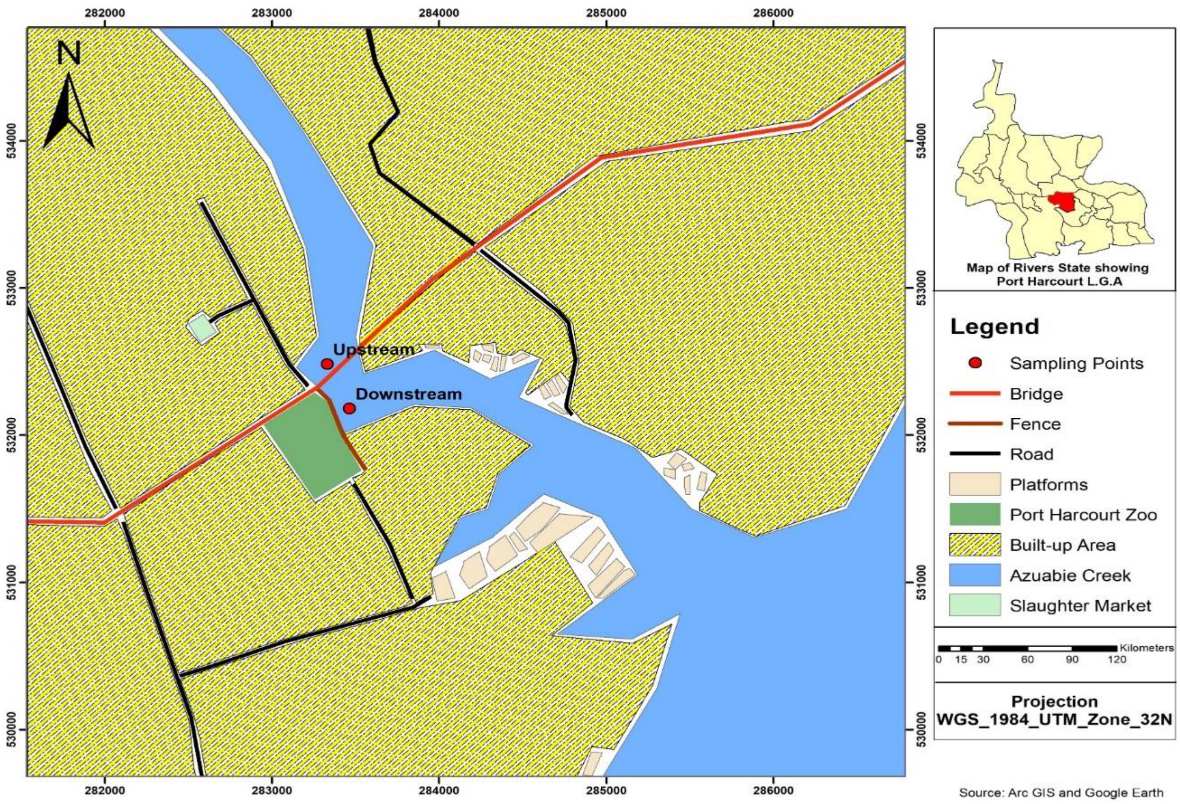

Fig. 1. Map of Azuabie Creek Showing Sampling Points

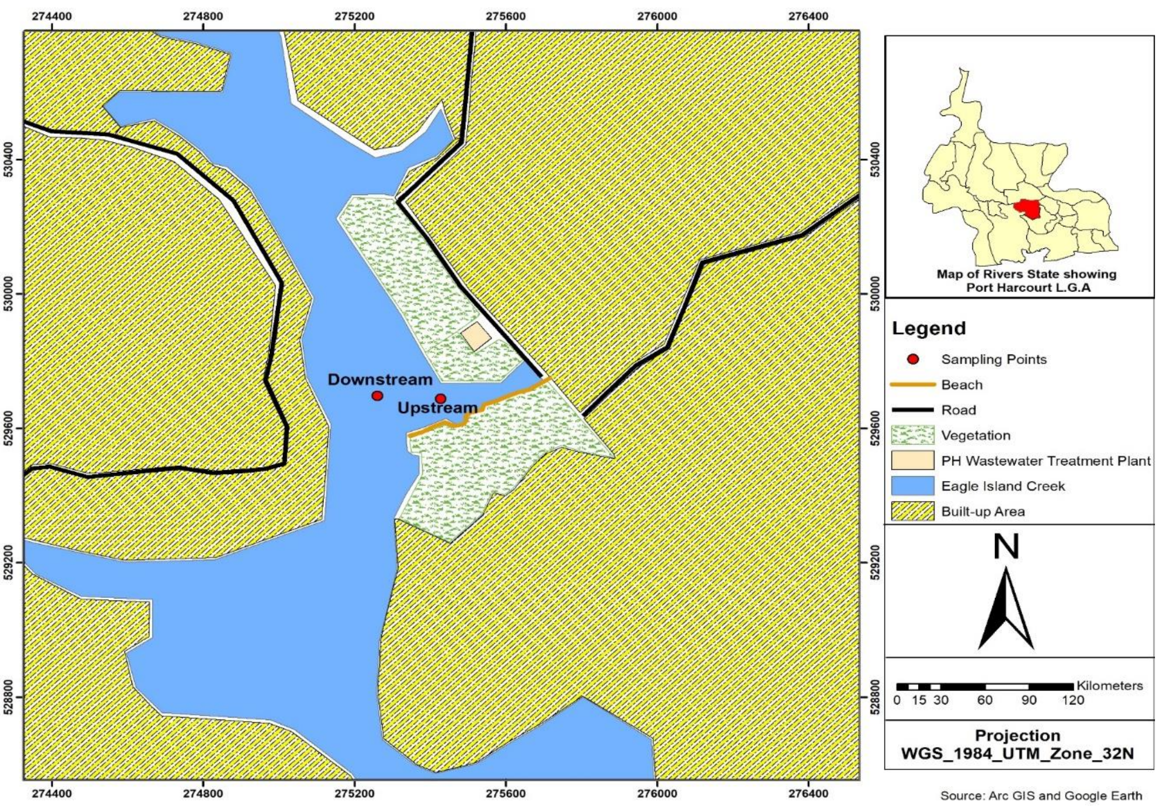

Fig. 2. Map of Eagle Island Creek Showing the Sampling Point

2.3 Sampling and Sampling Technique

A total of four sampling points (Figs. 1 and 2) were established at Azuabie and Eagle Island creeks. At Azuabie creek, two sampling points were chosen approximately 300 meters apart along the creek shorelines with coordinates N04.814465° E07.046381° (upstream) and N04.811793° E07.047482° (downstream). At Eagle Island Creek, which serves as the control location, two sampling points were also chosen 300 meters apart along its shorelines with coordinates N04.789150° E06.975219° (upstream) and. N04.789220° E06.973712° (downstream). All stations were geo-referenced using a hand-held Global Positioning System (GPS) receiver unit (Magellan GPS 315) to generate geographic coordinates of the sampling area. Sampling was carried out once a month between June and August 2022. The appropriate equipment and method of sample collection were applied depending on the matrix.

Sediments were collected with an Eckman grab (15 cm by 15 cm) upstream and downstream of Azuabie and Eagle Island Creeks. Sediment trapped in the grab was transferred into 250 ml amber bottles and kept in a cooler with icepacks.

2.4 Laboratory Analysis of Microplastics

The analysis of collected samples is a multi-step process that includes sample preparation (pre-treatment/digestion, density separation and filtration), observation, and identification of microplastics. These steps, however, depend on the matrix to be analyzed. Sediments collected were transferred to Giolee Global Resources Limited, Port Harcourt for laboratory analyses.

2.5 Sample Preparation

Sediment samples were first treated by a freeze-drying method. Then, 50 g dry-weight sediment was transferred into a 1 L beaker, to which 400 mL of zinc chloride solution (1.5 g/cm^3) and a stirring bar was added. After stirring for 30 minutes, samples were allowed to settle for 24 hours to achieve density separation. Supernatants were then collected and treated with the surface water treatment method (using the National Oceanic and Atmospheric Administration laboratory method for the analysis of microplastics [8].

Microplastics were then filtered through a 0.22 µm pore size GF/C filter (Membrane solutions LLC. Kent, WA, USA). The filters were oven-dried at 60°C to prevent culling and retained in a petri dish.

2.6 Observation and Identification of Microplastics

Materials retained in the petri dish were visually inspected under a Stereomicroscope (MS007) [31]. Tweezers and probes were used to poke at individual pieces. Pieces that bounced or sprung when prodded were microplastics, hence, they were counted and recorded. Inspected microplastic particles were classified based on the observed characteristics: size (<0.5mm, 0.5-1mm, >1mm), colour (black, white/transparent, blue, yellow, green), and shape (fragment, fibre, bead, foam, film). Transparent microplastics were classified as white because transparent microplastics may scatter blue light under the light microscope. Microplastics were extracted from the filters on to a petri dish and made to undergo further analysis using the micro-Fourier Transform Infra-Red Spectroscopy (Agilent Cary 630 FTIR) following the method of Abidli et al. [32] to determine polymer type.

2.7 Statistical Analysis

Descriptive analysis was adopted because the results were presented in barcharts describing the patterns and types of microplastics.

3. RESULTS

3.1 Microplastic Characterization in Sediment

The results of microplastic characterization in the sediment of Azuabie and Eagle Island Creeks in terms of shape, size, colour and polymer type. This is represented in Figs. 3 to 6.

3.2 Microplastic Shapes in Sediment

Fig. 3 shows the percentage of various microplastics shapes in the sediments of Azuabie and Eagle Island Creeks between June and August 2022. Microplastic filament was the most occurring shape, detected in all sediment samples of Azuabie and Eagle Island Creeks. In Azuabie Creek, microplastic filament accounted for 75 % of investigated microplastics while microplastic fragments contributed 25 %. In Eagle Island Creek, 83.3 % of microplastics were filament while 16.7 % were fragment. Other shapes like film, bead and foam were not found in the sediments of both locations.

3.3 Microplastic Sizes in Sediment

The percentages of various sizes of observed microplastics in the sediments of Azuabie and Eagle Island Creeks between June and August 2022 are as shown in Fig. 4. In Azuabie Creek, 16.7 % of observed microplastics were in the size range of <0.5 mm, 25 % were in the size range 0.5-1 mm and 58.3 % in the size range >1 mm. In Eagle Island Creek, 16.7 % of microplastics were in the size range of <0.5 mm, 33.3 % were in the size range 0.5-1 mm and 50 % in the size range >1 mm. Microplastics of the size range >1 mm was the most prevalent in the sediment of both locations.

3.4 Microplastic Polymer Types in Sediment

Fig. 5 shows the percentage of various polymer types in sediments of Azuabie and Eagle Island Creeks between June and August, 2022. Polypropylene and Polyethylene were the only polymer types detected in the sediments of both locations, with polypropylene polymers being the most occurring. In Azuabie Creek, 66.7 % of polymers investigated were polypropylene and 33.3 % were polyethylene. In Eagle Island Creek, 66.7 % of polymers investigated were polypropylene while 33.3 % were polyethylene.

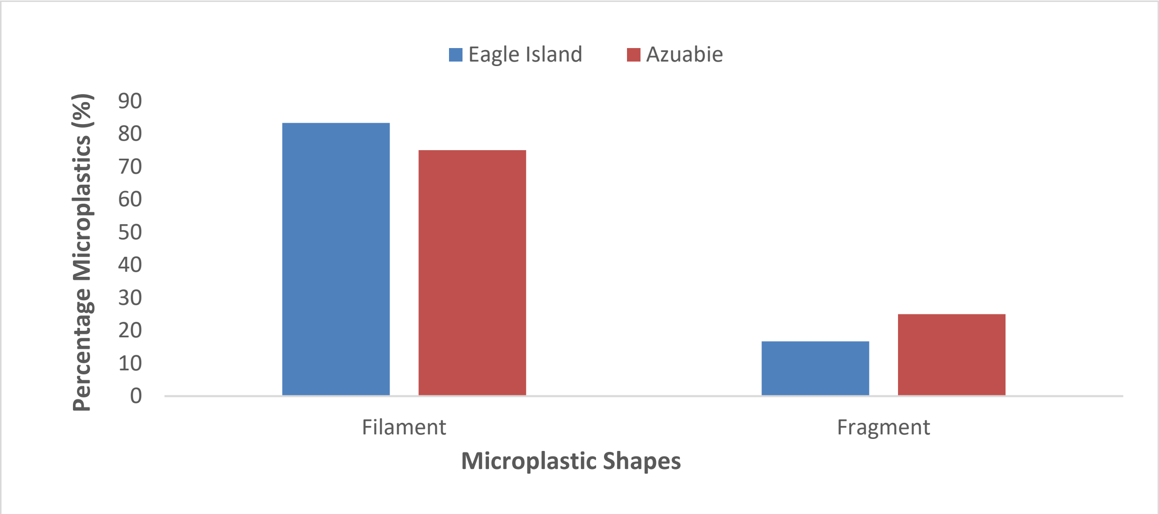

Fig. 3. Microplastic Shapes in Sediment

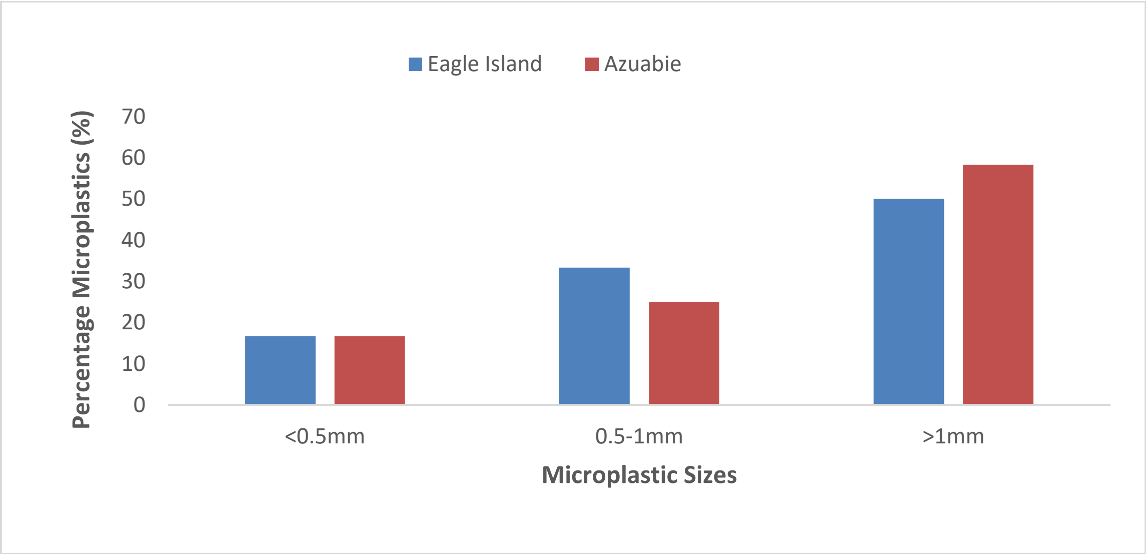

Fig. 4. Microplastic Sizes in Sediment

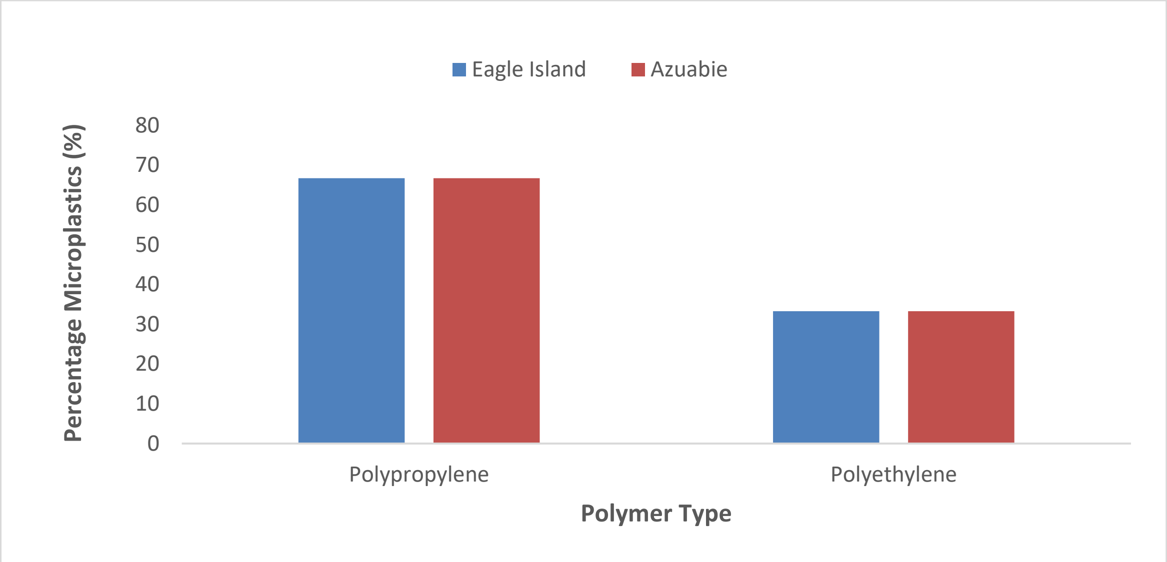

Fig. 5. Microplastic Polymer Types in Sediment

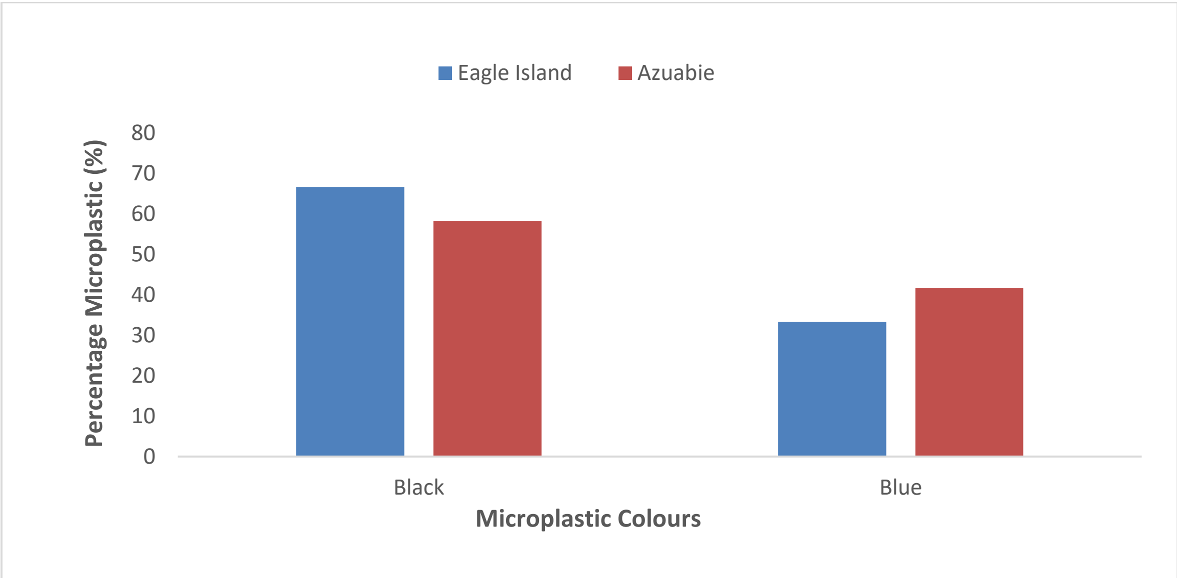

Fig. 6. Microplastic Colours in Sediment

3.5 Microplastic Colours in Sediment

Fig. 6 shows the percentage of various microplastic colours in sediments of Azuabie and Eagle Island Creeks between June and August, 2022. The most occurring colour observed in sediments of both locations was black, making up 61.1 % of microplastics investigated. In sediment of Azuabie Creek, 58.3 % of microplastics were black while 41.7 % were blue. In sediment of Eagle Island Creek, 41.7 % of microplastics were black while 33.3 % were blue. Other colours were not identified.

4. DISCUSSION

4.1 Microplastic Characterization in Sediment

The sediments of Azuabie and Eagle Island Creeks were reported to be dominated by microplastic filament, followed by fragments. This corresponds with the results garnered for the surface water of both locations. The higher percentage of filaments in Azuabie sediment corresponds with their quantity in surface water and it indicates the uniformity of their likely sources. Yahaya et al. [33] reported the prevalence of filament in sediments of West and South Dongting Lake, China and Badagry Lagoon, Nigeria respectively.

Microplastics of >1 mm size range were found to be most occurring in the sediments of both locations sampled in this study. This is indicative of how long the plastic has been in the water body, mechanical action, the rate of biodegradation, and the size range found in surface water. Yahaya et al. [33] reported that the most dominant microplastic size in the sediment of Lagos Beach was of the size range 1000-5000 µm which is similar to those observed in this study.

The prevalence of polypropylene microplastic polymers in the sediments of both locations can be attributed to the use and subsequent disposal of polypropylene-based plastics. Polypropylene is used in the manufacture of disposable bottles, piping systems, and automotive components [25]. Polypropylene fibres are used in ropes, fishing nets and diapers [25]. The higher quantity of polypropylene microplastics reported in Azuabie Creek sediment could be indicative of domestic activities around the creek, transport of worn-off automobile tyres into the waterbody, and the use of fishing nets for light fishing in the creek [34].

Only blue and black-coloured MPs were observed in the sediments of both locations with the most dominant colour being black. The sediment of Azuabie Creek accumulated more black-coloured MPs. This suggests the type of plastic waste disposed around or in the creek such as bottle caps, pen caps, twines, textile fibres, plastic bags, etc. The result shows the possibility of more of such wastes to be accumulated in Azuabie Creek sediments [35].

5. CONCLUSION

The result revealed that microplastic shape in the sediments of Azuabie and Eagle Island Creeks were dominated by microplastic filament followed by fragment in both stations with Eagle Island creek having the highest Percentage while other shapes like Film, bead and foam were not found. Microplastic (>1mm) was the most prevalent size identified. Polypropylene and Polyethylene were the only polymer type detected in both stations with Polypropylene the most prevalent polymer type in both stations. The study further revealed the presence of black and blue coloured microplastics with black colour occurring the most in Azuabie Creek. Statistically the values were not significantly different. Therefore, based on the result of this study, there is a need for constant monitoring of wastes discharged into both Azuabie and Eagle Island Creeks by the regulatory bodies in order to reduce their levels in the aquatic ecosystem.

6. RECOMMENDATIONS

Following the finding and observations from this study, we hereby recommend that:

1. Steps should be taken to regularly monitor and cut down on the quantity of waste discharged into both Azuabie and Eagle Island Creeks.
2. Regulatory policies should also be strict to make sure that violators of set standards for effluents discharge into water are penalized appropriately.
3. Awareness should be created on the plastic pollution status of these creeks and the Federal Ministry of Environment and the State as well as Local Government environmental regulators should make effort towards proper management of plastic wastes to prevent pollution of our water bodies.
4. The GIT and gills of fish should be thrown away prior to human consumption, and further research on plastic contamination of edible fish tissues is suggested to evaluate potential plastic pollution in human food.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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

ACKNOWLEDGEMENT

We sincerely express our deep gratitude to the Institute of Geoscience and Environmental Management, River State University and all the technologists for their contributions and the release of sample equipment’s in ensuring that these samples were collected and analyzed effectively and void of error even in the interpretations of the spectra.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://prh.ikprress.org/review-history/12468