Journal of
Water Pollution &
Purification Research

ISSN: 2394-7306
Volume 13, Issue 2, 2026
May–August
DOI (Journal): 10.37591/JoWPPR

https://journals.stmjournals.com/jowppr

Research JoWPPR

Variations of Macroplastics in Water and Sediments at Bundu Waterfront, Upper Bonny Estuary, Rivers State, Nigeria

Esaenwi A.L[1], Bubu-Davies O.A.[2], Ilesanmi A.I.[3,*], Ekweozor I.K.E.[4], Otene B.B.[5]

Abstract

Macroplastic pollution has become an increasingly severe environmental challenge, particularly in urban waterfronts where waste management is inadequate. Bundu Waterfront of the Upper Bonny Estuary in Port Harcourt, Rivers State is a sink for macroplatics from careless disposal of solid wastes and inadequate management thus affecting the biological integrity and aquatic life of this estuary. The resultant impact of the macroplastics on abiotic factors through the evaluation of different floating macroplastics in the water and sediments were investigated. The study also determined some physical and chemical parameters for twelve months from Bundu Waterfronts. Samples of macroplastics in water and sediments were collected in accordance with APHA guidelines. The data collected were analyzed statistically. Macroplastics in water and sediment were categorized into thirteen groups which included medicine dispensing products, food wraps, fishing materials, laundry materials, drink wraps, polyvinylchloride items, bags, wears, body care, household items, saloon accessories, electrical/electronic items and others (unclassified items). Macroplastics in water showed highest mass in food wraps (23.50±2.11%) and lowest in fishing materials (0.42±0.14%). However, macroplastics in sediments had highest value in food wraps (10.64±3.57%) with lowest in polyvinylchloride (0.25±0.60%). The mean values of the measured physico-chemical parameters were recorded. There was higher macroplastic load in water than in sediments in all categories except for saloon accessories and laundry materials. All physicochemical variables were within the permissible limit except for biochemical oxygen demand (BOD), turbidity and chlorine. This research calls for an integrated approach that includes governmental regulation, local involvement, and innovative waste reduction practices to address the growing macroplastic problem at Bundu Waterfront. Immediate action is critical to preserving Nigeria's coastal and marine environments, maintaining biodiversity, and ensuring sustainable development in affected communities.

***Author for Correspondence**
Ilesanmi A.I.
E-mail: kunsaac@gmail.com

[1]PhD Research Scholar, Department of Fisheries and Aquatic Environment, Rivers State University, Port Harcourt, Nigeria.
[2]Professor, Department of Fisheries and Aquatic Environment, Rivers State University, Port Harcourt, Nigeria.
[3]Lecturer 2, Department of Fisheries and Aquaculture, University of Agriculture and Environmental Sciences, Umuagwo, Imo State, Nigeria.
[4]Professor, Department of Animal and Environmental Biology, Rivers State University, Port Harcourt, Nigeria.
[5]Reader, Department of Animal and Environmental Biology, Rivers State University, Port Harcourt, Nigeria.

Received Date: April 14, 2026
Accepted Date: May 26, 2026
Published Date: June 10, 2026

Citation: Esaenwi, A.L, Bubu-Davies, O.A., Ilesanmi A.I., Ekweozor, I.K.E., Otene, B.B. Variations of Macroplastics in Water and Sediments at Bundu Waterfront, Upper Bonny Estuary, Rivers State, Nigeria. Journal of Water Pollution & Purification Research. 2026; 13(2): 12–22p.

Keywords: Macroplastics, pollution, waterfronts, sediment, environment

INTRODUCTION

Plastic are primarily synthetic organic polymers produced from petroleum through the polymerization of monomers derived from oil, gas, or coal [1, 2]. Plastic pollution represents one of the most significant environmental issues of the 21st century, classified base on size as mega-debris (100 mm), macro-debris (20 mm), meso-debris (20–5 mm), and micro-debris (<5 mm) [3]. They are group as polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET), polyvinylchloride (PVC), polyurethane (PU), naturally occurring polymers, cellulose, starch, natural rubber, protein etc [4]. This category of materials encompasses items like plastic bottles, bags, and packaging, which are notably durable and resistant to breakdown. As a result, they accumulate in water bodies and sediments. The presence of macroplastics adversely affects water quality and poses serious risks to aquatic organisms, ecosystem health, and human well-being through mechanisms such as ingestion, entanglement, and the release of toxic substances [5–7].

Bundu Waterfronts is located in the city of Port Harcourt, Nigeria, and is a densely populated and economically significant area, the improper disposal of plastic waste has intensified pollution levels. The waterfronts serve as a lifeline for many residents, supporting livelihoods through fishing, transportation, and trading [8, 9]. However, the growing presence of macroplastics in this environment threatens the sustainability of these activities and underscores the need for urgent interventions.

The estuary is open with rich composition of flora and fauna of unique biodiversity with various sites where many pollution problems exist [10] and where pollution heaping caused significant changes in abundance and species composition. The system is vulnerable to pollution by organic, industrial and chemical pollutants/wastes from several industries and human habitats located by the banks and waterfronts, and has been the subject of much research over decades [11, 12].

The presence of plastic debris has become a thing of concern in the marine environment due to its impact in the aquatic ecosystem [13, 14] as they are capable of clogging round the prop root of mangrove preventing the attached algae and oyster juveniles, overheating the environment by absorption of solar radiation, impairing the aesthetic view of the open waters, preventing carbon sequestration etc. Although there is a growing recognition of the effects of plastic pollution, there is still a significant lack of localized information regarding the distribution, origins, and composition of macroplastics in Nigeria's aquatic environments.

Gaining insight into the level of macroplastic contamination at the Bundu Waterfronts is essential for developing evidence-based strategies and policies to alleviate its impacts. This research aims to address this knowledge deficiency by examining the occurrence of macroplastics in both water and sediment at the Bundu Waterfronts, pinpointing their possible sources, and assessing the consequences for environmental health and the well-being of local communities.

MATERIALS AND METHODS

Study Area

The study was carried out at Bundu Waterfront along the stretch of Upper Bonny Estuary, Port Harcourt Rivers State Nigeria (Plate 1). Rivers State is located in the Niger Delta and Niger Delta lies between latitude 40 2” and 60 2” North of the equator and longitudes 50 1” and 70 2” East of the Greenwich meridian. The river body is tidal brackish water connecting the waterfronts within Port Harcourt Local Government Area. Human activities within and around this water body include fishing, landing sites, mangrove lumbering, bathing, sporting (canoe race or boat regatta) sewage disposal, transportation, dredging, waste dump site by the river bank, and landing/sales port for illegal refinery (Bunkery) products.

MAP OF STUDY AREA

Bundu Waterfront

Bundu Waterfront is located along $04^0$72’89.184’’ latitude $007^0$03’04.8’’. It is densely populated with living houses and is one of the largest waterfronts, it extends to Isaka, Bundu and new Bundu. It is densely vegetated with mainly red mangrove (*Rhizophora sp.*) and white mangrove, (*Avicenia sp*).

Plate 1. Study area

Duration of Study

Surface water samples for macroplastics and some physico-chemical parameters were collected once a month for one year from March 2022 to February 2023 which comprised dry and wet seasons mostly during the low tides or ebb tides.

Materials used in the study

Sample containers, 70% ethanol, 5% formalin, sieve (500 million), sorting tray, harvesting net, weighing scale, eckman grab, sample label, forceps, specimen vials and stopper, microscope and appropriate taxonomic keys etc.

Active Sampling

The floating plastic debris composition, size and identification were carried out through the deployment of small nets from the bridge to collect the (plastic) samples. The net was around 1m wide and 0.5m tall that can easily be operated by one or two people. This application followed the sampling method carried out at Mogami River in Japan [15], the Shaigon Rivers in Vietnam [16, 17].

Visual Observation Sampling

This method was focused on the collection of macroplastics samples at the rivers shore and were employed by counting and identifying the plastic debris seen along the river shore [18, 19].

Data Analysis of Microplastics

The percentage, density and most common products of the macroplastics were assessed and calculated based on the methods given by [20, 21].

Water Sample Collection

Water samples for physico-chemical examination were collected according to the protocol following standard [22]. They were collected at sub-surface from all the sampling stations at the depth of 15–30 cm between 8.30 hours and 16.30 hrs. The sampling containers to be used for sampling included, dark coloured reagent bottles (70 ml) for the collection of dissolved oxygen (DO) and biochemical oxygen demand (BOD). Plastic containers (1liter Jericans) was used to collect water for physico-chemical analysis. The sampling containers was properly washed, dried, corked with covers, well labeled and stored in cool box under laboratory condition a day before the sampling date. All sample containers were rinsed three times with the river water at each sampling point before samples are collected. The water samples were collected by hand lowering the sample containers below the water surface at the depth of 15-30 cm. the containers were completely submerged and allowed to fill to the bream with no air bubbles stroked inside and the covers were corked while under water. Each sample was treated accordingly as stated by standard procedure (APHA, 2012). Thereafter, all the samples were stored in the cool box and subsequently transported to the laboratory for analysis.

RESULTS

Macroplastic debris gathered from the sampling station water were sorted into thirteen different categories which included medicine dispensing product, food wraps, fishing material, laundry materials, drink wraps, polyvinylchloride (PVCs), bags, wears, body care, household items, saloon accessories, electrical/electronic and others (unclassified macroplastics) as shown in Table 1. Weight variations of macroplastics from the water samples indicated that medicine dispensing products had a value of 3.00±0.75 kg. A recorded mean of food wraps with 23.50±2.11 was observed. Fishing material recorded its mean value 0.42±0.14 kg. Laundry materials value is 2.08±0.33 kg. Drink wraps was 21.33±2.58 kg. The recorded PVC and bags value were 1.17±1.16 kg and 8.42±1.25kg respectively. Wears mean values recorded was 3.17±0.45 kg. Body care item 6.0±0.82 kg. Household items mean values recorded 8.17±1.16 kg. The recorded saloon accessories mean values 1.00±0.32 kg. Electrical/electronic items was 1.33±0.39 kg. Other items 2.0±0.49 kg.

Seasonal variation of macroplastics in water was recorded for the thirteen categories of macroplastics which included medicine dispensing product, wears, laundry, food wraps, drink wraps, household items, body care items, saloon accessories, electrical/electronic, PVC and others unclassified macroplastics (Figures 1–4). All the categories of macroplastics examined during this study were high in water during the wet season than in the wet season. Meanwhile, PVCs were only present in the wet season.

Weight variation of macroplastics from the sediment samples were stated in Table 2. The food wraps recorded the highest mean value 10.64±3.57 kg while Polyvinylchloride (PVC) mean value was the lowest recorded 0.25±0.60 kg.

Table 1. Weight variations of macroplastics in water of Bundu waterfront.

S.N.	Macroplastic	Sample mean (Kg)
1	Medicine dispensing products	3.00±0.75
2	Food wraps	23.50±2.11
3	Fishing material	0.42±0.14
4	Laundry materials	2.08±0.33
5	Drink wraps	21.33±2.58
6	PVCs	1.17±1.16
7	Bags	8.42±1.25
8	Wears	3.17±0.45
9	Body care	6.0±0.82
10	Household items	8.17±1.16
11	Saloon accessories	1.00±0.32
12	Electrical/electronics	1.33±0.39
13	Others	2.0±0.49

Polyvinylchloride (PVC), Others-unclassified macroplastics

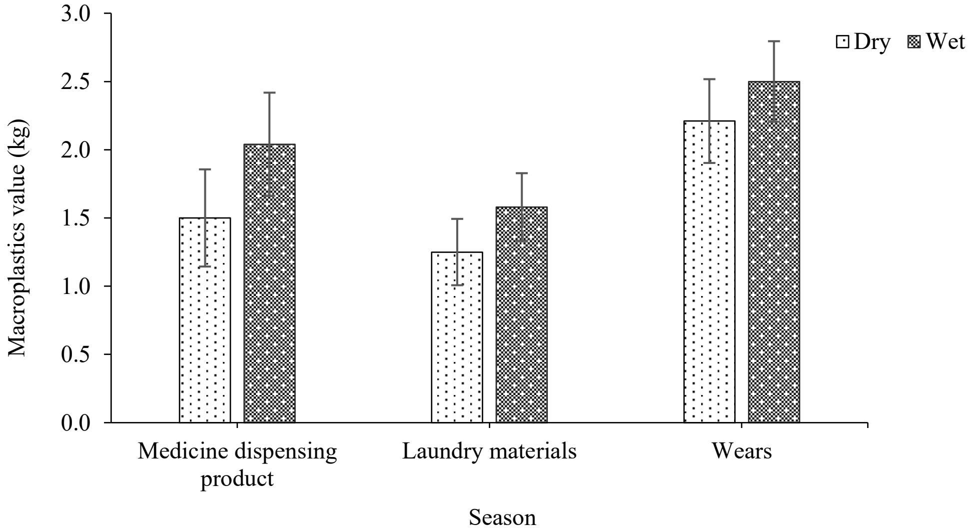

Figure 1. Seasonal variation of some macroplastics in the water of the study area.

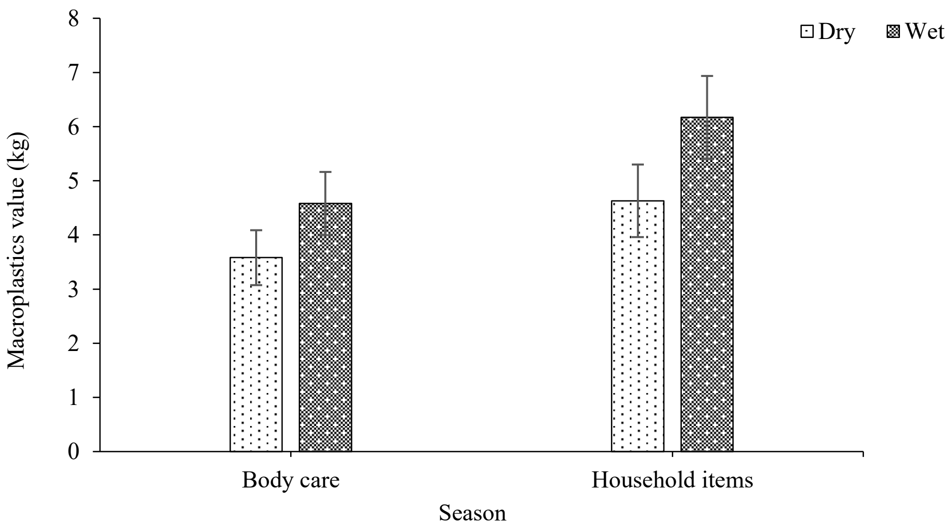

Figure 2. Seasonal variations of household items and bodycare items in the water of the study area.

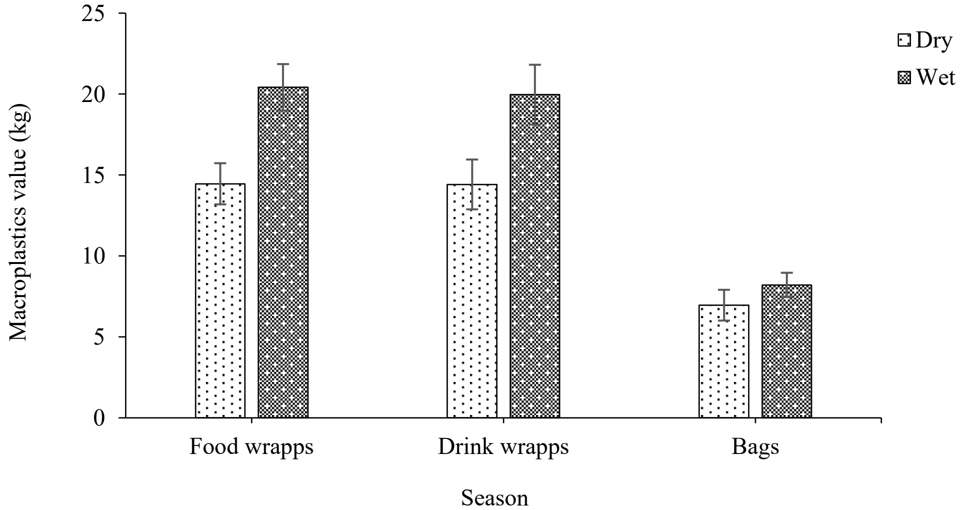

Figure 3. Seasonal variations of food based wastes in the water of the study area.

Comparative Weights of Macroplastics in Water And Sediments at the Bundu Waterfronts

The weights of the macroplastics in the water and sediments during this study were compared in Figure 6 to 9. It was observed that macroplastics weight was higher in water than in sediments of all the thirteen categories of macroplastics in this study except in the saloon accessories and laundry materials.

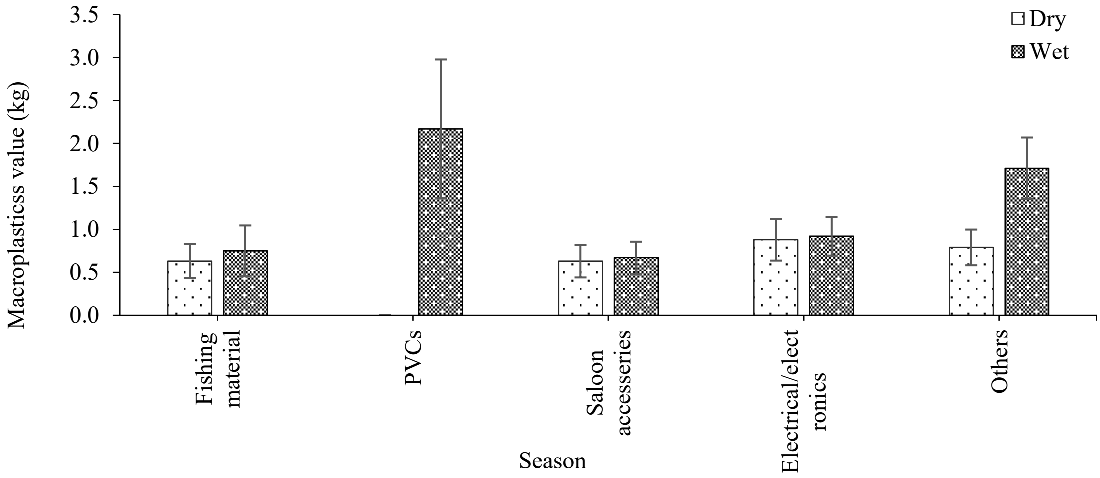

Figure 4. Seasonal variations of some macroplastics in the water of the study area.

Table 2. Weight variations of macroplastics in the sediments of Bundu waterfront

Macroplastic	Sample mean (Kg)
Medicine dispensing products	1.50±0.77
Food wraps	10.64±3.57
Fishing materials	0.58±0.12
Laundry materials	1.67±1.33
Drink wraps	8.33±3.15
PVCs	0.25±0.60
Bags	5.86±1.94
Wears	2.14±0.76
Body care	3.86±2.04
Household items	2.94±1.24
Saloon accessories	1.11±0.20
Electrical/electronics	0.58±0.12
Others	1.47±1.02

Polyvinylchloride (PVC), Others-unclassified macroplastics

Comparative Weights of Macroplastics in Water and Sediments of Bundu Waterfront

The weights of the macroplastics in the water and sediments during this study were compared in Figure 5 to 8. It was observed that macroplastics weight was higher in water than in sediments of all the thirteen categories of macroplastics in this study except in the saloon accessories and laundry materials.

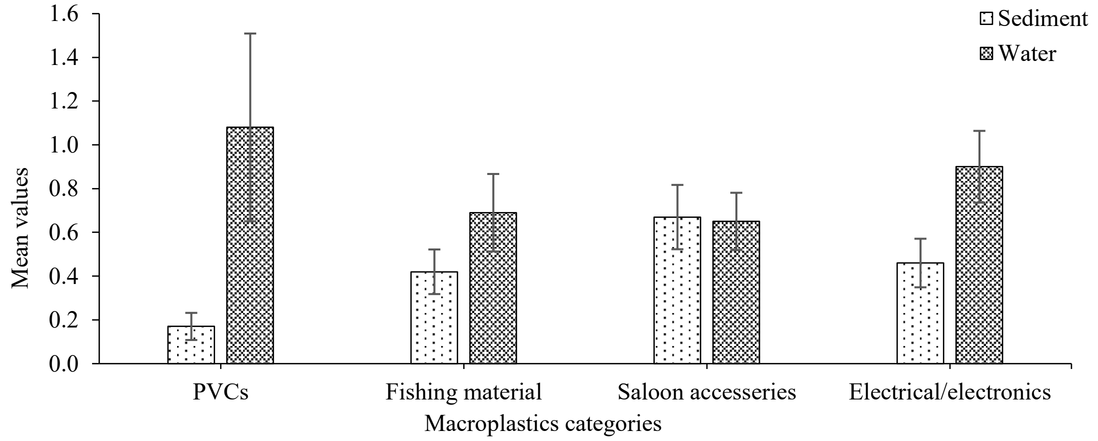

Figure 5. Comparative values of macroplastics in water and sediment of the study area.

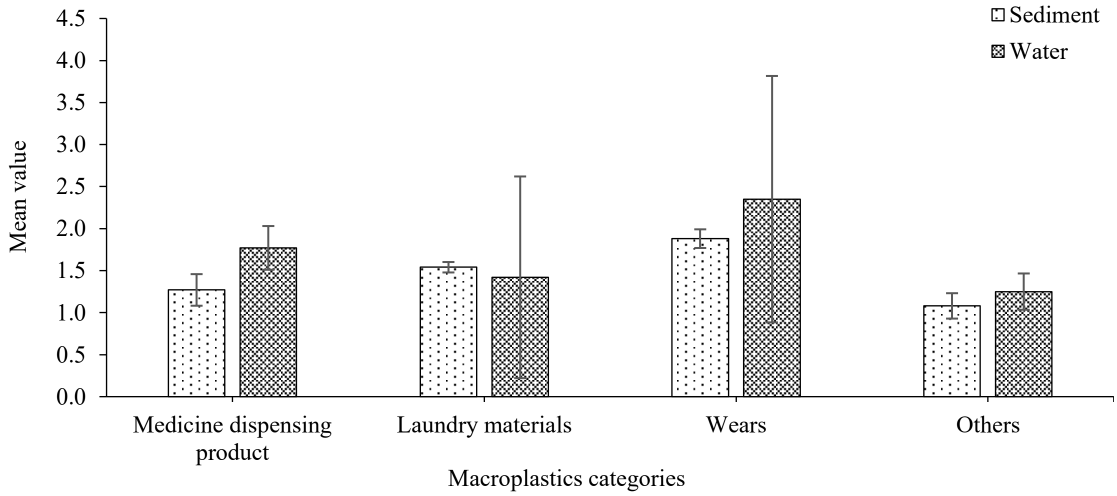

Figure 6. Comparative values of macroplastics in the water and sediment of study area.

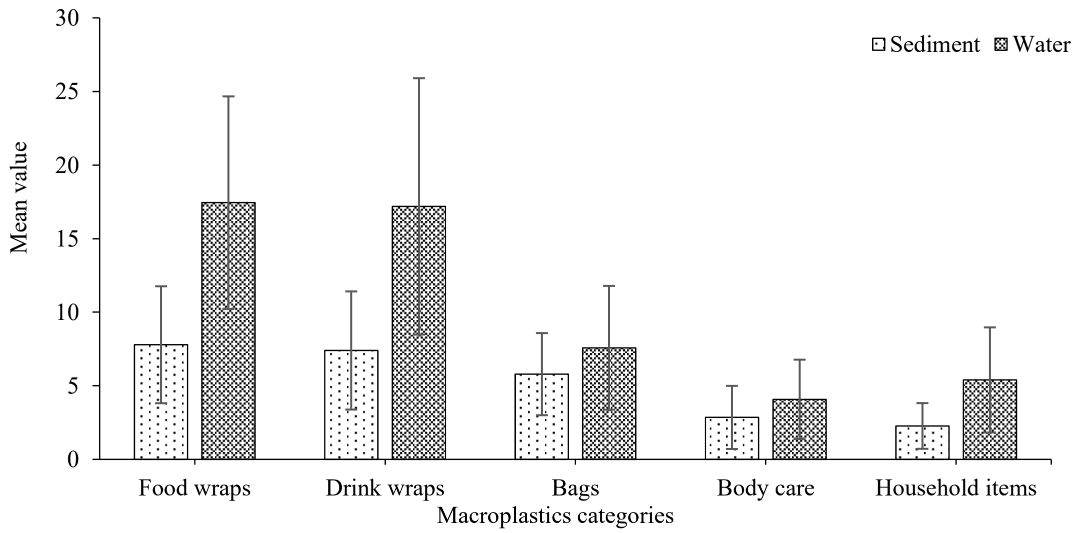

Figure 7. Comparative values of macroplastics in the water and sediment of study area

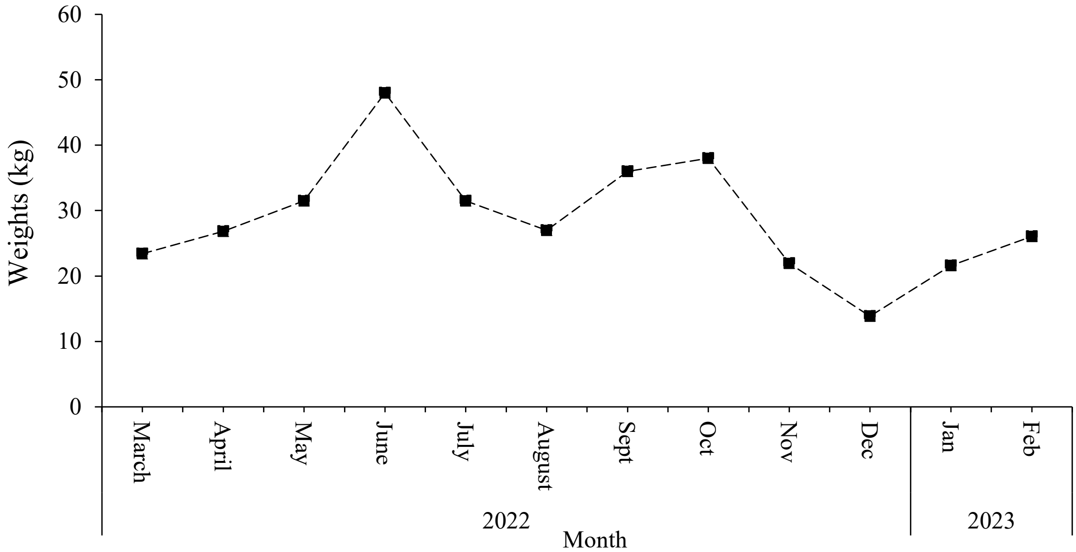

Figure 8. Macroplastics weights in relation to months in the study area.

Table 3. Physico-chemical parameters of the study area.

Parameter	Mean	Standard
Temp (˚C)	30.63±1.80[a]	≤35°C (EPA, 2014))
pH	7.23±0.90[a]	5.5-8.5(EPA,2001)
EC (µs/cm)	30.67±9.71[a]	340-700 (WHO, 2011).
TDS (mg/L)	19.90±6.20[b]	≤500 (WHO,2011)
DO (mg/L)	7.98±1.66[a]	5.0-9.0 (WHO/UNEP, 2004)
BOD (mg/L)	4.09±0.54[a]	3.0(WHO/UNEP,2004)
Salinity (‰)	33.58±7.62[a]	≤40(EPA,2001)
Turb (NTU)	11.60±3.19[c]	5.0 WHO
Transp (m)	1.30±0.58[a]	>1(EPA,2001)
Cl (mg/l)	1.67±0.84[a]	<0.05(EPA,2001)

Temp-Temperature, pH-Hydrogen concentration, EC-Electrical Conductivity; TDS-Total dissolved solids; DO- dissolved oxygen; BOD- Biological oxygen demand, Cl-Chlorine, Transp-Transparency, Turb-Turbidity. Means with different superscripts are significant at $p<0.05$.

Variations of Some Water Physical and Chemical Parameters

Variations of some water physical and chemical parameters as stated in Table 3 included temperature, pH, electrical conductivity (EC), dissolved oxygen (DO), biological oxygen demand (BOD), total dissolved solids (TDS), turbidity, salinity, transparency and chlorine (Cl). Temperature, pH, EC, TDS, DO, salinity and transparency were within the acceptable limits while BOD, turbidity and Cl exceeded the standard values.

DISCUSSION

In the Bungu waterfront (study site), the sources of contamination and accumulation for macroplastics (MAPs) were observed to be personal usage, landfill/dump site disposal, and accumulation of plastic wastes from runoffs. Macroplastics accumulation and contamination documented in this study was in agreement with the report of [23] who reported that plastic debris apart from obstruction and reduction in the aesthetic value of water body, they are non-biodegradable rather they leach out their toxic component into water consumed by human and aquatic organism. Food wrappers with the highest mass throughout the sampling period across the sampling station agreed with the findings of [24] who documented food wrappers as the most abundance in the top ten categories of marine in environmental menace of plastic waste in Nigeria. It also aligned with [25] for food containers and packaging as the largest components of municipal solid wastes by weights. This could be attributed to indiscriminately discarding of food wraps from food consumption. The findings in this study concurred to the documentation of [26] on suspended marine litter in Akwa-Ibom State, Nigeria.

The runoffs from the rain water was the major factor for the entrance of the plastics to the waterfront; it brought garbage from the residential environment which is also stated by [27, 28]. Rainwater runoff is a key factor because it passed through residential and brought garbage in the environment into the river. This might be the reason for the significant difference in raining season and dry season where all the categories of macroplastics examined during this study were higher in water during the wet season than in the dry season.

Likewise, just as microplastics can also be found in sediments [29]; macroplastics were also found in the sediments of the Bundu waterfront which gave a confirmation on the report of [30] where the study found microplastics in the sediments of the six location of Montenegrin coast. This confirmed that plastics are readily present in the sediment of the exposed aquatic environment. The food wraps had higher value in sediments of Bungu waterfront than every other categories of macroplastics examined during this study where PVC was the least. It also aligned with [25] for food containers and packaging as the largest component of municipal solid waste by weight.

The water detected higher macroplastics load in this research than in sediment except in saloon accessories and laundry materials. This was contrary to the report of [29] that the concentration of microplastics in sediment samples is typically greater than that observed in surface water. This phenomenon could be attributed to the effects of gravitational force and the density of plastics, which exceeds that of water, leading to the sinking and accumulation of these materials in sediment. Microplastic particles predominantly present in sediments tend to possess a density that is higher than that of water, whereas those with lower density are more likely to be found floating on the water's surface [31].

The weight of macroplastics in relation to the months in the examined area which showed higher values during the wet season than in the dry season could be as a result of the run-offs experienced during the raining season (November–March). The movement of microplastics might be subject to the flow conditions, vegetation patterns, and water levels in particular rivers, which have a significant impact on their transport. Contrary to this study [32] found no seasonal differences in macroplastic pollution. Also with the report of [33] where the general distribution of macroplastic debris, when analyzed by counts, weights, polymer types, and functional groups, exhibited a high degree of similarity across various sites and seasonal periods.

The water physico-chemical parameters especially temperature, pH, electrical conductivity, TDS, dissolved oxygen and salinity observed in the present study were still in the range of tolerable levels for marine life and within the range of normal condition for coastal environment [34–38]. The exceptions were the total dissolved solids, BOD, turbidity and chlorine. [39], reported that TDS value reaches its maximum range in rainy seasons which agreed with the result of this study.

The alteration in the environmental factor of the study area might be attributed to the value gotten for the BOD which is in contrast with the standard values given by [34] $\leq$3.0mg/L. This high level of BOD could suggest the pollution level of the Bungu waterfront especially as a result of the domestic runoff, sewage disposal and decomposition of organic matter, including plastics. The degradation of macroplastics, supported by [40, 41], present in the water body could add to the organic load of the experimental area. Also, macroplastics could contribute to high BOD recorded by trapping organic debris and hindering natural decomposition processes.

The fragments of the plastic debris might be one of the factors contributed to the high level of turbidity recorded in this study. In addition, runoff which was also reported by [42], a significant contributor to plastic pollution in the examined region, is a major source of suspended solids, increasing turbidity levels. Elevated turbidity diminishes water clarity, which might adversely affect aquatic organisms by restricting light penetration and impeding the process of photosynthesis.

Meanwhile the increase level of chlorine might not be directly linked to the macroplastics, and might be due to the discharge of industrial effluents, sewage, or other sources of chemical contamination. Although, plastics have the potential to serve as carriers for chlorine-based compounds, either by absorbing them or incorporating them into their chemical structure. High level of chlorine is harmful to aquatic organisms.

CONCLUSION AND RECOMMENDATIONS

The study revealed that the macroplastics accumulation showed higher plastic load in water than sediments in the thirteen categories except for saloon accessories and laundry materials. Food wraps and drink wraps were the recorded largest components of municipal solid wastes by weight in water and sediments. Also, the study showed the levels of accumulation of macroplastics in surface water and sediments and some physico-chemical variables of Bondu waterfronts of Upper Bonny Estuary, Rivers State, Nigeria. In view of these, there is need for urgent actions through government regulation and local community. There should be innovative waste management practices where wastes can be reduce, reuse, and recycle, aiming at mitigating plastic pollution in Nigeria's coastal environments.

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