Abundance and Distribution of Microplastics in Sediment Samples from Ten (10) Selected Recreational Beaches in Lagos, Nigeria

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Abstract

This study investigated the abundance and identity of microplastics in sediments samples from 10 selected beaches along the Lagos Atlantic Ocean. Samples were collected during the rainy season from 28th April to 29th May 2018 and during the dry season for the period of 5th January – 9th February; 2019. Microplastics samples were separated, identified, and categorized according to their sizes, shapes and colours using Dissecting Microscopes and FTIR- ATR. Microplastics particles were detected in all sediment samples at a mean of 32.4 ± 0.34 pieces per sample (at mean abundance 3741.8 ± 34 pieces/kg dry weight) for both seasons. The mean abundance of microplastic particles during the rainy season was 58%. The mean abundance in A, B, C and F, sites within Oniru, Elegusi, Eleko and Alpha beaches were high compared to other sites. Site C showed the highest abundance in both seasons. Beads were the most abundant types under the size category <5.0mm while pellets were the most dominant type under the <2.5mm size category. Pellets were the most abundant microplastic types in both seasons occurring at 33% and 31% respectively. The most abundant size fractions in both seasons were particles <2.5mm occurring at a mean abundance of 51.4%. The most common color of microplastics during the wet season was white (25.52%) while clear/colourless (21.1%) dominated during the dry season. The results of FTIR-ATR analysis indicated that polyethylene (PE) was the most abundant in both seasons occurring at 20% and 30% respectively. The result of the study indicated the prevalence of microplastics in Lagos beach sediments in both seasons with higher abundance during the rainy season.

Keywords: *Microplastics; FTIR- ATR; Polyethylene; SEM-EDX*

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1. Introduction

Plastics are partially degraded in the marine environment by the combined forces of biotic and abiotic factors to give rise to Microplastics. The National Oceanic and Atmospheric Administration (NOAA) defined microplastics as particles less than 5mm in size (Wright et al; 2013). Thompson et al., 2004; Arthur et al., 2009; Hidalgo-Ruz et al., 2012.Barnes et al., 2009; Ryan 2009; and Betts 2008; also described them as tiny fragments of plastic less than 5mm in the water column and in sediments

Microplastics are currently described in a general context as a heterogeneous classis of synthetic particles of various sizes (usually from a few microns to several millimeters) with specific densities, chemical composition, shapes and origin, found in any of the marine environments or biota (Hidalgo-Ruz et al., 2012; Filella, 2015; Thompson, 2015).

There have been serious environmental concern on the widespread occurrence of microplastics in oceans, seawater and beaches and bottom sediments of seas, and biota worldwide (Browne et al., 2011; Browne et al., 2010; Woodall et al.,2014; Desforges et al., 2014; Zhou et al., 2015; Su et al., 2016), with sediments being considered as the major sink for microplastics in the beach (Cauweuberghe et al 2013;Cozar et al 2014; Woodall et al 2014, Fisher et al 2015; Zhao et al 2017).

The sources of the microplastics in the beaches and ocean have been linked to both terrestrial and marine sources. Land-based sources are the dominant input of microplastics into oceans (Andrady, 2011; Browne et al., 2011; Cole et al., 2011; Auta et al., 2017).

These microplastics are in the form of primary or secondary microplastics. Primary microplastics are engineered micro-sized plastic beads and industrial production pellets (about 5mm diameter) and

powders (< 0.5 mm), widely used in cosmetics formulations (Castaneda et al., 2014; Napper et al., 2015) such as makeup, sunscreen, nail polish, hair coloring, eye shadow, shower gels, and personal care products containing scrubs and abrasives (such as toothpastes, facial cleansers, and air-blasting) (Chang, 2015; Fendall and Sewell, 2009; Lei et al., 2017; Waller et al., 2017). On the other hand, secondary microplastics, such as fibers, fragments, and flakes, may come from poor plastic waste management leading to release of plastic litter, release of fibers through everyday use and washing of synthetic textiles (Browne et al.,2011; Boucher and Friot; 2017).

Primary microplastics may enter directly into the oceans or pass through freshwater courses to the marine environment while pellets and other forms of primary microplastics used as industrial raw materials accidentally spill or discharged into the water body during transportation or by run-offs from factory site into marine environment. Secondary microplastics are the by-product of fragmentation and weathering of larger plastics in the environment (GESAMP, 2015) which occur when plastics are disposed into the environment.

Plastics that enter river systems – either directly through discard waste, direct dumping into drainages during rainfall, mismanaged plastic wastes, refuse dumpsites, leachates, or waste-water effluent etc. – will then be transported out to sea. Also, a considerable amount of microplastics may be released to the environment through tire abrasion (Boucher and Friot, 2017), which has the potentials to contribute an estimated 5–10% to the total global plastics entering oceans (Kole et al., 2017).

Tourism and recreational activities also account for an array of macroplastics being discarded along beaches and coastal resorts (Derraik, 2002), although it is worth noting that marine debris observed on beaches may arise from the beaching of materials carried on inshore and ocean currents (Thompson,

2006).

Also, commercial fishing, marine transport, aquaculture and oil and gas exploration all contribute to marine plastic loads and by extension microplastics in the beach sediments. Several studies on sandy beaches, estuarine and sub-tidal habitats, and marine sediments all over the world, have yielded microplastics data in other parts of the world, however there is paucity of research data on microplastics in sediments from the Nigerian Beaches. This study therefore investigated the abundance and distribution of microplastics in sediments from sandy beaches of Lagos Nigeria.

2.0 Materials and Methods

2.1 Study Area

The study area comprises of sampling points within ten (10) coastal beach locations in in Lagos, Nigeria. The beaches lie situate within the Oniru Beach (Long 3.486967 and Lat 6.422099) and Eko Tourist Beach (longitude 3.460588 and Latitude 6.455424). The beaches are characterized as sandy with fine sands and have similar prevailing ocean waves and current pattern depositing fine sand, large pebbles, stones, plastic wastes along the shorelines.

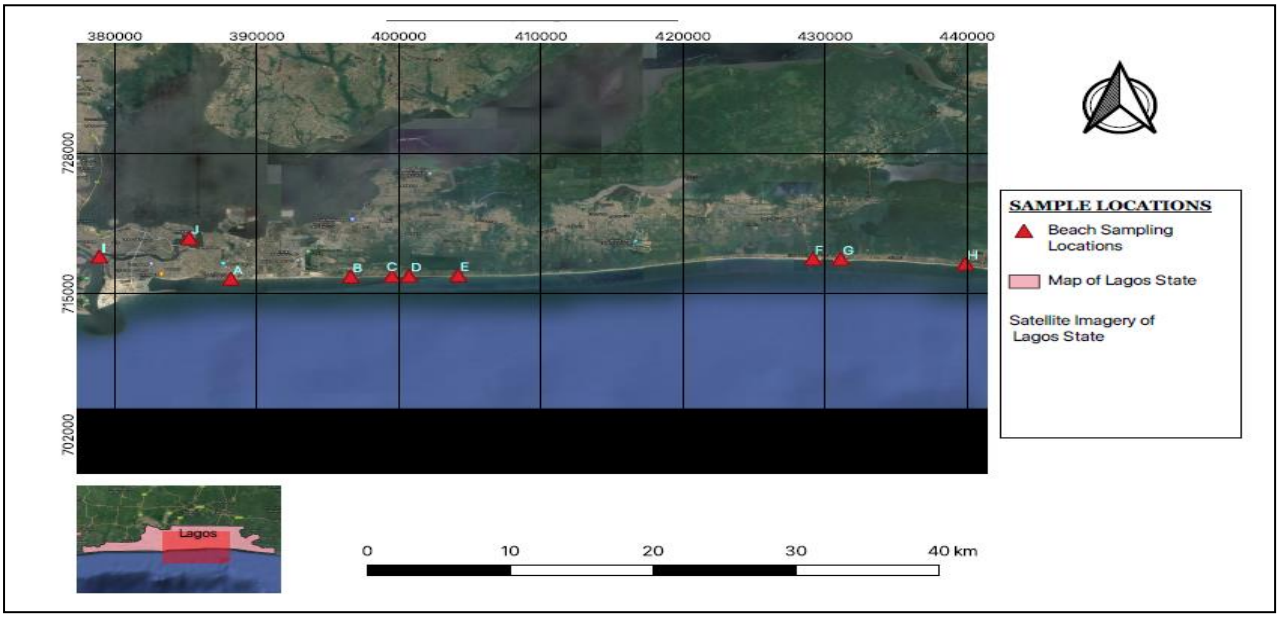

Fig. 1: Sampled beach location along the Lagos Atlantic Ocean

2.2 Collection and Analysis of Microplastics

Sample collection was divided into two surveys, one carried out during the rainy season (28th April to 29th May 2018) and the second during the dry season (5th January – 9th February; 2019), in order to study the effects of seasonal variations on the abundance of microplastics in the sediments of the beaches of Lagos, Nigeria. Beach sampling was preceded by visual characterization of the shoreline to determine the strandline and map out a 100m^2 area from the strandline to the back of the beach where sediment sampling will be collected. Transects were created in each beach and identified with a hand-held Garmin-GPSMAP 76S-type global positioning system. A transect is defined as a fixed section of a beach covering the whole area from the strandline to the back of the beach measuring about 100-metres stretch from the strandline to 10 meters back.

The strandline was sampled by scraping the two first centimeters of sand from 900cm^2 quadrats, a well-established protocol to monitor microplastics on beaches (Ivar do Sul et al., 2009). Three quadrats were

thrown along the strandline on each surveyed beach, in a total of 20 samples. Samples of wet sediments were collected along the transect parallel with the shore between the high and low tide lines using a stainless spoon. Fine sediments were sampled within each transect at a depth of 1- 2cm as a larger number of microplastics were expected to be bound in the fine-grain layer than among coarse grains regularly rinsed with seawater.

Studying the stratification of sediment cores to a depth of 25cm, Carson et al.,(2011) found that 50% of microplastics fragments were contained in the topmost 5cm of each core and that the top 15cm hosted 95% of all detected plastic particles. It is expected that the largest concentration of microplastics when sampling the sediment surface will be captured within this zone.

Table 1: Coordinates of Sampling Locations

S/N	Location Name	Site Code	Coordinates	
			Latitude	Longitude
1	Oniru Private Beach Area/Landmark Center	A	6.422099	3.486967
2	Elegushi Beach	B	6.423903	3.562703
3	Lekki	C	6.424371	3.588796
4	Lagos Beach/ lekki Miami Beach	D	6.424500	3.599568
5	Prime Beach	E	6.424926	3.630767
6	Atican -Beach/ Barracuda Resort Area	F	6.438615	3.855029
7	Fatima Banibo beach - Okun -Ajah Area	G	6.438381	3.872645
8	Eleko Beach -Badore/ Segun Adesanya	H	6.434525	3.951354
9	Oko-Olowo Beach Ibeju Lekki/Somerset Jeep Bar Area	I	6.440156	3.403723
10	Eko Tourist Beach/Lekki Atlantic Beach Resort	J	6.455424	3.460588

2.3 Extraction of Microplastics

Samples were processed using a stepwise approach including sieving, organic material digestion, density separation, centrifugation, and filtration to separate microplastics from the bulk sediment. All laboratory works were conducted under a vacuum hood and exposed samples and equipment were covered with foil to prevent contamination from airborne microplastics (Reeves et al.,2016).

2.3.1 Sieving

Air-dried sediment samples were placed in a beaker with deionized water and agitated with a metal spatula to disassociate a large clump of sediment. The contents of the beaker were then poured through a stacked sieve (5.0 mm, 2.50 mm, and 1.0 mm), with the largest mesh-size at the top, allowing large organic debris and plastics to be removed from the largest sieve (≥5 mm). Each sieve was rinsed with deionized water and left to dry, and samples categorized into two <2.5mm and <5mm.

2.3.2 Organic Material Digestion

Each dried sample was placed in a beaker with 20ml of 30% hydrogen peroxide, 20ml of 0.05M iron (II) solution and a magnetic stir bar. The sediment solution was left at room temperature for 5min, and then placed on a heating magnetic stirrer and heated to 75◦C for 30minutes. Where organic materials were visible after 30min, 20ml of hydrogen peroxide was added every 15min and stirring/heating continued until all visible organic materials were completely digested.

2.3.3 Density Separation, Centrifuging, and Filtration

Each digested sample was placed in a 50ml centrifuge tube. Large sediment samples were split evenly between two tubes. Sodium iodide (NaI) solution (density 1.6–1.8g.ml) was added to each tube until 30ml of NaI was overlaying the sediment sample. Each tube was capped, shaken manually for the 20s and then placed in a benchtop centrifuge for 5min at 3,500 revolutions per minute.

Tubes were removed gently to minimize sediment re-suspension. The top 10ml of supernatant NaI solution was poured off into a glass Büchner vacuum apparatus fitted with a 1.2µm polycarbonate membrane filter. The remaining sediment in the tube was subjected to this procedure repeatedly and each time, the supernatant was decanted out and concentrated using 3500rpm centrifuge for 10 minutes and stored in a

glass bottle. Concentrated supernatant was then filtered, labeled, air-dried in the laboratory, and stored for Stereo-Microscope sorting and counting.

2.4 Microscopic Identification of Microplastics

Total counts of all plastics and shapes were carried out using dissecting Stereoscope (Olympus) at 40x magnification. Each filter paper was placed under the dissecting microscope at 40x magnification (Hidalgo-Ruz et al; 2012, Masura et al; 2015). Tweezers were used to remove the identifiable plastics from the filter paper to the petridish.

All microplastic particles present were removed, counted and identified as either a fragment, pellet, line/fiber, film, or foam according to the morphological categories used in in several other surface water studies (Eriksen et al., 2013; Free et al., 2014; Mason et al., 2016). The microplastic particles identified were counted and placed into labeled 4ml screw cap glass vials using thin forceps according to their size range (<2.5mm and <5.0mmin the sieve fractions). The vials were then sealed and preserved for identification using Fourier Transformed Infrared Spectroscopy (FTIR).

2.5 Chemical Identification of Microplastics

The FTIR analysis provides chemical identification of microplastic particles by comparing the particles' individual spectrum to a spectral database for all commonly known polymers. Several studies have demonstrated there are many false-positive microplastic identifications using pre-set criteria (Song et al., 2015). A subset of samples was selected for Fourier transform infrared spectroscopy (FTIR).

The FTIR imaging was carried out using an Agilent 5500 FTIR instrument with a single reflection Attenuated Total Reflectance (ATR) accessory used in the infrared imaging of the samples. The ATR takes advantage of the physical properties of light when encountering two materials with differences in the index

of refraction. The samples were placed on the ZnSe crystal of the ATR unit with tweezers and covered with a stainless-steel plate. The pressure was applied to the particles to maximize the contact surface with the ATR crystal.

Five scans per sample were acquired from 4000-700 nm, and a database search was carried out with Spectrum Search Plus (V3.00.05). The polymers were identified by means of an automatic comparison of the resulting spectra with spectra of a polymer library (Synthetic polymers ATR-library) with a match factor threshold of 0.70 to ensure accurate identification of the polymer.

2.6 Statistical Analysis

Data analysis was carried out using SPSS Software with significance level (p) for the performed statistical tests set at 0.05. Data were tested for normal distribution using the Shapiro-Wilk test and was found not to be normally distributed, and therefore a non-parametric test was performed.

Wilcoxon Mann-Whitney U-test was applied to test the difference in abundance of the microplastics between different sites. It was also applied to test the difference in abundance of the size categories of microplastics among the different sites. Chi-Square was used in the evaluation of the different categories of microplastics in sediment samples while Linear regression was used to assess the relationship between the wet and dry season microplastic abundance in each site. Descriptive statistics were used to find the sum of microplastic types (fragments, beads, or pellets) for each site and season.

3.0 Results

3.1 Microplastic Abundance

Microplastic abundance was determined as items per kg of dried weight of sediment sample. Microplastics particles were detected in all sediment samples collected from the 10 beaches (A - J) with

a mean of 32.4 ± 0.34 pieces per sample in both wet and dry seasons. Microplastic abundance occurred at an average of 3741.8 ± 34 pieces/kg dry weight particles during the wet and dry seasons. The mean abundance of microplastic particles were 58% higher during the rainy season than the dry season. During both seasons survey, the abundance of particles was high in site A, site B, site C, Site F areas around Oniru, Elegusi, Eleko and Alpha beaches with site C showing the highest abundance in both seasons.

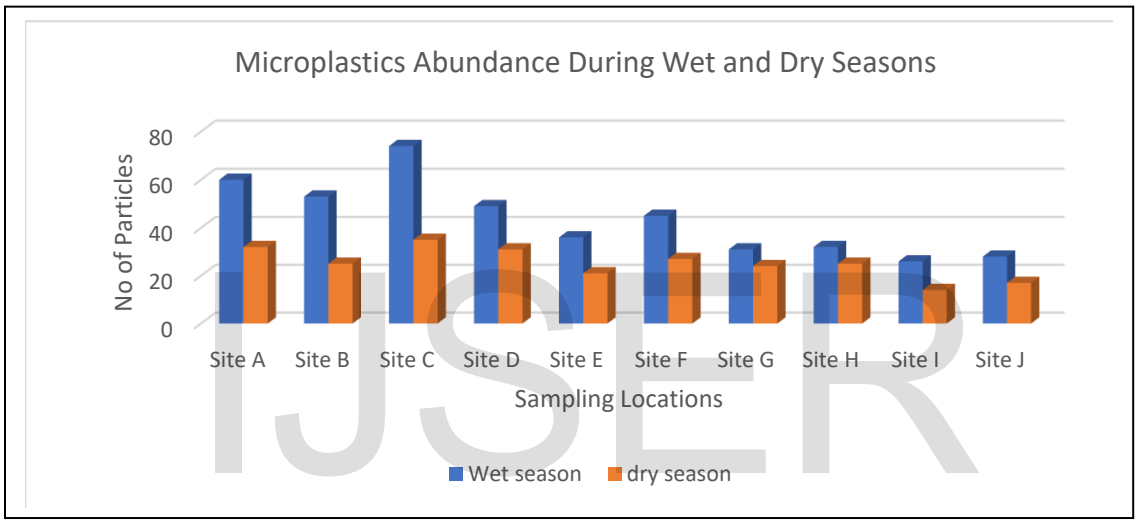

Fig. 2: Microplastic abundance in beach Sediment

Site A, B, C were most active in terms of exposure to tourists and nearness to other economic activities amongst all the beaches studied. Also, the high abundance during the rainy season may be related to anthropogenic input of plastics and plastic debris from floods through drains and municipal waste dump within Lagos Island during rainfalls and other anthropogenic inputs which is augmented by hydrodynamic factors.

Microplastic abundance decreased from Site D towards other beaches in the Lekki Epe axis, showing decreasing abundance moving away from the city Centre towards Epe on the Northern part of Lagos.

3.2 Microplastic Particles Distribution by Type in Sediment

Six classes of distinct microplastic types were recognized as shape criteria for this study (Hidalgo-Ruz et al; 2012) and represented as fiber, sheet, beads, foams, fragments, and pellets. The distribution is as shown in **Table: 2** below

Table 2: Distribution of Microplastics by types and category

Type	Size Category <5mm		Size Category <2.5mm	
	Wet Season	Dry Season	Wet Season	Dry Season
Fiber	2.40±1.74	1.60±0.69	5.50±2.38	2.80±1.74
Sheet	3.0±2.56	1.60±0.67	2.10±1.55	2.60±1.55
Beads	6.40±5.26	2.50±1.37	2.60±1.75	3.20±2.65
Foam	1.80±1.91	1.71±1.29	2.70±2.11	1.20±0.83
Fragments	5.0±4.21	2.60±1.43	3.6±1.43	1.50±0.92
Pellets	5.90±5.18	2.40±1.29	9.40±3.67	1.60±0.52

The most abundant shapes found in the beach sediment during the rainy season were pellets and fragments. Beads were the most abundant types under the size category <5.0mm while pellets were the most dominant type under the <2.5mm size category.

Overall, pellets had a total abundance of 33% for both seasons. Fragments were the second most abundant particle shape found within the study area accounting for 19% and followed by fiber which contributed 17% of the total plastic count. Others include beads found at 14%, sheets 11% and foam 6%.

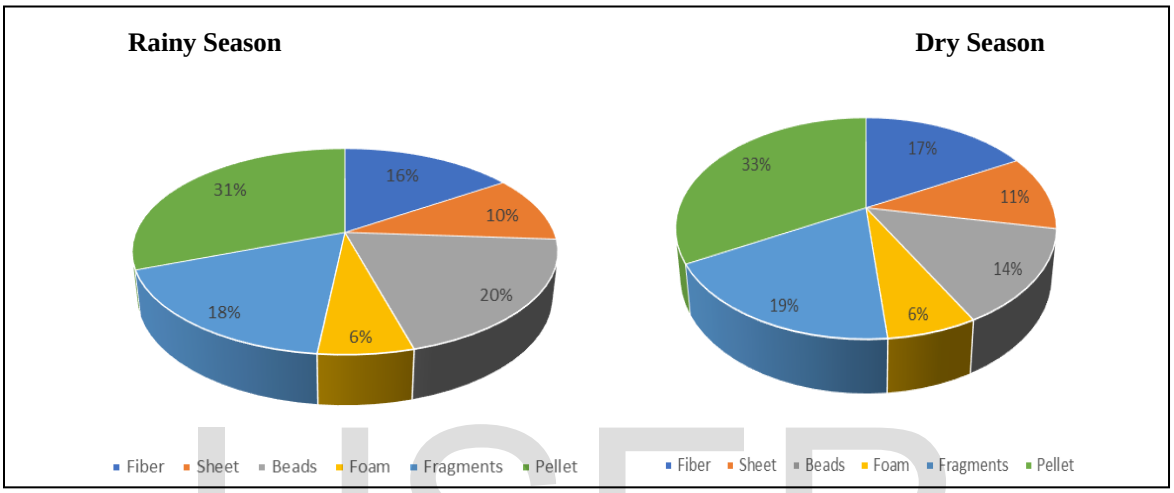

Fig. 3: Microplastic abundance by shape for both seasons

During the dry season, the most abundant shapes found in the beach sediment were pellets (31%). Beads were second abundant accounting for 20%, followed by Fragments 18%, Fibers were 16%, Sheets contributed 10% of the total plastic count, and foam 6%.

3.3 Microplastic Distribution by Sizes in Sediment

The most abundant size fractions in the beach sediment during both seasons were particles with the range of <2.5mm with mean percentage abundance of 51.5% while the particles of <5mm had a percentage abundance of 48.5%. The <2.5mm had a uniform distribution throughout the entire beach sites in both seasons.

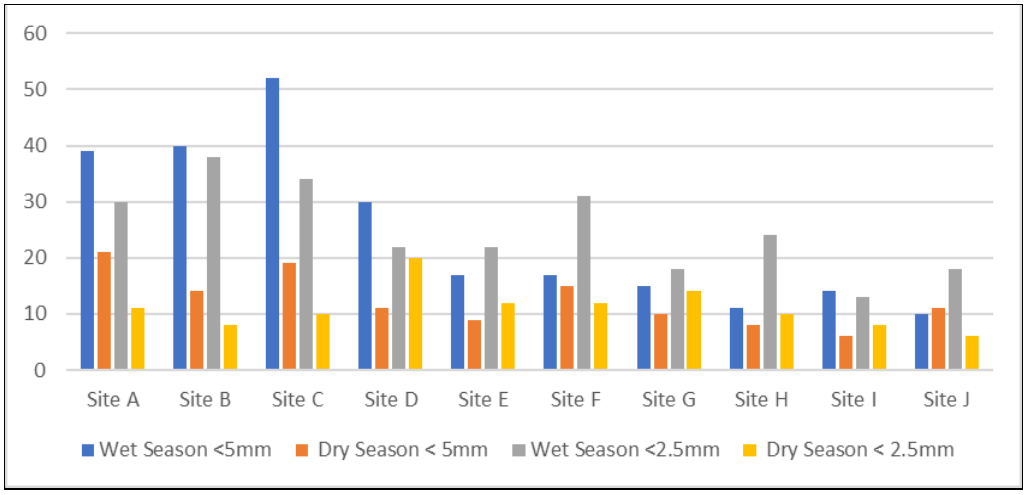

Fig. 4: Distribution of Microplastic particles by size in beach sediment

3.4 Microplastic Colour Distribution in Sediment

During the rainy season, most of the microplastic particles found in the beach sediment were colourless/clear (23.7%) white (19.4%). Other colours were present in the following proportions blue (16.4%), black (12.7%), green (10.8%) grey (2.2%), brown (8.2%), orange (5.6%) and pink (1%) respectively.

White, colourless/clear and blue colours were widely spread in high proportion among all the various shapes like fiber, sheet, fragments and pellets. Majority of the fibers and sheets were blue while fragments were mostly orange.

During the dry season, white, colourless/clear, blue, black and brown particles were the predominant colours of microplastic particles in the beach sediment. White (36.2%) was the most dominant followed by clear/colourless particles (24.5%). Other colours present include blue (11.6%) black (13.0%), yellow (7.3%) green (1.2%) orange (2.9%) and pink (2.9%).

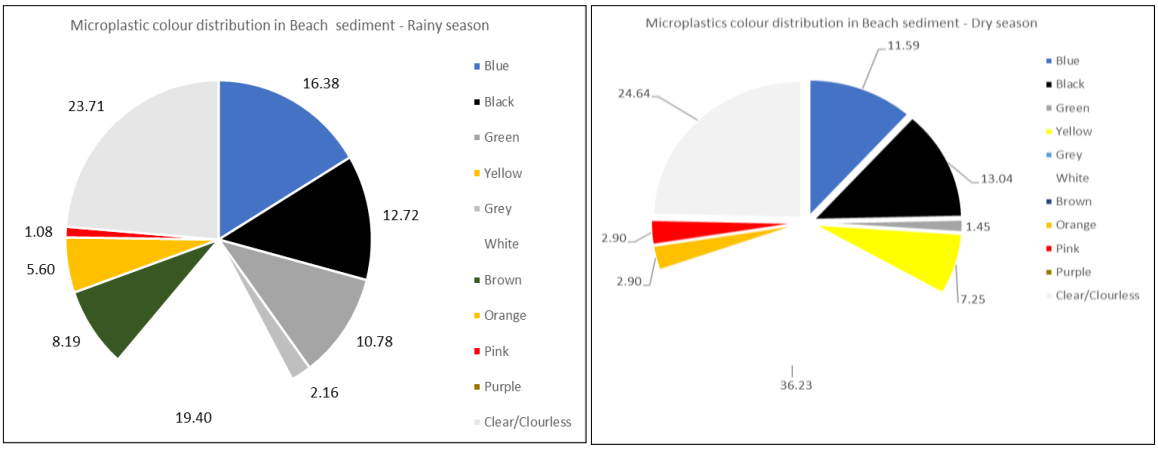

Fig. 5: Distribution of Microplastic particles by colour in both seasons

The most common colors in both seasons were white and the clear/colourless. The white colour ranged from 19.4% to 36.2% with cumulative of 25.52% of the total number of plastic particles. The next most common color of the particles was clear/colourless ranging from 23.7% to 24.6% with a cumulative 21.1% of the total microplastic particles. Blue colour ranged from 11.6% to 52% with a cumulative percentage abundance of 15.6% of the total microplastic particles. Black ranged from 12.7% to 13.0% and had 13.8% cumulative abundance in both seasons

The color distribution in the beaches was consistent within each size and shapes categories ($p = 0.01$, Kruskal-Wallis test). The proportion of the number of black particles in each size category were significantly different from each other. Student's t-test (after Shapiro-Wilk test to confirm normality); at $p = 0.01$, there were significant differences in percentages of colored particles among the particle types- fiber, pellets, foams and others.

For each beach, when the data from all samples were combined, the mean percentages for color categories across all size classes were not significantly different between the beaches ($p= 0.01$, Wilcoxon test) except for orange, brown and purple colors. Far fewer particles of these colors were collected so there is much greater variability in the mean percentage values.

The data of the rainy and dry seasons were combined to provide summary ranking based on numbers of particles, white (71.8%), clear/colourless blue (8.5%), green (7.5%), black (7.3%), red (2.6%), yellow (1.2%), orange (0.6%), brown (0.3%) and purple (0.2%).

3.5 Chemical characterization of Microplastics in Sediment using FTIR - ATR

A subsample of 92 suspected microplastic particles; representing 40% of the total particles identified visually from beach sediment samples collected during the rainy and dry season were subjected to FTIR-ATR analysis. The results confirmed the presence of plastics in all of the samples tested.

The following were identified in different percentages in the rainy season samples in the beach sediment, Polyethene (PE) mostly HDPE (High-density polyethylene) and LLDPE (linear low-density polyethylene) were the most common type Polyethylene terephthalate (PET) 15%, Polypropylene (PP) 10%, Polyamide (PA) 15%, Polystyrene (PS) 10%, and Polyvinyl chloride (PVC) 5%, Poly(methyl) methacrylate known as acrylic (PPMA) 5% polycarbonate (PC) 5%, Polytetrafluoroethylene (PTFE) 5% and Acrylonitrile butadiene styrene (ABS) a common thermoplastic polymer 5%.

Also, a subsample of 56 suspected microplastic particles from dry season sediment samples representing 40% of the total microplastic particles was subjected to FTIR-ATR analysis. The result showed Polyethene (PE) mostly HDPE (High density polyethylene) 30%, Polyethylene terephthalate (PET) 25%, Polypropylene (PP) 15%, Polyamide (PA) 10%, Polystyrene (PS) 10%, Polyvinyl chloride (PVC) 5% and others 5%.

Wet season **Dry Season**

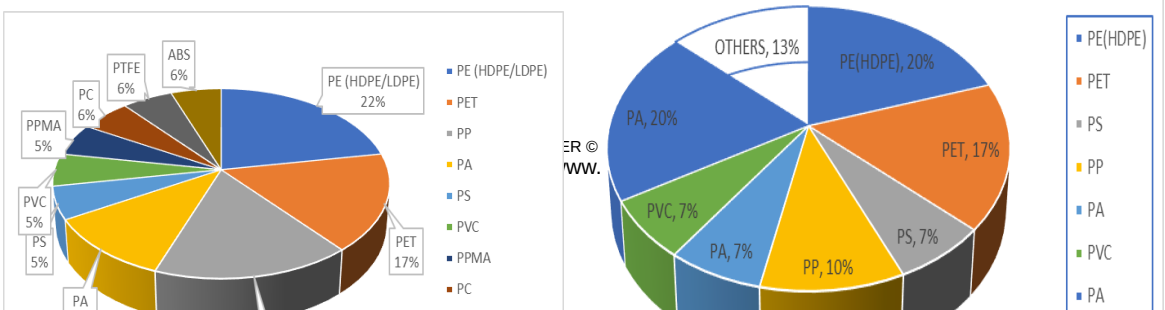

Fig. 6: Percentage abundance of identified Microplastic particles in beach Sediment

The spectra of other particles were also identified including styrene-butadiene rubber, which is an important polymer used in car tire manufacture, Ethyl vinyl acetate (Poly) and Polyurethane (PU), suspected transition metal, ketones, phenols and carbonyls among other product and these made up 5% of the subsamples.

Most of the particles not identified were as a result of weak spectra which is an indication that not all particles that were visualized as plastics were actually plastic. This as noted by Horton et al.,who found that 7% of particles initially identified as microplastic were natural in origin.

A large number of particles could not be identified due to weak spectra or low match factors with the database matching. Measurements of the polymer surfaces from unidentified samples often resulted in spectra with a visible C-H stretching vibration that was obtained in a ratio indicating the presence of a PE chain. Broad and dominating absorption peaks between 1600-900 cm^{-1} are difficult to be identified further identification.

4.0 Discussion

This research work demonstrated the the widespread distribution of microplastics in the Lagos beach, Nigeria. The results showed high abundance of microplastics in the beach sediments. Sites A, B and C are within the Oniru and the Lekki Free Trade Zone within the urban and industrial areas of Lekki – Ajah part of Lagos State. There is also a wide range of microplastics identified which is indicative of the varieties of plastics in use in Lagos and environs. The output of this work will form a baseline for future works and critical for policy reforms and effective control of plastic wastes in Lagos State Nigeria.

The quantification and characterization of microplastics in the sediments of the selected 10 recreational beaches in Lagos, Nigeria, it was observed that microplastics were present in all the beaches. More microplastics were however observed in exposed beaches than the more remote beaches which indicated a progressive decline in microplastic abundance we move towards the farthest beach towards the Refinery.

Pellets were the most abundant in both rainy and dry seasons followed by fragments were the second most abundant shape within the study area. This findings are contrary to the findings in the Microplastics study conducted in Belgium (Claessens et al. 2011), in Singapore's coastal mangrove ecosystems, Nor and Obbard (2014), and in Canadian Lake Ontario nearshore, Ballent et al. (2016), all of which reported fibers as the most common type of prevailing particle.

The predominant size in this study is in the size range of < 2.5mm. This size of microplastics were the most abundant in all the sites and in both season while in terms of colour white colour was the most predominant colours in both seasons.

A wide range of polymers indicative of the different types of microplastics commonly in use were identified in both the dry and rainy seasons. In both instances PE mostly HDPE, PE, PP, PA, PS and PVC were most prevalent.

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