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Microplastics in Marine Sediments from Dar es Salaam Coast: Spatial Distribution and Characterization

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Abstract

The purpose of the research was to determine the spatial distribution and characterization of microplastics in marine sediments of beaches along the Indian Ocean of Dar es Salaam coast. The sediment samples were extracted in triplicate using floatation method followed by digestion of organic debris, then analyzed using At-FTIR spectrophotometer and stereomicroscope. The mean concentrations of microplastics for Kijichi Beach were 700 ± 907 particles/m^2 at 1 cm, 859 ± 839 particles/m^2 at 5 cm and 590 ± 782 particles/m^2 at 10 cm; from Palm Beach were 157 ± 15 particles/m^2 at 1 cm, 130 ± 182 particles/m^2 at 5 cm and 16 ± 0 particles/m^2 at 10 cm; from Coco Beach were 167 ± 155 particles/m^2 at 1cm, 104 ± 100 particles/m^2 at 5 cm, 70 ± 86 particles/m^2 at 10 cm; from Mbezi Beach were 115 ± 108 particles/m^2 at 1cm, 74 ± 82 particles/m^2 at 5 cm and 16 ± 0 particles/m^2 at 10 cm. The microplastics were polypropylene, polyethylene, polyurethane, polyamide, polyvinyl chloride, polyethylene terephthalate, and polytetrafluoroethylene, in the form of fibres, fragments, sponges and pellets. The sediments were confirmed to be contaminated with microplastics with high amount at 1 cm compared to other profile location.

Keywords: Microplastics, spatial distribution, beach sediments.

Introduction

Microplastics (also known as plastic pollutants) are tiny plastic fragments, fibres and granules (Cole et al. 2011), which are either manufactured (primary microplastics) or formed from degradation of larger plastics (secondary microplastics). Primary microplastics include plastic particles that are manufactured as small pellets, beads and fragments, which are purposely made as components of cosmetic products, face wash, toothpaste, exfoliates, deodorant, personal care products and nurdles as raw material in the creation of plastic products (Dekiff et al. 2014). Examples of primary microplastics include acrylic and polyester used commonly as scrubbers to remove rust and worn-out paints, and resin pellets made from polyethylene and polypropylene of different shapes and colours from which plastic moulds are made (Fok et al. 2017). Secondary microplastics originate from the degradation of larger plastic items into smaller plastic fragments once exposed to environments. The degradation of plastics can be through biodegradation, photo-degradation, mechano-chemical degradation or thermo-degradation (Talsness et al. 2009) as well as weathering processes of mismanaged wastes such as discarded plastic materials or from unintentional losses such as fishing nets.

Microplastics have dimensions of 1 µm ≤ x ≤ 5000 µm, and for fibres, a length of 3 µm ≤ x ≤ 15000 µm, where x refers to a measured microplastic diameter. There are different forms of microplastics described as micro-beads, micro-films, micro-fibres, micro-sponges, micro-pellets and micro-fragments (Qiu et al. 2016).

Microplastics can be buoyant, or sink, depending upon composition and density. For instance, polyethylene and polypropylene are low-density plastics and are buoyant, while polyvinyl chloride, polystyrene, polyester, and polyamide are high-density plastics which tend to sink (Cole et al. 2011). However, low density polymers can become high density if there is addition of mineral fillers during production (Vermeiren 2016).

Microplastics have been considered as pollutants in the environment (Cole et al. 2011). About 70–80% of microplastic contaminants originate from land-based sources like beach littering, sewage treatment plants, urban and agricultural runoff, maritime activities (marine aquaculture, shipping, oil drilling), river discharge, atmospheric dust and scrubbers in cosmetics which are then transported by rivers to seas and oceans (Zhang 2017). For example, freshwater systems can become contaminated by microplastics in three ways; effluent discharge from wastewater treatment plants, overflow of wastewater sewers during rain, and escape of sludge from agricultural land (Eerkesen et al. 2015). Storms and freshwater systems carry microplastics to rivers, lakes and oceans (Cole et al. 2011, Browne et al. 2011). They have been found in oceans and beaches and sediments in the form of film, sponges, pellets, irregular fragments and fibers (Browne et al. 2011). The study done by Liang et al. (2022) indicates that microplastics were found in 12 lakes sediments and were found in the range from 17–2644 particles/m^2 with a mean value of 5445 ± 298 particles/m^2. Another study reported that microplastics existed in all seasons and sampling sites with an average abundance of 398 ± 67 particles/m^2 (Rasta et al. 2021).

The interaction of microplastics at the shoreline depends on the presence of some characteristics, for example, bedrock, gravel, sand, mud, vegetation and bioturbation (Mansui et al. 2015). The height at which plastics become stranded depends on wave action, size and weight of particles (Carson et al. 2013). Floating microplastics are cast onto sandy beaches with surface currents and onshore wind and waves. Some microplastic particles are washed back into the sea (Fok et al. 2017). The burying of microplastics inside sediments protect them from washing back into the sea water which indicates that microplastics can be found in the vertical profile of beach sediment as deep as 2.0 m (Turra et al. 2014). The distribution of microplastics in the intertidal zones exhibits dynamic spatial-temporal patterns according to the local geometry and tidal regimes (Thiel et al. 2013).

There has been very little data published regarding microplastic abundance in the coastal sediment of the Indian Ocean around Dar es Salaam. The speciation of microplastics in sediments is not well informed in most studies. Most studies do not report microplastics according to sediment profile, because marine organisms exhibit their life both on top and deep in the sediments (Lattin et al. 2004). In Tanzania, microplastics were reported at levels of 2972 ± 238 particles/m^2 at Kijichi Creek (Mayoma et al. 2020). Since no study showed the distribution of microplastics in sediments, this research was conducted to determine the spatial distribution and characteristics of microplastics in beach sediments.

Materials and Methods

Sampling areas

The sediment samples were collected from the Indian Ocean coast of Dar es Salaam. The coastline of Dar es Salaam is located between latitudes 6°27'S and 7°15'S and longitudes 39°E and 39°33'E, extending about 100 km from the Mpiji River in the north to the Mzinga River in the south. Four beaches were selected for collection of sediment samples; Kijichi Beach, Mbezi Beach (Kawe Beach), Palm Beach and Coco Beach. Kijichi Beach is flooded with storms of rain water through the Mzinga and Kizinga Creeks. The common possible source of microplastics in all four beaches is floating plastic pollutants in the sea water. The possible sources of microplastics in Kijichi Beach are plastic wastes from the domestic, garage and market together with industrial raw materials in Toangoma, Mbagala, Msasani, Gongolamboto and Kigamboni. Mbezi Beach sources of microplastics are plastic wastes and sewages which are directed along the beach area, flood storms through Mbezi Creek which collect plastic wastes from Mbezi Beach urban area, Kawe and Lugaro. Palm Beach receives rain storms through Msimbazi Creek and Ng'ombe Creek. The storms carry plastic wastes from all Msimbazi, Jangwani, Buguruni, Magomeni, Mwananyamala, Sinza and Ubungo. Moreover, there are plastic industries in Temeke which are sources of microplastic pellets. The main possible sources of microplastics in Coco Beach are floating plastic wastes in sea water from other parts of the Indian Ocean Coastal region, sewages directed into sea water, and dumped plastic wastes along the beach.

Collection of sediment samples

Sediment samples from beaches were collected from 29th September 2020 to 23rd October 2020. The sampling of sediment samples was conducted using the standardized protocol for monitoring microplastics in sea water (Frias et al. 2019). The points in each site (beach) were located at a distance of 100 m from one point parallel to the water edge (Figure 1). The high tide area was preferred for the collection of samples because there was an accumulation of debris that marks the maximum extent of water height and where microplastics are expected to be most dense, without much action to carry them away (Figure 2). The sampling design was stratified random at 1 cm, 5 cm and 10 cm depths. The purpose of collecting samples at 1 cm, 5 cm and 10 cm was to find out how the microplastic concentrations differ with sediment profile due to behavioural effects of sea water tides and winds (Carson et al. 2013, Turra et al. 2014, Mansui et al. 2015, Fok et al. 2017). Seven sample points were allocated at Kijichi, six sampling points at Palm Beach, five sampling points at Coco Beach, and four sampling points at Mbezi Beach (Kawe Beach). Three samples were taken from each sampling point in each area, making a total of 66 samples: 21 samples from Kijichi Beach, 18 samples from Palm Beach, 15 samples from Coco Beach, and 12 samples from Kawe Beach.

Extraction of microplastics from sediments

The extraction of microplastics in sediments was performed using the Laboratory Methods for the Analysis of Microplastics (Frias et al. 2019). The collected sediment samples were air dried in the laboratory until a constant weight. Then samples were sieved on a mesh (5 mm) so that the floatation could be handled more easily. A sediment sample (200 g) was weighed accurately in beam balance. The sample was placed in a 1000 mL beaker, then 300 mL of 4.4 M NaCl solution was added followed by quick stirring for floatation of microplastics for 2 min. The mixture was left to settle down for 2 min to allow decantation and particles less than 1.2 g/cm^3 (the density of NaCl) to float. Later, the solution part containing debris and microplastics was decanted in a 500 mL beaker. Then the solution of 3.3 M NaI (density of 1.8 g/cm^3) was added to the remainder of the decantation in order to obtain microplastics with a density less than 1.8 g/cm^3. The two salts were used in the extraction of microplastics from the same sample in order to minimize costs. The extracts using NaCl and NaI were mixed to form one component, followed by filtration using Whatman filter paper (a qualitative grade 1 filter paper with a pore size of 11 µm). The microplastics in the filter paper were air-dried and then collected in a 250 mL beaker ready for the next stage.

Figure 1: Map showing sampling points at Mbezi Beach, Coco Beach, Palm Beach and Kijichi Beach.

Figure 2: Sampling sites: (1) Palm Beach (2) An area of high and low tide in Coco Beach.

Cleaning of microplastics by oxidation

The Fenton solution, which is a mixture of 35% H_2O_2 (20 mL) and 20 mL hydrated iron(II) sulphate ($FeSO_4.7H_2O$) solution, was mixed with the mixture of microplastic solids and debris in a 250 mL beaker, followed by warming at 75 °C for 20 min to remove non-plastic organic materials. Then, the mixture was filtered using Whatman filter paper (11 µm pore size) to separate microplastics from the solution portion. The collected microplastics on the Whatman filter paper were cleansed several times with distilled water, and then left to dry in Petri dishes.

Analysis of microplastics

Analysis of microplastics involved the determination of size, enumeration, and identification of the microplastics according to the methods described in the Laboratory Methods for standardized protocol for monitoring microplastics in seawater (Frias et al. 2019).

Determination of number and size of microplastics in marine sediments

Determining the number involved counting the microplastics. Large and visible microplastics (1000–5000 µm) were counted using the help of a hand lens (5 x magnification) and a scalpel. The microplastics of sizes less < 1000 µm were placed in a Petri dish, and then a stereo binocular microscope (10x magnification) was used to visualize the particles and count their numbers. All microplastics enumeration from sediments was recorded as the number of particles/m^2. Microplastics size analysis was done using sieves of different pore size; the limit of sieves was 100–5000 µm. Fibres were measured using a veneer calliper with a help of a hand lens and stereomicroscope. In this study, microplastics were grouped into sizes of 100–5000 µm for fragments and sponges, 1000–5000 µm for pellets, while 100–15000 µm for fibres (Qiu et al. 2016).

Identification of microplastics

Identification of the microplastics in sediments samples was performed using the Attenuated Fourier Transform Infrared Spectrophotometer instrument (At-FT-IR, Bruker, Massachusetts, USA) at the Chemistry Laboratory, University of Dar es Salaam. Standards of polypropylene (PP), polyethylene (PE), polyvinyl chloride (PVC), polystyrene (PS), polyethylene terephthalate (PET), polyurethane (PU) and polyamide (PA) microplastics were run in the At-FT-IR instrument to obtain their spectra prior to the microplastics sample analyses. The resolution was set at 4 cm^{-1}. The attenuated total reflection (ATR) diamond crystal was cleaned with acetone and a background scan was performed between each sample. Each sample was compressed against the diamond with a force of at least 80 N to ensure good contact between the sample and the ATR crystal, according to the manufacturer's specifications. The At-FT-IR instrument was used to collect spectra from 4000 cm^{-1} to 450 cm^{-1} at a data interval of 1 cm^{-1}. The spectra were collected using Microlab PC software in transmittance mode. The absorption bands of microplastics which were identified using a peak height algorithm within the Bruker software were recorded and compared to the absorption bands of each polymer reported in the literature and the standards (Junga et al. 2018).

Recovery of microplastics from sediments

Polyethylene (which is less dense than NaCl, 0.98 g/cm^3), polyethylene terephthalate (which is denser than NaCl, 1.38 g/cm^3) and polyvinyl chloride (denser than NaCl, 1.38 g/cm^3) microplastic pellets were selected for the recovery study. The polyethylene pellets (20 particles) were spiked in sand sediments (200 g), and then mixed thoroughly to get uniform distribution of particles. The PE was extracted from the sediments in triplicate using a solution of 4.4 M NaCl (300 L) in a 1000 mL beaker, followed by stirring, settling, decantation, filtration, drying, and counting similar to normal samples. The process was repeated for PET, and PVC, except that 3.3 NaI solution was used instead of NaCl.

Data analysis

Data analysis was done using analysis ToolPak-VBA in excel for mean, standard deviation and range. One way Analysis of Variance (ANOVA) was used for comparison of microplastics in different sites, site sampling points and depths.

Results and Discussion

Abundance and distribution of microplastics in beaches

Microplastics were found in the sediments of all the four beaches (Table 1). All concentrations of microplastics in this study have been reported as mean ± standard deviation. The concentrations of microplastics in sediments from the four beaches were 245 ± 249 particles/m^2. Microplastics were found in the sampling points and depths as shown in Table 1. Microplastics ranges at the study areas were 41 ± 27–2195 ± 396 particles/m^2 in samples from Kijichi Beach, 26 ± 0–314 ± 158 particles/m^2 in samples from Palm Beach, 44 ± 33–272 ± 206 particles/m^2 in samples from Coco Beach, 13 ± 4–199 ± 95 particles/m^2 in samples from Mbezi Beach. Microplastics levels depth-wise at Kijichi Beach were 700 ± 907 particles/m^2 at 1 cm, 859 ± 839 particles/m^2 at 5 cm, and 590 ± 782 particles/m^2 at 10 cm. Similarly, microplastics levels at Palm Beach were 157 ± 156 particles/m^2 at 1 cm, 130 ± 182 particles/m^2 at 5 cm and 16 ± 0 particles/m^2 at 10 cm. Furthermore, microplastics levels at Coco Beach were 167 ± 155 particles/m^2 at 1 cm, 104 ± 100 particles/m^2 at 5 cm and 70 ± 86 particles/m^2 at 10 cm. The microplastics levels in samples from Mbezi Beach were 115 ± 108 particles/m^{2}at 1 cm, 74 ± 8 particles/m^2 at 5 cm, 10 ± 0 particles/m^2 at 10 cm. There was a significant difference (ANOVA one way, $p < 0.05$, df = 167) between sampling points in all the sites. There was also a significant difference (ANOVA one way, $p < 0.05$, df = 167) between microplastic levels in sediment depths.

The previous reports on microplastics in sediments from studies done along the coast of the Eastern Gulf of Thailand showed concentrations of microplastics in the range of 400 ± 566–1698 ± 1252 particles/m^2 (Jualong et al. 2021). Another study in Tanzania for microplastics in Mtoni Kijichi Creek indicated microplastic concentrations of 2972 ± 238 particles/m^2 dry weight and at Mission Cross Beach 589 ± 99 particles/m^2 (Mayoma et al. 2020). The results of this study indicate that microplastics were found in different depths and different locations along the beach with different concentrations. The distribution might have been caused by recurring on shore ocean wave currents and winds which cause sediments to burry microplastics deeper, differences of some geographical physical features like the presence of bed rocks, gravel, mud, vegetation, differences in densities of microplastics, and some human activities done along the beach like dumping of wastes, beach refreshments (Carson et al. 2013, Fok et al. 2017). Moreover, in beaches like Palm Beach, Kijichi Beach and Mbezi Beach, the points that were close to the river creek mouth had high concentrations of microplastics; for example at point 5 in Palm Beach, point 1 in Mbezi Beach and point 7 in Kijichi Beach (Table 1), which might be due to interactions of tidal waves and river water flow (Lattin et al. 2004).The results of this study are similar to those observed in other studies like Southern Caspian Sea Coasts where sediment concentrations of microplastics were 398 ± 67 particles/m^2 dry weight (Rasta et al. 2021). Also, the concentrations of microplastics in sediments from 12 lakes in the Tibetan plateau in China were 544 ± 298 particles/m^2. In the Tibetan plateau, the 12 lakes had microplastics in the range of 17–2644 particles/m^2, there was no significant difference (ANOVA one way, $p > 0.05$) (Liang et al. 2022). In this study, it was found that there was a significant difference (ANOVA one way, $p < 0.05$, df = 167) in microplastics concentrations among the four beaches. The concentrations of microplastics were 613 ± 753 particles/m^2 at Kijichi Beach, 189 ± 107 particles/m^2 at Palm Beach, 90 ± 218 particles/m^2 at Coco Beach and 90 ± 81 particles/m^2 at Mbezi Beach. The four beaches had differences in concentrations of microplastics in sediments because of some present geographical features. Kijichi Beach receives some water storms during the rainy season from the Mzinga and Kizinga Creeks, and also it is a bay which is filled with some aquatic vegetation. Palm Beach receives water storms from Msimbazi Creek. Coco Beach does not have heavy floods towards it. Mbezi Beach receives water storms from Mbezi Creek. There are sand ridges which act as sinks and barriers for microplastics which are carried by ocean currents to reach the high tide in the beach.

Table 1: Mean and standard deviation (s.d.) of microplastics concentrations (Particles/m^2 ± s.d.) in sediments for Kijichi Beach, Palm Beach, Coco Beach and Mbezi Beach

Point	n	Depth (cm)		Kijichi Beach	Palm Beach	Coco Beach	Mbezi Beach
1	3	1		118 ± 25	208 ± 45	52 ± 28	266 ± 3
	3	5		92 ± 45	ND	336 ± 23	132 ± 6
	3	10		52 ± 5	ND	6 ± 3	ND
			Point mean	87 ± 33	208 ± 0	98 ± 124	199 ± 95
2	3	1		664 ± 22	82 ± 14	418 ± 31	100 ± 85
	3	5		458 ± 19	50 ± 42	126 ± 26	ND
	3	10		660 ± 560	16 ± 5	ND	ND
			Point mean	594 ± 118	49 ± 33	272 ± 206	100 ± 00
3	3	1		2648 ± 214	196 ± 33	218 ± 31	10 ± 8
	3	5		2026 ± 19	14 ± 14	36 ± 11	16 ± 6
	3	10		1912 ± 158	ND	168 ± 40	ND
			Point mean	2195 ± 396	105 ± 128	141 ± 94	13 ± 4
4	3	1		642 ± 59	6 ± 2	66 ± 8	82 ± 25
	3	5		860 ± 141	252 ± 16	ND	ND
	3	10		306 ± 36	ND	ND	10 ± 8
			Point mean	603 ± 279	129 ± 174	66 ± 0	46 ± 51
5	3	1		74 ± 8	426 ± 19	80 ± 17	
	3	5		ND	202 ± 36	16 ± 6	
	3	10		ND	ND	36 ± 11	
			Point mean	74 ± 0	314 ± 158	44 ± 33	
6	3	1		62 ± 19	26 ± 8		
	3	5		ND	ND		
	3	10		20 ± 16	ND		
			Point mean	41 ± 27	26 ± 0		
7	3	1		694 ± 65			
	3	5		ND			
	3	10		ND			
			Point mean	694 ± 0			

Key: ND = not detected; n = number of sediment samples for microplastic extraction.

Physical properties of microplastics in beaches

The microplastics in the form of fibres, fragments, pellets and sponges were observed in sediment samples from all the four beaches with size ranges of 100–5000 µm for fibres, fragments and sponges, while pellet sizes ranged from 1000 to 5000 µm. Sponges were found to be the most abundant of all the forms of microplastic particles (38.87%) in the beach sediments followed by fragments (27.47%), pellets (23.40%) and last fibres (10.27%). The sponges were polystyrene plastics (float in water) which were commonly used as cushion of breakable materials, while most fragments were polyethylene and polypropylene (all float in water) which form plastic goods that were in daily use. Most pellets were polyethylene or polyethylene terephthalate for industrial plastic raw materials. The different forms of microplastics had various concentrations in the depths of 1 cm, 5 cm and 10 cm (Table 2 and Figure 3).

The distribution of microplastics according to depth (Table 2) has shown that that fragments were abundant at 5 cm (42.41% of total fragments) and less at 10 cm (22.96%) whereas fibres were more abundant at 1 cm (44.1% of total fibres) and less at 10 cm (23.7%). Pellets were more abundant at 5 cm (48.48% of total pellets) and less at 1 cm (18.7%). Moreover, sponges were more abundant at 1 cm (40.08% of total sponges) and less at 10 cm (27.75%) (Table 2).

Table 2: Concentrations of different forms of microplastics and their distribution in Kijichi Beach, Palm Beach, Coco Beach and Mbezi Beach

1. Mean ± s.d. (particles/m^2) and percentage of forms of microplastics in beach

	D/cm	Kijichi	Palm	Coco	Mbezi	D mean	Ptd%
Fragments	1	96 ± 103	44 ± 46	16 ± 15	31 ± 46	75 ± 35	34.62
	5	169 ± 276	29 ± 18	25 ± 27	6 ± 3	57 ± 12	42.41
	10	88 ± 70	24 ± 0	12 ± 11	ND	41 ± 41	22.96
Fibres	1	56 ± 67	28 ± 18	ND	5 ± 1	30 ± 16	44.1
	5	42 ± 51	15 ± 14	4 ± 0	4 ± 0	16 ± 18	32.18
	10	40 ± 51	8 ± 0	ND	ND	24 ± 23	23.76
Pellets	1	46 ± 37	9 ± 8	27 ± 18	4 ± 0	22 ± 19	18.7
	5	166 ± 179	38 ± 20	19 ± 20	ND	80 ± 0	48.48
	10	130 ± 173	ND	21 ± 28	ND	77 ± 0	32.83
Sponge	1	201 ± 256	46 ± 49	61 ± 63	29 ± 39	79 ± 0	44.2
	5	164 ± 226	27 ± 33	8 ± 4	16 ± 15	74 ± 0	28.14
	10	202 ± 280	ND	10 ± 0	ND	136 ± 0	27.75

2. Depth percentage distribution of forms of microplastics

Depth	1 cm		5 cm		10 cm	
	Particles/m^2	%	Particles/m^2	%	Particles/m^2	%
Fragments	75	36	41	23	41	14.65
Fibres	30	14	16	9	24	8.51
Pellets	22	10	74	40	76	26.76
Sponge	84	41	54	29	141	50.09

Key: D = Depth; PtD = Point depth; ND = Not detected; s.d. = Standard deviation.

Figure 3: Microplastics in Kijichi Beach. In Figure C, number 1 are sponges, number 2 are fragments, number 3 are fibres number 4 are pellets (nurdles), all found at 1 cm.

Comparing the distribution according to depths of all forms of microplastics has shown that sponges were more abundant at 1 cm (40.08% of all forms of microplastics at 1 cm), followed by fragments (35.58%). Pellets were more abundant at 5 cm (40.04% of all the forms of microplastics at 5 cm), followed by sponges (28.5%). Sponges were also dominant at 10 cm (50.09% of all the forms of microplastics at 10 cm) followed by pellets (Table 2).

The literatures reported that the microplastics in sediments from Caspian Sea were 95.09% fibres and 3.4% fragments (Rasta et al. 2021), Tibetan Plateau lakes in China had 300–5000 µm fragments, where those in range of 1000–2000 µm (35.58% fragments) were the most frequent (Zhang 2017), Sri Tujuh Beach had 1000–5000 µm fragments (Bitlus et al. 2020). Moreover, it was reported by Mayoma et al. (2020) that fragments were 39% of the all microplastics and pellets were 33% of all microplastics in East African Beaches. The sources of the forms of microplastics that have been identified in this study were probably from applied plastics and some from industrial raw materials. For example, sponges (foam plastics) were dominant in all the locations because of the disposal of plastics used as cushions, fragments originated from plastics like carpets, films, plastic bags, soft drink bottles, jugs, buckets, food packages, cups, pipes and curtains while pellets were raw materials for plastic manufacturing industries.

Identification of microplastics

The polymer identity of the particles was determined by using the absorption peaks mainly in the functional group region (4000–1500 cm^{-1}) and in the finger print region (less than 1500 cm^{-1}) of the FTIR spectrum, examples of absorption spectra of microplastics found in sediments (Figure 4).

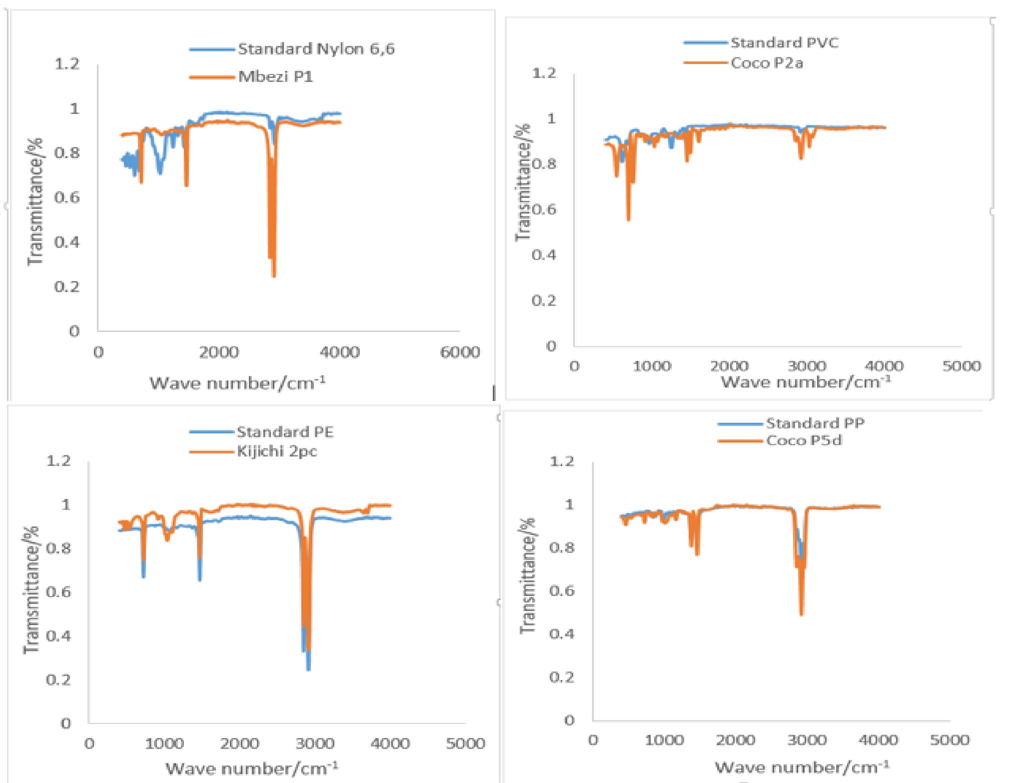

Figure 4: Superimposed spectral absorptions of microplastics in sediments for nylon 6,6, PVC, PE and nylon PP.

Chemical characterization of microplastics in samples from beaches

Seven types of microplastics identified were polyethylene, polypropylene, polystyrene, polyvinyl chloride, polyamides (nylon 6,6) polyethylene terephthalate and polytetrafluoroethylene. Polyethylene was the most abundant (53.75% of the total microplastics), followed by polypropylene (15.44%), polystyrene (13.85%), polyethylene terephthalate (11.66%), polyamide (3.1%), polyvinyl chloride (1.9%), and the last was polytetrafluoroethylene (0.3%) (Table 3 and Figure 5).

The study by Zhang (2017) in Tibetan Plateau lakes for sediment microplastics indicated that polyamide and polyethylene terephthalate were 55.97% and 33.77%, respectively, and the source was attributed to textiles. Another study in Sri Tujuh Beach by Bitlus et al. (2020) gave polyethylene 6 particles, polyethylene terephthalate 5 particles and polyamide 2 particles. Polyamide was the most abundant in sediment beaches along the coast of the eastern Gulf of Thailand where the abundance was 46.87% of all the identified microplastics. Other identified microplastic polymers were polyethylene terephthalate, polyethylene, polypropylene, polystyrene, and polytetrafluoroethylene (Jualaong et al. 2021). The polyethylene and polypropylene were found to be the most abundant in this study because their densities are smaller than sea water which leads to their floatation and deposition on the offshore easily (Cole et al. 2011). Domestic goods made of polyethylene such as shopping bags, film wrapping materials, bottles, buckets, cups, and pipes are very common in Dar es Salaam markets. Polypropylene (used for crop bags in markets) and polyamides were probably the sources of textile fibres in sediments. The soft drink bottles used daily were probably the sources of polyethylene terephthalate in sediments.

Table 3: Types of microplastics in sediment samples, concentrations (mean ± standard deviations) and their distribution at Kijichi Beach, Palm Beach, Coco Beach and Mbezi Beach

Chemical type	Depth/cm	Kijichi Beach	Palm Beach	Coco Beach	Mbezi Beach
		Concentration, Particles/m^2			
PTFE	1	84 ± 0	ND	ND	ND
	5	ND	ND	ND	ND
	10	ND	ND	ND	ND
PP	1	162 ± 198	27 ± 34	45 ± 30	ND
	5	87 ± 107	70 ± 59	17 ± 25	ND
	10	62 ± 93	20 ± 0	31 ± 23	ND
PE	1	65 ± 55	58 ± 70	72 ± 23	24 ± 6
	5	361 ± 473	25 ± 20	45 ± 80	96 ± 0
	10	97 ± 66	12 ± 0	6 ± 4	ND
PS	1	158 ± 199	61 ± 99	65 ± 111	47 ± 46
	5	235 ± 351	94 ± 110	16 ± 17	24 ± 8
	10	142 ± 223	ND	ND	ND
PA	1	ND	40 ± 0	ND	4 ± 0
	5	ND	4 ± 0	4 ± 0	ND
	10	ND	ND	ND	ND
PVC	1	ND	72 ± 0	60 ± 28	ND
	5	1120 ± 0	ND	ND	ND
	10	ND	ND	ND	ND
PET	1	ND	122 ± 20	ND	ND
	5	20 ± 0	148 ± 0	ND	ND
	10	ND	ND	ND	ND

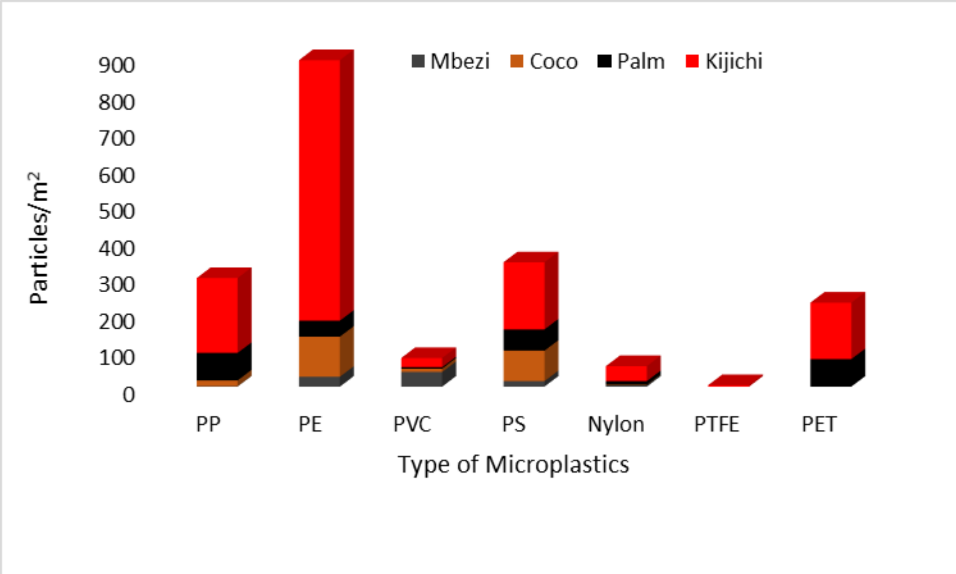

Figure 5: Comparison of type of microplastics in Dar es Salaam Beach sediments.

Conclusion

From the study results of the four sites, microplastics were found in all the areas of study in Dar es Salaam, and Kijichi Beach had the highest concentrations. All the sampling points had microplastics with different concentrations with high concentrations at 1 cm. The beach sediments were contaminated with microplastics which had the form of fragments, fibres, sponges, and pellets. The types of microplastics identified were polypropylene, polyvinyl chloride, polyethylene terephthalate, and polytetrafluoroethylene. The results indicated that the coastal marine region was highly polluted with microplastics whose sources might be more attributed to anthropological and industrial activities in the urban areas together with the influence of rain storms. However, more studies should be done to determine micro-toxins associated with microplastics in beach sediments.

Declaration of conflict of interest

The authors declare that there is no conflict of interest.

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