Abundance and Distribution of Microplastics in Fish and Sediments from Coastal River Watersheds of Dar es Salaam, Tanzania

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Abstract

Different reports indicate that microplastics have been environmental pollutants which are engulfed by aquatic organisms also are carriers of other toxic chemicals. This study aimed to characterize and determine the spatial distribution of microplastics in sediments and fish in Dar es Salaam. The study had to indicate the extent of plastic pollutants in the urban watersheds. Fish and sediment samples were collected from river watersheds and ponds. Gastrointestinal parts were digested using 10% KOH and incubated at 65 °C for 24 hours while sediment samples were extracted using the floatation method in 4 M NaOH and 3 M NaI solutions. The identity of microplastics was determined by an attenuated Fourier transform infrared spectrophotometer. The concentrations of microplastics were 94 ± 24 particles/kg for fish samples from River Msimbazi watershed ponds and 46 ± 16 particles/kg for fish samples from River Mzinga watershed ponds. The concentrations of microplastics in sediments were: 64 ± 35 particles/m^2 for the River Mzinga watersheds and 25 ± 18 particles/m^2 for River Msimbazi watersheds. The microplastics observed were polypropylene, polyethene, polyurethane, polyamide, polyvinyl chloride, polyethene terephthalate, and polytetrafluoroethylene. The microplastics were in the form of fragments, sponges, and fibres. The results confirmed that fish living in river watershed ponds in Dar es Salaam were exposed to microplastics and that sediments had microplastics. Further studies need to be performed to find out micro-pollutants adsorbed by microplastics in the river watersheds.

Keywords: *Dar es Salaam River watersheds; Microplastics; pond fish; spatial distribution; sediments*

INTRODUCTION

World plastic production has increased from 1.7 million tons to 348 million tons which has led to approximately 14 million tons of plastics being dumped as waste which degrade into microplastics (Mistri, 2022). Large proportions of plastic wastes are mismanaged so they enter the aquatic environments where they evolve into microplastics via progressive fragmentation

(Gewart, 2015; Zhang, 2017; Wang 2018; Adams *et al.,* 2021). Microplastics have a size which is less than 5 mm which can be primary in origin (purposely made) or secondary in origin (obtained through the degradation process) (Carson, 2013; Vermeiren *et al.,* 2016). Microplastics have been observed in freshwater and marine sediments, for example in the River Thames catchment in the United Kingdom, sediment samples had microplastics with an average abundance of 165 particles/kg (Tibbetts *et al.,* 2018). Microplastics in rivers remain in the watersheds during physical transport by stormwater while some are carried into the ocean.

Microplastic pollution in water and sediments has a potential life impact on aquatic organisms. Microplastics can be ingested by aquatic organisms like crustaceans and fish because of their small size (Oladejo, 2017; Turra *et al.,* 2014; Wang, 2018). Studies have shown microplastic presence in the fish gut, for example, fish from the northern Bay of Bengal in Bangladesh had microplastics with a range of 5.80 ± 1.4−8.72 ± 1.54 particles/kg (Hossain *et al.,* 2019). Animals exposed to microplastics in a laboratory setting have shown several adverse effects like histological alterations, lesions in the gastrointestinal tract, intestinal inflammation, neurotoxicity, oxidative stress, damage, immuno-regulation, feeding behavioural change, and developmental alterations (Jovanovic, 2017).

Most studies about microplastics in fish and sediments in African regions have been performed in seawater compared to fresh water like lakes, dams, ponds, and rivers. That means there is little information documented about microplastic contamination of freshwater bodies in many countries in Africa. Tanzania is one of the African countries that produce and utilize plastic goods in large amounts. Plastic waste has been a current problem in Tanzania's urban regions. Dar es Salaam City in Tanzania is one of the regions that are much affected by the disposal of plastic wastes in its water bodies. Solid waste generation that includes plastics has been increasing in Dar es Salaam City from less than 2000 tons per day in 2011 and the waste composition is 27% plastics (Fassin et al. 2017). This leads to the occurrence of microplastics in water bodies (sea and river water). Microplastics in river streams are carried to the ocean but during the rainy season are also distributed in the watersheds and watershed ponds where they can be engulfed by pond fish (Cole et al. 2011). This study was conducted to assess the abundance and distribution of microplastics in freshwater fish and sediments from river watersheds of Dar es Salaam.

MATERIALS AND METHODS

Sampling Areas

The research was carried out in Dar es Salaam river watersheds and their ponds. 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. Samples of sediments for microplastic determination were collected from the River Mzinga and River Msimbazi watersheds (Figure 1), while samples of fish were collected from ponds found in the watersheds of Dar es Salaam. River Mzinga and Msimbazi were selected for study because of various anthropological activities and rainstorms accompanied by plastic wastes (Figure 2).

Figure 1: A Map showing the locations of River Msimbazi and River Mzinga

Figure 2: Plastic waste along River Msimbazi Watersheds in Dar es Salaam

Methods of Sample Collection

Fish samples from River Mzinga were collected at Toangoma ward while those from River Msimbazi were collected between Jangwani Valley and Kijitonyama Valley during the dry season. Three ponds were selected for the collection of fish samples from each river watershed using fish nets. A total of 32 fish samples were collected from the river watersheds: 18 fish samples from River Mzinga and 14 fish samples from River Msimbazi ponds. The samples were stored in an ice box and later were kept frozen in the laboratory. On the next day, the gastrointestinal parts (from the buccal cavity to the anal part) were removed and then separately frozen ready for microplastic determination.

The samples of sediments from the River Mzinga and River Msimbazi watersheds were collected during the dry season. Eight sampling points were identified along River Msimbazi; Buguruni Mivinjeni A, Buguruni Mivinjeni B, Kigogo Bridge, Car wash bridge area, Jangwani truck haulage area, Jangwani bridge area and Jangwani opposite to Muhimbili National Hospital area, Jangwani and Mwananyamala areas. For the case of River Mzinga, ten sampling points were identified at Zakiem Bridge, Car wash, Zakiemu Valley, Gardening, Mpangule, Zakiem, Mbagala Kuu, and Mbagala Mountain, Kibonde Maji A and Kibonde Maji B. The river sediment sampling points were at a distance of 100 m from one point and the next. The samples were collected downstream toward the ocean. At each sampling point, 1000 g of sediment sample was collected in the area of 50 cm x 50 cm, and at 1 cm and 5 cm depth respectively, using shovels, and were then kept in aluminium foil. The number of sediment samples collected from River Mzinga were 20 samples and from River Msimbazi were 16 samples.

Extraction

Extraction of Microplastics in Fish

The reagents (potassium hydroxide and sodium iodide salts) which were used in the extraction of microplastics were Analar compounds which were purchased from Chem Precur Company Limited. The gastrointestinal parts were placed in a 250 mL beaker then 150 mL of 2 M KOH (10% KOH) was added (Hermsea, 2018). The mixture of gastrointestinal parts and 2 M KOH in a beaker was then covered with aluminium foil to avoid contamination from outside and then warmed in a water bath at 64 °C for about 24 hours. The warmed mixture containing organic matter and other solid particles was left to cool followed by filtration using Whatman filter paper with the help of a filter pump. The particles in filter paper were collected in a 250 mL beaker, and then 50 mL of 3.3 M NaI solution was added for floatation of microplastics. The upper portion was decanted in a beaker followed by filtration using the Buchner funnel fitted with Whatman filter paper (a qualitative grade 1 filter paper with a pore size of 11 µm). The microplastics were preserved in vials for analysis using a stereomicroscope and an Attenuated Fourier Transform Infrared Spectrophotometer (At-FT-IR).

Extraction of Microplastics in Sediments

The extraction of microplastics in sediments followed manuals (Frias et al. 2019). The collected sediment samples were air dried in a laboratory until a constant weight. Then samples were sieved on a mesh (5 mm) so that the floatation could be handled more easily. An accurately weighed sediment sample (200 g) was placed in a 1000 mL beaker, thereafter, 300 mL of 4.4 M NaCl solution was added followed by a quick stirring for floatation of microplastics for 2 min. The mixture was left to settle down for 2 min to allow 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. A total of 300 mL of 3.3 M NaI (density of 1.8 g/cm^3) was then added to the remainder of the decantation 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 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 on the filter paper were air-dried and collected in a 250 mL beaker ready for the next stage.

Recovery of Microplastics from Sediments

Polyethene (which is less dense than NaCl, 0.98g/cm^3), polyethene 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 200 g sand sediments and then mixed thoroughly to get a uniform distribution of particles. The PE was extracted from the sand sediments using a solution of 4.4 M NaCl (300 L) in a 1000 mL beaker, followed by stirring, settling, decantation, filtration, drying, and counting. PETE and PVC were extracted using 3.3 M NaI solution because of their high density compared to NaCl solution. The process of extraction was done in triplicates. Microplastic recovery was 95% for PE, 80% for PVC, and 100% for PETE. That showed that the method was adequate for the extraction of microplastics.

Recovery of Microplastics from Fish

Fish from Farmers were collected for laboratory quality assurance of microplastic extraction. Gastrointestinal parts of the fish were accurately weighed and then spiked with selected microplastics (polyvinyl chloride, polyethylene and polyethylene terephthalates). The gastrointestinal parts were placed in a 250 mL beaker then 150 mL of 2 M KOH (10% KOH) was added. The procedure of extraction was the same as that of section 2.3.1. Microplastic recovery was 85% for PE, 77% for PVC and 91% for PETE. The results showed that the method was adequate for the extraction of microplastics from fish.

Analysis of Microplastics

Analysis of microplastics involves the determination of size, enumeration, and identification of microplastics (Frias *et al.* 2019).

Determination of Number and Size of Microplastics in Fish and Sediments

Large and visible microplastics (1000–5000 µm) were counted using the help of a hand lens (5x magnification) and a scalpel. The microplastics less < 1000 µm were placed in a Petri dish, and then a stereo binocular microscope (10 x magnification) was used to visualize the particles and count their numbers. All microplastic enumeration was recorded as the number of particles/kg for fish and particles/m^2 for sediments, according to the microplastics analysis protocol (Frias *et al.* 2019). It has to be noted that all sediment samples were collected at 0.5 x 0.5 m^2 while fish samples were weighed then the wet weights were recorded. Microplastic size analysis was performed using sieves of different pore sizes. Fibres were measured using a veneer calliper with the help of a hand lens and stereo microscope. In this study, microplastics were grouped into sizes of 100–500 µm, 500–1000 µm, and 1000–5000 µm for all fragments, fibers and sponges.

Identification of Plastics

Identification of microplastics was performed using an Attenuated Fourier Transform Infrared Spectrophotometer (At-FT-IR, Bruker, Massachusetts, USA), available at Chemistry Laboratory, University of Dar es Salaam. Standards of polypropylene (PP), polyethene (PE), polyvinyl chloride (PVC), polystyrene (PS), polyethene terephthalate (PET), polyurethane (PU) and polyamide (PA) microplastics were run in the At-FT-IR instrument to obtain their spectra before the analyses of microplastics samples. The resolution was set at 4 cm^{-1}. The Attenuated total reflection (ATR) crystal was cleaned with acetone and a background scan was performed between each sample. Microplastic particles which were analysed for identity were extracts of 62 sediment samples and 18 fish samples. Each particle was compressed against the diamond to ensure good contact between the particle and the ATR crystal, according to the manufacturer's specifications. The At-FT-IR instrument collected spectra from 4000 cm^{-1} to 450 cm^{-1} at a data interval of 1 cm^{-1}. The spectra were collected using Micro lab computer 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 standard spectra.

Data Analysis

Excel Analysis ToolPak was used for summarizing the raw data into means, standard deviation and range of microplastic concentrations in sediments and fish samples. The one way-ANOVA was used to compare the mean concentrations of sediment microplastics from different sampling points, depths and sites where the number of laboratory bench sediment samples (n); for River Mzinga, n = 62 and River Msimbazi, n = 42.

RESULTS AND DISCUSSION

Microplastic Occurrence in Watershed Sediments and Fish

Microplastic Occurrence in Watershed Sediments

The concentration (mean ± standard deviation) of microplastics in sediments from River Mzinga at 1 cm was in the range of 14 ± 0 particles/m^2 to 106 ± 0 particles/m^2, while at 5 cm was in the range of 14 ± 9 particles/m^2 to 128 ± 11 particles/m^2. The overall average concentration of microplastics in the River Mzinga watersheds was 64 ± 35 particles/m^2. The statistical analysis (one way-ANOVA) indicated that there was no significant difference in mean concentration between depths ($p = 0.38$) also there was no significant difference between points in River Mzinga ($p = 0.9$).

The concentration (mean ± standard deviation) of microplastics in River Msimbazi at 1 cm was in the range of 6 ± 0 particles/m^2 to 54 ± 8 particles/m^2 while at 5 cm was in the range of 6 ± 0 particles/m^2 to 86 ± 8 particles/m^2. River Msimbazi watersheds had an overall average concentration of 26 ± 18 particles/m^2 (Table 1). The statistical analysis (one-way ANOVA) indicated that there was a significant difference in mean concentration between the depth (df = 31, $p = 0.01$) and that there was no significant difference in the mean concentration of microplastics between points in River Msimbazi ($p = 0.9$).

The mean concentration of microplastics in watersheds (River Mzinga and River Msimbazi) was 45 ± 27 particles/m^2. The statistical analysis (one-way ANOVA) indicated that there was no significant difference in mean concentration ($p = 0.06$) between River Mzinga and River Msimbazi.

The occurrence of microplastics in all sampling points in River Mzinga and River Msimbazi is an indication that watersheds in Dar es Salaam urban being contaminated by microplastics. There were anthropological activities like plastic waste disposal, agricultural practices, motor vehicle garages and plastic goods industries which were performed near and far from the river valleys. Rainstorms collect plastic wastes into River Mzinga valley from Mbagala, Toangoma and Mzinga urban areas which are highly populated by human settlements and industries. This also was the same with River Msimbazi where there were various anthropological activities which were performed along the valley of Msimbazi (Figure 2). Rainstorms collect plastic wastes into River Msimbazi from various industrial, markets, garages and populated domestic areas of Buguruni and Chang'ombe. Msimbazi Valley extends to Jangwani Valley which receives plastic wastes from Magomeni populated settlements and River Ng'ombe which passes through Mwananyamala Valley. Either the differences in geographical physical features along the river had a great influence on retaining microplastics at the point, for example, River Mzinga has a large land plain which has many bushes and grasses. The results for concentration levels of microplastics in river watershed sediments in this study are similar to those reported in urban rivers from other parts of the world. For instance, the study on River Thame and four of its tributaries in Birmingham city in the UK reported that all sediment samples were found to contain microplastics with an average abundance of 165 particles/kg (Tibbetts *et al.,* 2018). Li et al., (2019) also reported that microplastic concentration in river estuaries in Maowei Sea ranged from 520 ± 8 to 940 ± 17 items/kg. Furthermore, Hitchcock and Mitrovic, (2019) reported that microplastics were in the pattern in such a way that the lowly human-impacted estuary in Bega in Australia had 98 particles/m^3 and the highly human-impacted estuary had 246 to1032 particles/m^3. In this study, microplastics have been found in all sampling points in River Mzinga as well as in River Msimbazi. These results are similar to the study in the River Thames Basin (UK) by Horton *et al.,* (2017) which reported the presence of microplastics at all four sites where one site had a significantly higher number of microplastics than other sites in a range of 16 to100 particles/kg. The microplastic concentration levels in this study did not differ much downstream as was reported in other similar studies by Widigdo et al., (2017) in Citanduy River, West Java, where the highest microplastic abundance was in the downstream area, followed by the upstream with the concentration of 18, 70−190, 405 particles/m^2. This might be due to geographical features like vegetation cover found along the river watershed area.

Table 1: Concentration (mean ± standard deviation) of Microplastics in Sediments at Different Points and Depth

River Msimbazi Average Microplastics (mean ± standard deviation), particles/m²					
	Depth		Depth		
Point	**1 cm**	**n**	**5 cm**	**n**	**Point Mean**
1	6 ± 3	3	6 ± 3	3	6 ± 0
2	26 ± 14	3	36 ± 0	3	31 ± 7
3	8 ± 0	3	18 ± 3	3	13 ± 7
4	8 ± 3	3	ND	3	8 ± 0
5	8 ± 0	3	14 ± 3	3	11 ± 4
6	20 ± 6	3	86 ± 8	3	53 ± 47
7	42 ± 8	3	46 ± 19	3	44 ± 3
8	54 ± 8	3	26 ± 3	3	40 ± 20
Mean	38 ± 18		33 ± 30		26 ± 18

River Mzinga Average Microplastics, particles/m²					
	Depth		Depth		
Point	**1 cm**	**n**	**5 cm**	**n**	**Point Mean±std**
1	106 ± 3	3	ND	3	106 ± 0
2	14 ± 8	3	ND	3	14 ± 0
3	70 ± 59	3	ND	3	70 ± 0
4	54 ± 3	3	34 ± 8	3	44 ± 14
5	26 ± 3	3	70 ± 14	3	48 ± 31
6	ND	3	128 ± 11	3	128 ± 0
7	26 ± 3	3	102 ± 8	3	64 ± 54
8	52 ± 17	3	14 ± 8	3	33 ± 27
9	60 ± 11	3	36 ± 7	3	48 ± 17
10	60 ± 11	3	118 ± 8	3	89 ± 41
Mean ± std	52 ± 28		72 ± 45		64 ± 35

ND= Not Detected, std = standard deviation, n = number of laboratory bench sediment samples.

Microplastic Occurrence in Watershed Fish

The concentration (mean ± standard deviation) of microplastics in fish from ponds in the River Mzinga watershed was in the range of 32.54 ± 26.1 to 50.32 ± 20.67 particles/kg while in River Msimbazi watershed was in the range of 17.5 ± 13.44 to 35.67 ± 16.20 particles/kg. The average concentration of microplastics in fish from all ponds was 33.81 ± 7.66 particles/kg (Table 2). The statistical analysis of samples of fish, one way-ANOVA, from ponds in watersheds indicated that there was no significant difference in the mean concentration of microplastics ($p = 0.2$).

The results in this study for the occurrence of microplastics in fish imply that freshwater fish engulf microplastics. The study was performed during the dry season; therefore these results also imply that there is the distribution of microplastics in both watershed sediments and watershed ponds during the rainy season which in turn were engulfed by fish. There is a similarity between the results for an abundance of microplastics in fish in this study and those from other studies. For instance, the concentration of microplastics in fish from the Northern Bay of Bengal in Bangladesh was 443 particles/kg (Hossain et al., 2019). Mistri *et al.*, (2022) reported that 47.8% of examined fish from the Adriatic Sea contained 233 fragments of microplastics with a mean concentration of 4.11 ± 2.85 particles/kg. From the Southern Northern Sea, Witte *et al.,* (2022) reported that fish had a concentration of 0.48 ± 0.81 to 0.26 ± 0.64 particles/kg.

Table 2: Mean Concentration of Microplastics in Fish from Watershed Ponds

	Mean Concentration in Ponds, /Particleskg-1			
Pond	1	2	3	Mean
Mzinga	32.54±26.1	50.32±20.67	34.79±0.00	39.22±8.00
Msimbazi	32.00±28.15	35.67±16.2	17.5±13.44	28.39±9.61

Physical Properties of Microplastics in Watershed Sediments and Fish

Physical Properties of Microplastics in Watershed Sediments

Microplastics in sediment samples from watersheds were in the form of fragments, fibres, and pellets. Fibres had size of 1000-5000 µm which had a concentration (mean ± standard deviation) range of 4 ± 3 to 40 ± 6 particles/m^2. Fragments had sizes of

100−500 µm for small microplastics and 1000−5000 µm for large microplastics. The fragments with the size of 100−500 µm had a concentration range of 4 ± 1 to 44 ± 3 particles/m^2. Fragments with the size of 1000−5000 µm had a concentration range of 4 ± 3 to 60 ± 5 particles/m^2 Pellets had a size range of 1000−5000 µm (Table 3). In River Mzinga watersheds, microplastics in the form of fragments were more abundant at 46.30% of the total mean concentration of microplastics followed by fibres which had 31.48% of the total mean concentration and lastly, pellets which had 22.22% of the total mean concentration. In the River Msimbazi watersheds, microplastics in the form of fibres were more abundant by 56.10% of the total mean concentration of microplastics and fibres had 43.90% of the total mean concentration (Figure 3). Generally, in watersheds, fragments were more concentrated at a depth of 5 cm by 59.02% of total fragment concentration while 40.02% of total fragment concentration was at a depth of 1 cm. Fibers were 100% concentrated at 5 cm as well as pellets (Table 3). Therefore, microplastics were highly found at depths greater than 1 cm which might be because of burial effects by physical factors like wind and sediment movements.

Table 3: Distribution of Shapes, Size and Concentration (mean ± standard deviation) of Microplastics in Sediments

Size and Shapes of Microplastics in Sediment Samples from River Mzinga

			Point										
Depth	Shape	Size Range	1	2	3	4	5	6	7	8	9	10	Conc
1 cm	Fragment	100-500	12±3	ND	ND	ND	ND	ND	ND	ND	ND	ND	12±0
		1000-5000	20±2	12±1		36±3	4±3	ND	16±7	ND	24±23	8±3	17±11
	Fibers	100-500	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		1000-5000	17±4	ND	ND	ND	ND	ND	20±2	12±8	4±3	10±8	13±6
	Pellets	100-500	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		1000-5000	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
5 cm	Fragments	100-500	ND	ND	ND	ND	ND	ND	44±4	ND	ND	44±3	44±0
		1000-5000	ND	ND	12±6	22±20	8±0	60±5	ND	20±7	16±6	32±0	24±18
	Fibers	100-500	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		1000-5000	ND	ND	ND	ND	32±5	40±6	4±2	ND	12±0	32±5	21±16
	Pellets	100-500	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		1000-5000	ND	ND	ND	ND	ND	12±2	ND	ND	ND	ND	12±2
		Mean±sdev	16±4	12±0	12±	29±10	15±15	37±24	21±17	16±7	14±8	25±16	

Size and Shapes of Microplastics in Sediments from River Msimbazi

			Point								
Depth	Shape	Size Range	1	2	3	4	5	6	7	8	Conc
1 cm	Fragments	100-500	4±1	12±2	ND	ND	ND	16±3	ND	24±2	14±7
		1000-5000	ND	244±3	8±2	ND	8±2	ND	ND	ND	87±136
	Fibers	100-500	ND	ND	ND	ND	ND	ND	ND	ND	ND
		1000-5000	ND	32±1	ND	8±1	ND	4±1	40±2	24±1	22±15
5 cm	Fragment	100-500	ND	4±0	ND	ND	ND	60±3	ND	20±3	28±29
		1000-5000	12±0	ND	36±2	ND	4±0	4±1	48±2	4±1	18±19
	Fibres	100-500	ND	ND	ND	ND	ND	8±2	ND	ND	8±0
		1000-5000	ND	ND	ND	ND	20±1	ND	ND	4±0	12±11
		Mean±sdev	8±6	73±115	22±20	8±0	20±11	18±24	44±6	15±10	

Conc = Concentration

Microplastics in form of fragments from sediments originated from degradation of large plastics utilized in markets, domestics, garages, industries, agricultural and other fields which were carried by rain floods from different urban areas to River Mzinga and Msimbazi. Examples of degraded plastics were films, plastic bags, soft drink bottles, jugs, buckets, food packages, cups, and pipes which were common in Dar es Salaam good plastic market. Microplastics in form of fibers mostly originate from plastic degradation of ropes, carpets, toothbrushes, fishing nets, clothes, saloon wigs, bags and other plastics which were also common in the Dar es Salaam plastic good market.

The results for forms of microplastics conform with reports from other studies for example from River Thames and its distributaries in Birmigham city in United Kingdom where it was seen that the forms of microplastics in sediments were 22% fibers, 49% fragments and 15% sponges and at each sampling location the size < 1mm was the greatest abundance and 2-4 mm was least abundant (Tibbetts *et al.*, 2018), while from River Thames Basin in United Kingdom 91% were fragments and the rest were fibers (Horton *et al.*, 2017). Fragments are reported in studies to be in most abundance compared to other forms of microplastics, Hoellein *et al.*, (2018) at the University of Notre Dame's, USA, due to reason that depositional velocity is highest for fragments, intermediate for fibers and lowest for pellets.

Physical Properties of Microplastics in Fish

Microplastics in fish from watershed ponds were in the form of fibers, fragments and sponges. Fragments had size range of 100−500 µm for small microplastics, while large microplastics had size of 500−1000 µm. The fragments with size 100−500 µm had concentration range of 8 ± 0 to 50 ± 29 µm with mean of 31 ± 15 particles/kg while those with size of 500-1000 µm had mean concentration of 120 ± 26 particles/kg. Fibers had size range of 1000−5000 µm. The concentration range of fibers was 27 ± 0 to 53 ± 0 particles/kg with mean of 33 ± 5 particles/kg. The sponge size was 1000−5000 µm with mean concentration of 17 ± 23particles/m^2 (Table 4). The fragments in fish were more abundant with 75.12% of total concentration, fibers 16.42% and sponge 8.46 % of the total concentration. This indicates that fish could engulf different forms of microplastics in water. Mayoma et al. 2020 also reported the occurrence of microplastics in 48% of all collected cockles' samples in East African Coastline Beaches (138 microplastics in tissues), although the different forms were not indicated in the report.

Table 4: Concentration (mean ± standard deviation) and Forms of Microplastics in Sediments and Fish from River Watersheds

		River Mzinga		River Msimbazi	
		Size	Particles/m^2	Size	Particles/m^2
Pond	Fragments	100−500	33 ± 26	100−500	29 ± 10
I	Fibers	ND	ND	1000−2000	37 ± 33
Pond	Fragments	100−500	50 ± 29	500−1000	120 ± 26
II	Fibres	4000−5000	53 ± 0	2000−3000	35 ± 16
	Sponges	ND	ND	500−1000	33 ± 0
Pond	Fragments	100−500	35 ± 0	500−1000	8 ± 0
III	Fibres	ND	ND	1000−1500	27 ± 0

Microplastics in the different forms found in fish are an indication that fish can engulf microplastics without selection. The results show that fragments are engulfed in large amounts may be due to the great occurrence in the environment as has been found in sediments in section 3.2.1. This was because the fishponds were within the watershed area. The findings in this study are similar to those found in other studies in sizes although there are some differences in concentrations. For example, Hossain *et al.*, (2019) reported that fibre dominated in *S. gibbosa* with 55%, followed by fragments (26%) and particles (19%) (fibres up to 5810 µm and fragments up to 4333 µm were retained in gills of the studied specimens. The overall size of microplastics closely overlaps with those documented in other studies, such as 100 to 1000 µm, from gills of Minho estuary fish microplastics had size of 159–5810 µm (Abbasi et al., 2018).

Identity of Microplastics in Fish and Sediments

Identity of Microplastics in Sediments

The polymer types for microplastics in sediments from River Mzinga and Msimbazi watersheds were polyethene, polypropylene, polyurethane, polyamide, and polyvinyl chloride (Figure 4). The concentration (mean ± standard deviation) of polyethylene was in the range of 4 ± 2 to 84 ± 0 particles/m^2. The concentration of polypropylene was in the range of 4 ± 0 to 68 ± 0 particles/m^2. The concentration of polyamide was in the range of 4 ± 3 to 36 ± 0 particles/m^2. The mean concentration of polyurethane was 20 ± 28 particles/m^2. The concentration of polyvinyl chloride was in the range of 1-0 to 8 ± 17 particles/m^2 (Table 5). Polyethene was more abundant at 29% of the total concentration, polyamide at 28.49%, polyurethane was 17.15% of the total concentration, polypropylene at 19.83% and lastly, polyvinyl chloride that had 5.17%.

Table 5: Type of Microplastics and concentration (mean ± standard deviation) in Sediment and Fish from River Watersheds

Site	Type	Sampling Point										
River Mzinga		1	2	3	4	5	6	7	8	9	10	Conc
	PU	40±0	ND	ND	4±0	ND	ND	ND	ND	ND	ND	22±25
	PA	ND	ND	ND	12±0	ND	ND	4±0	28±28	22±8	32±26	32±20
	PE	ND	12±0	24±0	28±11	45±45	96±0	24±0	16±0	44±6	84±0	41±30
	PP	68±0.	8±0	4±0	16±0	40±11	32±0	20±0	ND	ND	ND	27±22
	PVC	ND	ND	ND	ND	ND	ND	52±73	ND	ND	ND	8±17
River Msimbazi	PA	ND	36±0	ND	ND	ND	ND	ND	32±0			34±3
	PE	47±64	4±0	36±0	ND	8±0	12±6	60±0	24±0			27±21
	PP	ND	32±0	8±0	8±0	20±0	ND	40±0	4±0			19±15
	PVC	ND	ND	ND	ND	8±0	ND	ND	ND			1±16

Conc = concentration

The analysis of the particles demonstrated infrared absorption over the entire region of absorption from 4000−450 cm^{-1}. The polymer identity of the particles was determined by using the spectra microplastics absorption peaks mainly the functional group region of the IR spectrum (4000-1500 cm^{-1}) and in the fingerprint region (1500−500) cm^{-1}. Examples of absorption of which were extracted from fish and sediments were polyamide, polyethylene, and polypropylene (Figure 4).

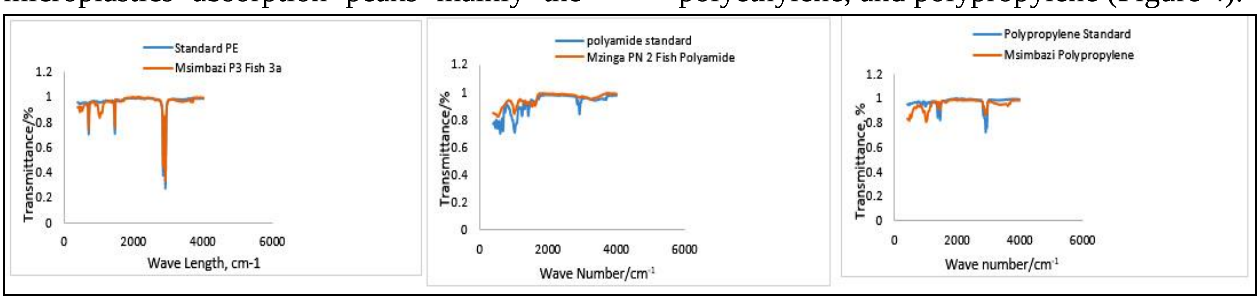

Figure 4: Superimposed At-FT-IR Spectra for standards and their matches from samples for polyethylene from fish, polyamide (nylon 6, 6) from fish and polypropylene from sediments

The identified microplastics in this study are similar those which have been reported in other studies in the light of commonly applied plastics. For example, the type of microplastics in sediments from river estuary in Maowei Sea and River Thames Basin in United Kingdom were reported by Li *et al.*, (2019) to be polyethylene and polypropylene: Polyethylene and polypropylene in this study were dominant in the occurrence because of their wide application in the market in Tanzania. Polyethylene is used in formation of plastics like shopping bags, film wrap, bubble wrap, bottles, buckets, cups, pipes and ropes. Polypropylene is used for formation of plastic ropes, carpets, fertilizer bags, bottle lids, plastic chairs, and sterile containers. There has been large amount of polyurethane microplastics which originate from degrading and deformed foam materials. The polyamide reported in this study might be originating from degradation of plastic fibers used in saloon and other utilities for clothes, fishing nets and ropes which were carried into the River Mzinga and Msimbazi.

Identity of Microplastics in Fish

The identified microplastics in Mzinga and Msimbazi River watersheds were polyurethane, polyethylene, polyamide and polyvinyl chloride. The concentration (mean ± standard deviation) of polyurethane was in the range of 19.64 ± 20 to 69.77 ± 0.00 particles/kg with average concentration of 39 ± 11 particles/kg, polyethylene was in the range of 28.57 ± 0.00 to 35.00 ± 0.00 particles/kg with average concentration of 33 ± 1 particles/kg, polyamide was in the range of 18.00 ± 30.00 to 53.63 ± 0.00 with mean of 33 ± 1 particles/kg and polyvinylchloride was in the range of 5.00 ± 0.00 to 68.57 ± 96 particles/kg with mean of 27.30 ± 35.78 particles/kg (table 6). Polyurethane was more abundant in watershed fish by 29.77% of total concentration, followed by polyamide with 25.19%, polyethylene with 24.43% and polyvinyl chloride 20.61% of total concentration. The type of microplastics found in pond fish are linked to those occurring in river watershed sediments, although they differ in concentration (Section 3.3.1).

Table 6: Type of Microplastics and concentration (mean ± standard deviation) in Fish from River Watersheds

	River Mzinga			River Msimbazi			
	PU	PA	PE	PU	PA	PE	PVC
Pond 1	32.53 ± 26.10	ND	ND	19.64 ± 20.71	41.06 ± 26.44	35.00 ± 0.00	5.00 ± 0.00
Pond 2	69.77 ± 0.00	52.63 ± 0.00	28.57 ± 0.00	33.34 ± 0.00	35.38 ± 16.23	33.34 ± 15	68.57 ± 96.92
pond 3	ND	ND	34.78 ± 0.00	ND	26.67 ± 0.00		8.33 ± 0.00
Mean±sdv	51.15 ± 26	18 ± 30	32 ± 4	26.49 ± 9.7	34.37 ± 7.2	34.17 ± 1.17	8.33 ± 358

The results indicate that fish could engulf different types of microplastics from the water environment. The source of microplastics in fish could be attributed to water, sediments, or other organisms in the food chain. The results which indicate the presence of microplastics in fish have been reported also in different kinds of literature although from different environments, for example, Hossain *et al.,* (2019) report that 13 particles/kg of polyethene terephthalate and 66 particles/kg of polyamide were found in fish from Northern Bay of Bengal at Bangladesh.

CONCLUSION

The purpose of this research was to determine the occurrence and speciation of microplastics in sediments and fish from watershed environments. Microplastics were found in sediments from all study sites (River Msimbazi and River Mzinga) in Dar es Salaam. However, all sampling points had sediment microplastics with different concentrations but a high concentration of microplastics was at 1 cm compared to 5 cm depth. The different forms of microplastics which were found contaminating sediments were fragments, fibres, sponges, and pellets. The type of microplastics identified were polypropylene, polypropylene, polyvinyl chloride, polyurethane and nylon 6.6. The study also indicated that the fish in watershed ponds had been contaminated by microplastics. The form of microplastics in fish were fibres of the type of polyamide and polypropylene, sponges of the type of polyurethane and fragments of the type of polyethene and polyvinyl chloride. These results indicated that the river watersheds were polluted with microplastics whose sources were more attributed to anthropological activities in the urban area together with the influence of rainstorms. The occurrence of microplastics in watersheds and watershed pond fish implies that there is a need for further studies on the dissemination of other toxic chemicals which tend to be adsorbed by microplastics in freshwater bodies.

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