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Research Article

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Bangladesh's Commercial Fish Feed Industry: A Source of Microplastic Contamination

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Abstract

Microplastics are mostly abundant in marine and coastal systems, while synthetic pollutants chemically interact with organic pollutants and metals (Guo and Wang, 2019a). Bangladesh is the fifth largest aquaculture producer in the world, and uses commercial fish feeds extensively. Previous studies have detected microplastics in fish feed ingredients, fish rearing water, and aquaculture fish. Therefore, we conducted this study to evaluate the extent of microplastic contamination in commercially available fish feeds in Bangladesh. We collected five different commercial fish feed samples from three stages (pre-starter, starter, and grower) from markets and analyzed them in the laboratory following the NOAA protocol for microplastic assessment. We detected and identified microplastic particles by microscopic examination. Our study provides evidence of the presence of microplastics in commercial fish feed in Bangladesh. All feed samples contained microplastic particles, with a mean abundance of 567±296.18 particles/kg. The average size of particles was 744.03±242.55µm. We found seven types of particles (fiber, film, fragments, foam, pellets, micro beads, & nurdles), with fiber (52%) being the most common, followed by film (21%) and fragment (15%). We identified eight different colors of particles, with brown (24%) being the most frequent, followed by black (22%) and blue (17%). Our study suggests that commercial fish feed is a source of microplastic pollution in aquaculture fish in Bangladesh. This could have negative impacts on fish health and human consumption. We recommend raising awareness about the presence of microplastics in fish feed and conducting further research to monitor their effects on fish physiology and food chain transfer. We also suggest investigating the origins of microplastics in fish feed by examining the feed ingredients and manufacturing processes.

Keywords: Microplastics, aquaculture fish, NOAA protocol, fish physiology and food chain transfer

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Introduction

Fishmeal is a valorized product of by-catch or by-products of marine capture fisheries and is a nutritionally enriched source of high-quality animal protein with higher digestibility, palatability, growth-promoting, and immune-boosting effects. As a result, fishmeal use in developing artificial feed for livestock animals and aquatic organisms, including fish and shrimp, is rapidly increasing globally (Cashion *et al.*, 2017; Miles and Chapman, 2006). However, several recent findings have demonstrated that due to the rapid increase of plastic pollution in marine water bodies (Hanachi *et al*., 2019; Lusher *et al*., 2017), the abundance of microplastics in fishmeal is sharply increasing (Foekema *et al*., 2013; Lusher *et al*., 2013; Tanaka and Takada, 2016). The objectives of this study are as follows:

1. Assessing the presence of microplastic contamination in commercial fish feed.
2. Characterization of the identified MP particles according to their different properties (size, color, and type).
3. Analyzing the statistically significant variation in different dependent variables (company type, feed brand, feed form, particle size, color, type, etc.) in relation to microplastics in fish feeds.

Study area: The economy of the nation is notably impacted by the fisheries industry. To establish a sustainable economic framework, it is essential to have a well-managed marketing system and a favorable environment. Various areas within Chittagong city were selected for obtaining fish feed samples, including the local markets of Aturar depo, Hathazari, and Khatunganj.

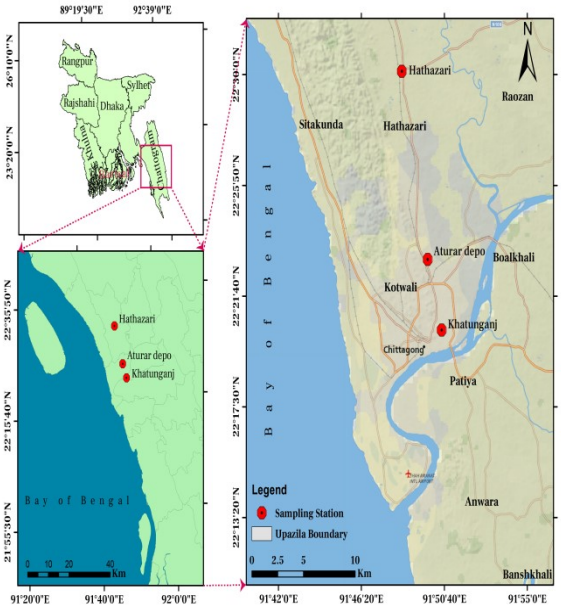

Figure 1: Location of fish feed sampling sites around Chittagong city.

Methods: Fish feed samples were collected in a period between 2nd to 10th April, 2023. A total of five brands of commercial fish feed samples were collected from the market. The samples were separated as pre-starter, starter, grower or finisher.

Laboratory Analysis: This research was done to evaluate the presence of microplastics in fish feed samples that were purchased commercially. Following standard procedures for evaluating microplastics, such as sample pretreatment, density separation, H_2O_2 treatment, plastic particle detection, and analytical work was carried out. This study was done in the light of National Oceanic and Atmospheric Administration (NOAA) provided guidelines for laboratory methods for the analyzing and quantifying synthetic particles.

Sample Preparation: Fish feed samples were collected, air dried for three days, and then sealed in a foil bag. With the aid of an analytical balance, a 40g feed sample was weighted for analysis, and the weighted sample was then put into a glass beaker. After the Sample was ready it was about to go through to the next step- organic matter digestion.

Extraction of MP: To extract MPs from fish feed samples several steps were done following density separation, H_2O_2 treatment, and filtration.

Density Separation: For replicate analysis, each sample was divided into three pieces and placed in three glass beakers. Each glass beaker contained 40g of dried feed and 120ml of saturated salt solution, which were manually swirled for 10 minutes with a clean glass rod. The water solution above the layer was carefully transferred to another glass beaker after 12 hours of setting.

Hydrogen Peroxide Treatment: To degrade the possible organic matters present in the water solution, 20 ml of 30% H_2O_2 was added into solutions. After that, the beaker was covered with aluminum foil paper and kept for 24 hours for sedimentation.

Figure 2: Hydrogen Peroxide Treatment

SI No.	Sample code	Sample stage	Sample form	Sample image
1.	F1	Pre-starter	Pellet	
2.	F2	Starter	Pellet	
3.	F3	Grower	Pellet	
4.	P1	Pre-starter	Pellet	
5.	P2	Starter	Pellet	

6.	P3	Grower	Pellet	
7.	A1	Pre-starter	Powder	
8.	A2	Carp grower	Pellet	
9.	A3	Tilapia grower	Pellet	
10.	N1	Starter	Pellet	
11.	N2	Starter	Pellet	
12.	T1	Starter	Pellet	
13.	T2	Starter	Pellet	

Table 1.1: Description of collected fish feed sample

Filtration: After allowing a 24-hour period for sedimentation, the clear liquid portion, known as the supernatant, underwent filtration through a vacuum system. For the process of filtration a 20µm Whatman GF/F membrane were used. To minimize potential loss of samples due to microplastics adhering to the filter apparatus walls, thorough cleaning was performed on the glass beaker and all transfer equipment, using 200 ml of Milli-Q water. The resultant cleaning solutions were also filtered through the same glass-fiber filter to ensure no loss of particles (as outlined by Zhou *et al*., 2018). Before proceeding to microscopic examination, the filter was placed on a petri dish and shielded with aluminum foil. Each sampling phase consisted of three replicates.


Figure 3: Microplastic items filtration process

Quality Assurance of Experiment: To mitigate the risk of contamination, every piece of equipment underwent triple purification using filtered distilled water, as recommended by both Li *et al.* (2015) and Yang *et al.* (2015). The process of separating and counting microplastics took place within designated, uncontaminated rooms. Precautionary steps were also implemented in the laboratory preceding the flotation procedure. These measures encompassed the practice of immediately covering all materials with aluminum foils after each instance of washing and subsequent steps, following the guidelines outlined by Zhou *et al.* (2018).

Microplastics Enumeration: Upon the complete drying of the filter membranes, microplastic items were tallied individually on each membrane. Utilizing a microscope, the items were visually recognized, quantified, and measured, with photographic records taken. Visual identification stands as one of the most frequently employed techniques for microplastics recognition (Hidalgo-Ruz *et al.,* 2012). To ensure accurate selection and avoid misclassification of microplastics, specific criteria were applied, following the guidelines established by Cole *et al.,* (2011):

1. No observable presence of cellular or organic structures.
2. Consistent thickness throughout the entirety of fibers, lacking any tapering at the ends.
3. Uniform coloring of colored particles.
4. Absence of segmentation or resemblance to twisted flat ribbons in fibers.
5. Particles exhibit no reflective shine.

Characterization of Microplastics: After density separation, the microscopic examinations of separated particles were done under a laboratory microscope at 10X magnification. A digital camera was equipped with the microscope (AmScope) Model: MU1000 to take photographs of identified particles.

Image Analysis: Images captured by a digital camera that was attached to the laboratory microscope were used to determine the colours of the discovered particles. The length (size) of the detected particles was determined using the ImageJ software. In this analysis, 1029.89 pixels were used as 0.5 millimetres (500 micrometres) when determining the size of the particles.

Figure 4: Microscopic observation of microplastic items in feed sample

Data Analysis: SPSS software version 29 was used for the statistical analysis. Microsoft Excel 2010 was applied to generate the figures. One-way analysis of variance (ANOVA) was used to examine differences

in MPs across several brands of feed samples and various firm types. One-way ANOVA and Duncan Multiple Range Test (DMRT) Post-hoc analysis were used to examine color variation and particle type variation.

FT-IR Analysis: FT-IR analysis was conducted for identification of different MP polymers from different brands of fish feed sample. This analysis were done from Bangladesh Oceanographic Research Institute by Shimadzu iRsprit FTIR.

Results

Occurrence & Abundance of Particles

This study analyzed five brands of fish feed samples from three different stages such as; pre-starter, starter, and grower. From each brand of sample, 45g of feed was taken for microplastic content analysis. In total, the thirteen samples weighing 585g of feed contained 331 particles. On an average each feed sample contains 25.47±13.35 particles in 45g.

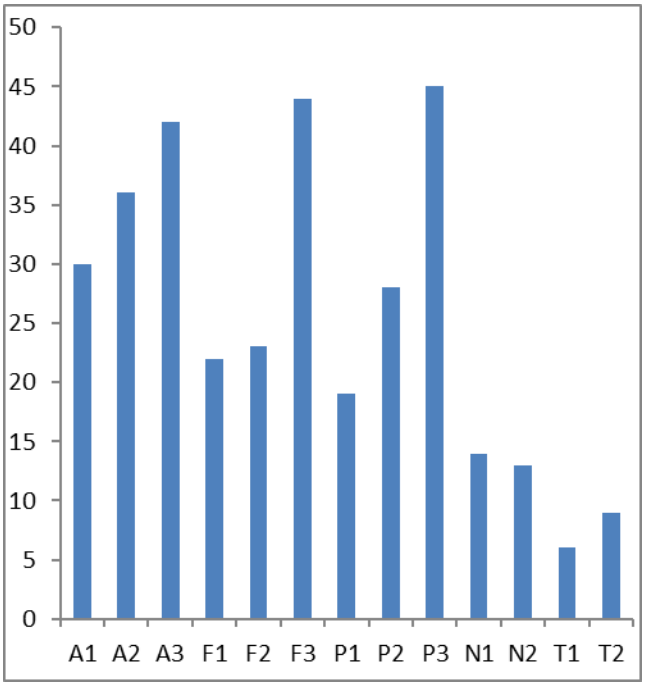

Figure 5: Particles found in total amount of analyzed samples

The results also show that the particle count varies depending on the brand, stage, and form of the feed. The highest number of particles is found in P3 feed sample, which is a pre-starter pellet from a local company. The lowest number of particles is found in T1feed sample. This suggests that there may be differences in the quality, ingredients, and manufacturing processes of the feed samples that affect the microplastic content. If we consider F3, A3, and A2, it is showing that the particle contents in analyzed amount of these are 44, 42, and 36, which very close to each other. In this study, the particle count in samples are following trend- P3> F3> A3> A2> A1> P2> F2> F1> P1> N1> N2>T2> T1.

Particle Count per Kg of Sample: The particle count in different commercial fish feed samples on a per-kg basis is shown in figure 6. All the samples were found to contain microplastics. The highest numbers of particles are found in the P3 feed sample, which is 1000±333.6 particles/kg. Then sample F3, which contains 978±308.3 particles/kg, is followed

by samples A3, A2, A1, P2, F2, F1, P1, N1, N2, T2, and T1. The particle content of these samples is as follows: 934±352 particles/kg, 800±266 particles/kg, 667±290 particles/kg, 623±252 particles/kg, 512±167 particles/kg, 490±203 particles/kg, 423±138 particles/kg, 312±101 particles/kg, 289±101 particles/kg, 200±66 particles/kg, and 134±67 particles/kg. On average, 567±296.18 particles/kg are present in commercially available fish feed samples analyzed in this study.

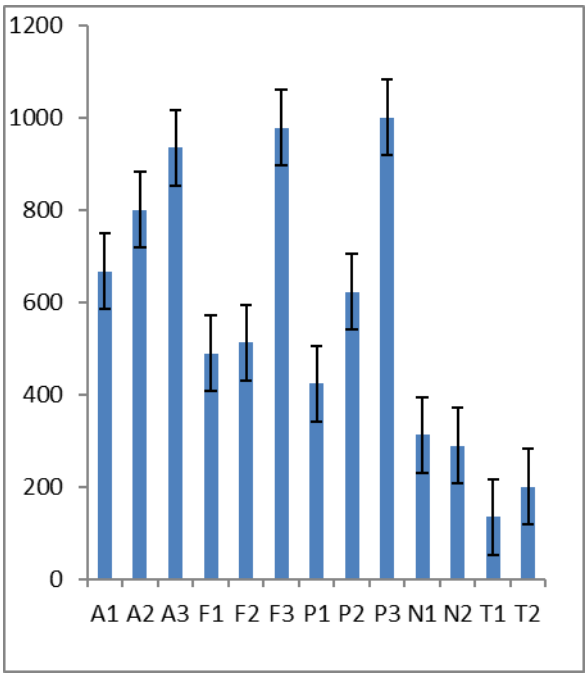

Figure 6: Microplastic particles in per kg (mean±SD) of fish feed sample

Size Distribution of Particles: There are a wide range of particles present in the analyzed feed samples. The sample A1, A2, A3, F1, F2, F3, P1, P2, P3, N1, N2, T1, and T2 contained 30, 36, 42, 22, 23, 44, 19, 28, 45, 14, 13, 6, and 9 particles, and the mean sizes of those identified particles are 275.67±34.02µm, 403.09±10.69µm, 903.86± 9.11µm, 513.6±16.56µm, 925.3±37.68µm, 1135.6±29.67µm, 702.52±4.98µm, 802.33± 12.32µm, 868.38±10.22µm, 609.88±12.38µm, 829.51±26.86µm, 716.03±7.04µm, and 986.73±8.47 µm. The average size of particles found in this study is 744.03±242.55µm. From Figure, it is evident that sample A1 contained smaller particles and sample F3 contained larger particles.

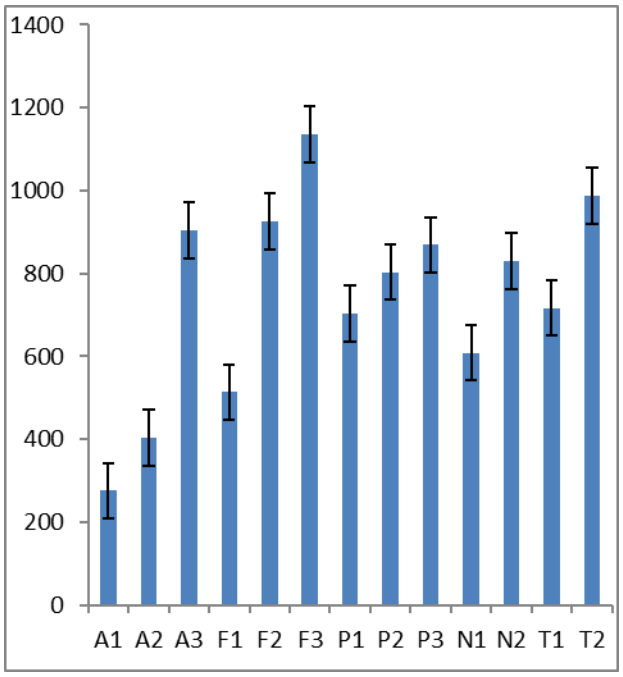

Figure 7: Size (Mean±SD) distribution among different feed sample

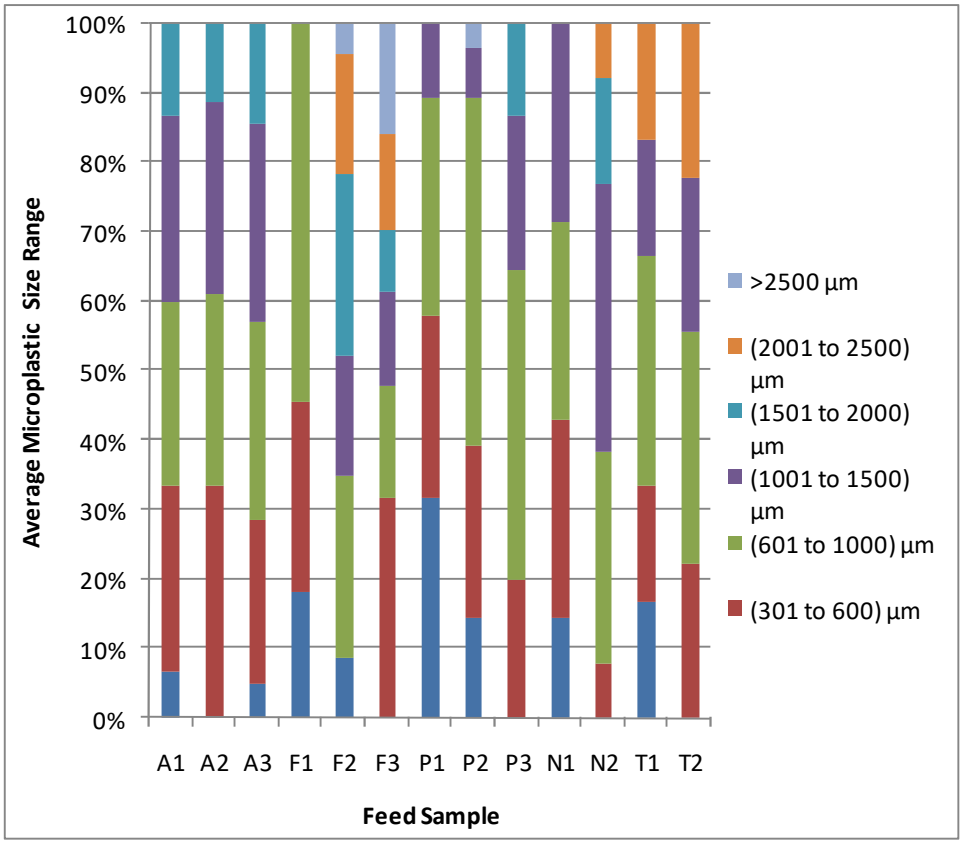

Figure 8: Size distribution of particles within the feed sample brands

The size of particles found in this study ranges from 236 µm to 2549 µm, and those are classified into 7 class categories, as such: 180 µm to 300 µm (6.94%), 301 µm to 600 µm (23.86%), 601 µm to 1000 µm (32.62%), 1001 µm to 1500 µm (19.94%), 1501 µm to 2000 µm (9.67%), 2001 µm to 2500 µm (4.23%) and >2500 µm (2.72%). We classified the size distribution of particles according to Mississippi State University-Microplastics sampling and processing guidebook.

Sample P1 contains the highest number of small particles. Among the identified 331 particles, the smallest particle is 236 µm and is found in F1, and >2500 µm-sized particles are found in F3.

Color Distribution of Particles: There are eight different colored particles—Blue, Black, Brown, Green, Red, Transparent, White, and Yellow—found in this study, as shown in Figure 9. A total of 13 samples (45g for each) were analyzed, and 331 particles were found. Among all particles, 23.56% are brown in color. Then black particles are the second-largest color category, which contains 23.35%. Other colors are followed by blue, red, green, white, yellow, and transparent, and the percentage of those particles are 16.91%, 16.30%, 13.28%, 4.21%, 2.71%, and 0.6%. So, the color distributions of particles are as follows: Brown> Black > Blue> Red> Green > White >Yellow> Transparent.

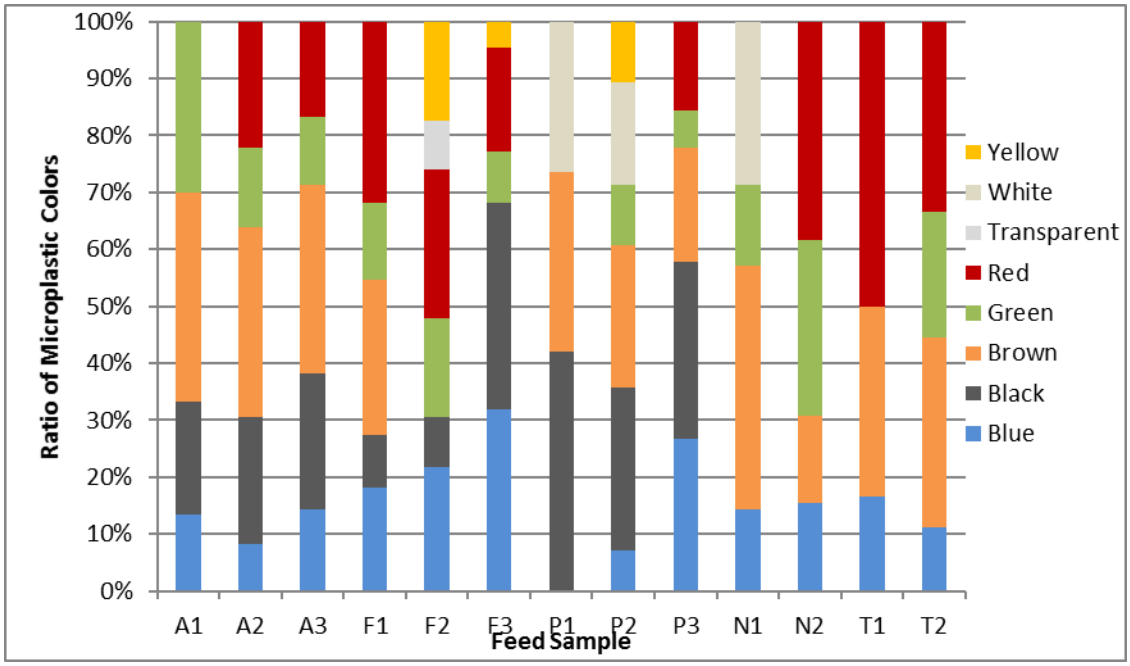

Figure 9: Color combination of identified particles

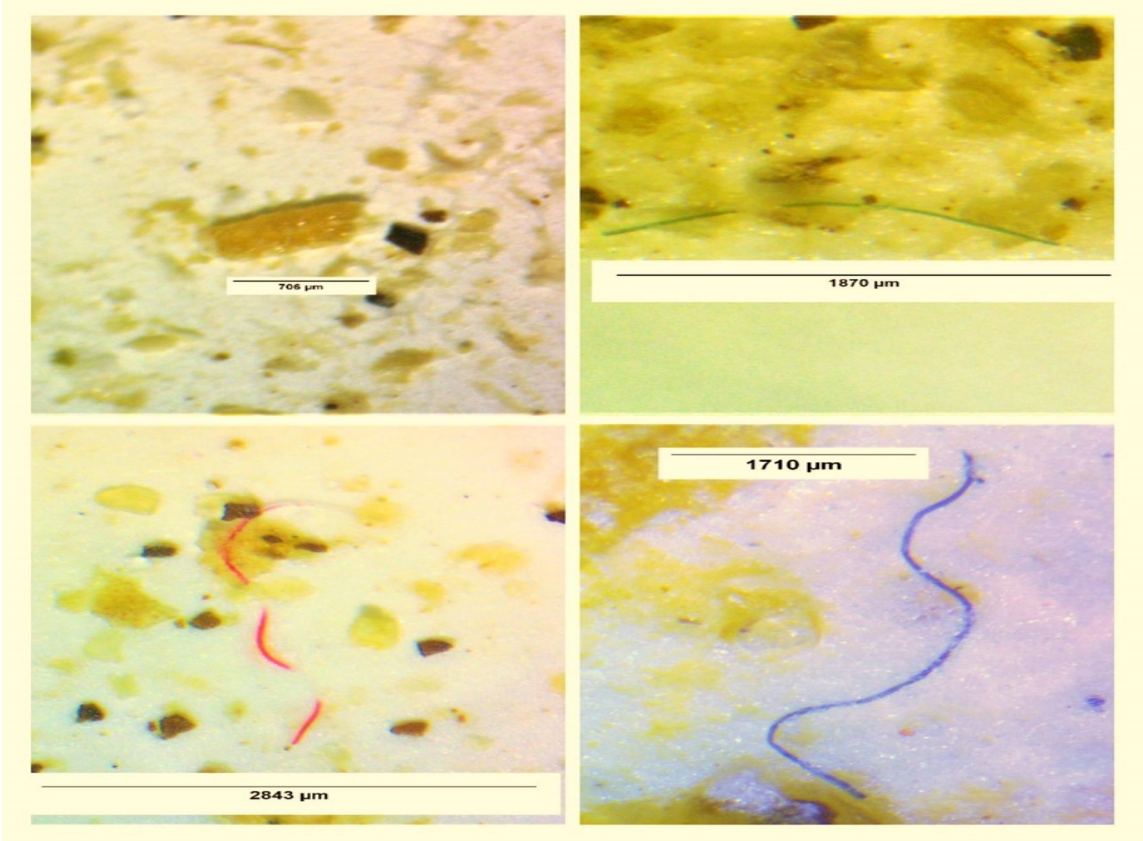

Figure 10: Different colors of identified microplastics

Particle Types Distribution: Particle type indicates whether it is fiber, film, fragments, foam, pellets, microbeads, or nurdles. Particle types found in this study are shown in Figure 11.

Here, fiber is the most dominant particle type, and this type holds 51.35% out of 331 identified particles in the total analyzed sample. Other types are followed by: fims (20.84%), fragments (15.10%), pellet (9.36%), foams (2.41%), microbeads (0.60%), and nurdle (0.30%).
The particle types are following the trend:

Fibers > Films> Fragments> Pellet> Foams> Micro beads> Nurdle.

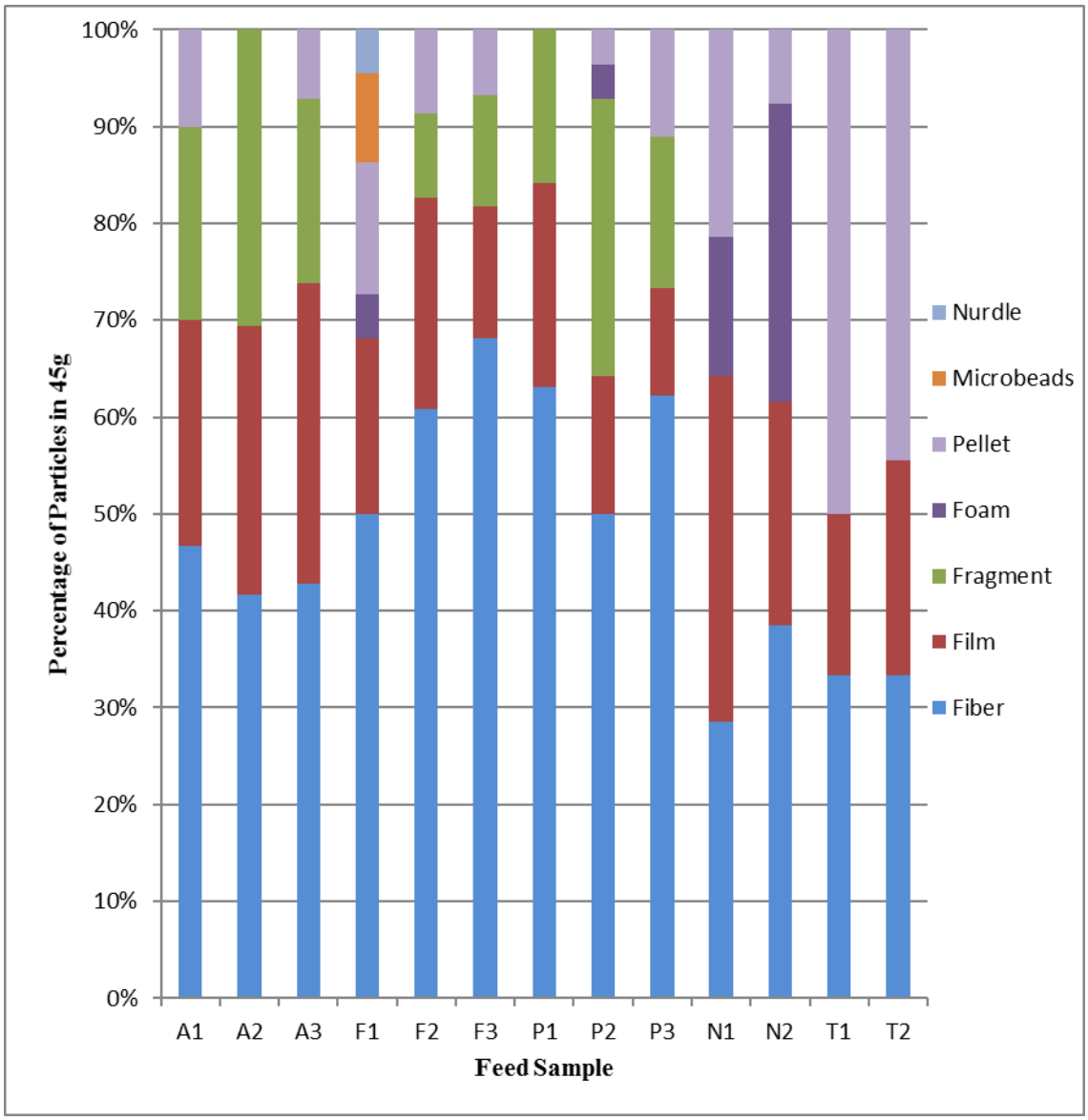

Figure 11: Types of particles found

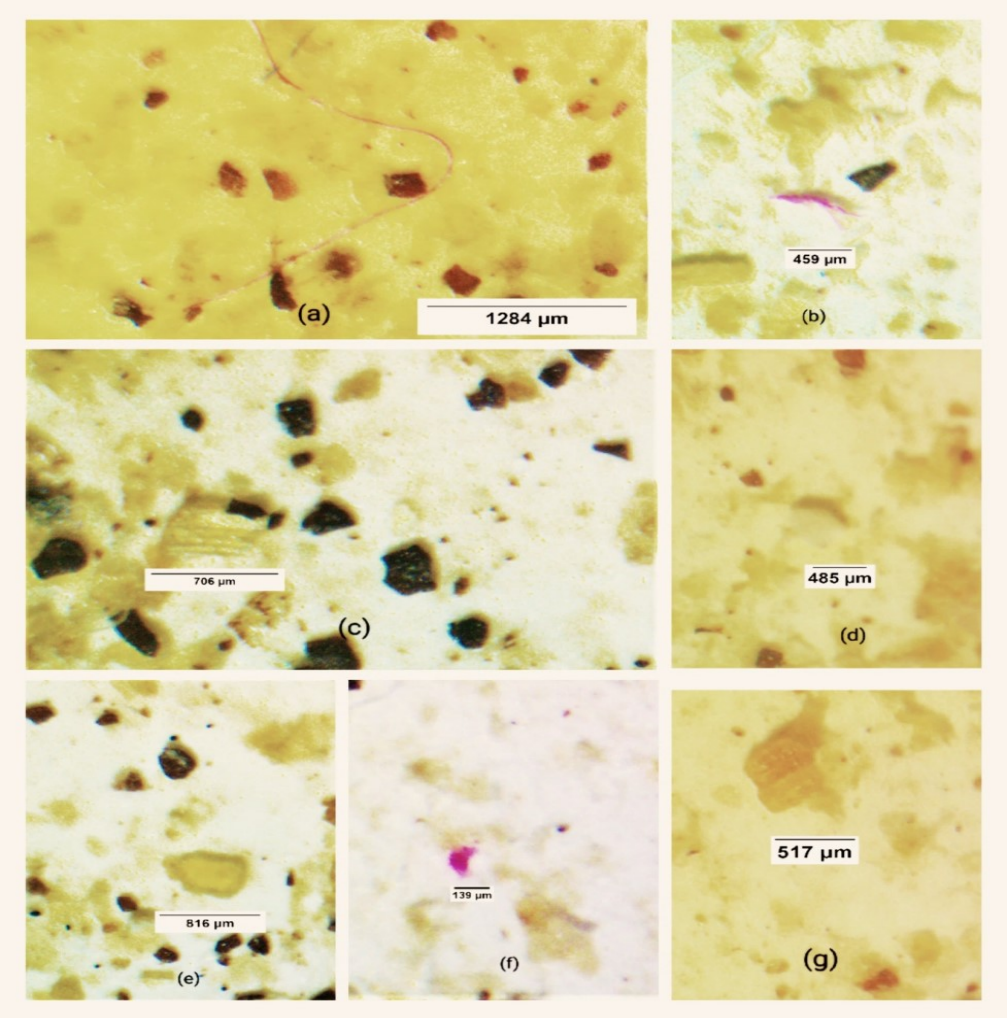

Figure 12: Different shapes of identified microplastics; (a) fiber, (b) film, (c) fragment, (d) foam, (e) pellet, (f) micro beads, & (g) nurdle.

Statistical Significance Testing: Comparing Between Feed Brand and Size of MP Particles

ANOVA

Particle_Size_micron

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	43316985.609	12	3609748.801	14.558	<.001
Within Groups	78852448.373	318	247963.674		
Total	122169433.98	330			

Table 1: Analysis of Variance (ANOVA) for feed brands and particle size

Particle_Size_micron

	Sample	N	Subset for alpha = 0.05					
			1	2	3	4	5	6
Duncan[a,b]	A1	30	273.03					
	A2	36	365.17	365.17				
	P1	19	593.16	593.16	593.16			
	F1	22	596.68	596.68	596.68			
	P2	28		721.89	721.89	721.89		
	A3	42			736.40	736.40		
	N1	14			789.07	789.07		
	T1	6				970.67	970.67	
	P3	45				972.27	972.27	
	T2	9					1169.00	1169.00
	N2	13					1242.62	1242.62
	F2	23					1295.48	1295.48
	F3	44						1393.89
	Sig.		.078	.051	.306	.188	.084	.225

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 17.729.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Table 2: Duncan Multiple Range Test (DMRT) Post-hoc analysis for feed brand and particle size

We compared the size of the particles among different brands. There was statistically significant variation at P<0.001 (Table 1), which suggests that the differences among the groups are statistically significant and that there are differences in the population means. When analyzed for the exact variation by post-hoc test (DMRT), we found that the brand A1 contained smaller particles with a mean size of 273.03 µm, and the brands F3 and F2 contained longer particles with a mean value of 1393.89 µm and 1295.48 µm, respectively.

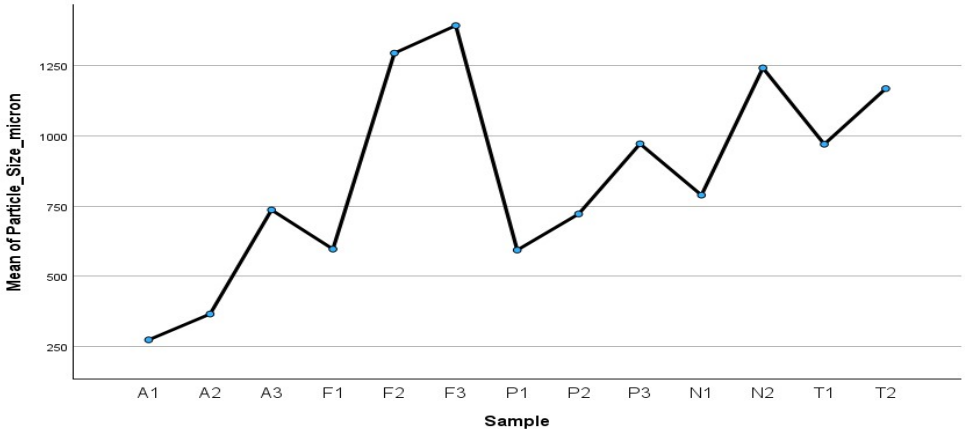

Figure 13: Mean Plots for feed sample and particle size

Comparing Between Color and Size of MP Particles

ANOVA

Particle_Size_micron

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	21074388.688	7	3010626.955	9.619	<.001
Within Groups	101095045.29	323	312987.756		
Total	122169433.98	330			

Table 3: Analysis of Variance (ANOVA) for particle color and size

Particle_Size_micron

	Particle_Color	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a,b]	Black	74	566.49		
	Blue	56	634.64	634.64	
	Green	44	667.23	667.23	
	Transparent	2	846.50	846.50	
	Red	54	954.17	954.17	
	Brown	78	1088.45	1088.45	1088.45
	White	14		1147.93	1147.93
	Yellow	9			1588.33
	Sig.		.062	.067	.054

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 10.417.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Table 4: Duncan Multiple Range Test (DMRT) Post-hoc analysis for particle color and size

We compared the color and size of the particles. There was statistically significant variation at P<0.001 (Table 3), which suggests that the differences among the groups are statistically significant and that there are differences in the population means. When analyzed for the exact variation by post-hoc test (DMRT), we found that the brand black and blue particles were smaller particles with mean sizes of 566.49 µm and 634.64 µm, and yellow particles were longer particles with mean sizes of 1588.33 µm, which significantly varied at the 1% level of significance.

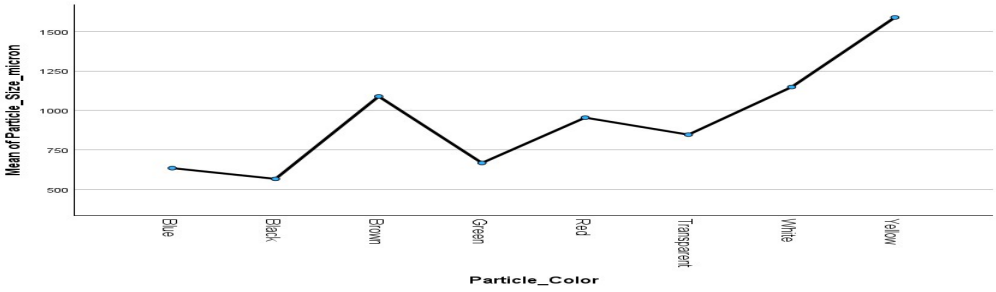

Figure 14: Mean Plots for particle color and particle size

Comparison between Particle Types and Size of MP Particles

ANOVA

Particle_Size_micron

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14128342.315	6	2354723.719	5.471	<.001
Within Groups	139450071.07	324	430401.454		
Total	153578413.39	330			

Table 5: Analysis of Variance (ANOVA) for particle type and size

We compared the size of the particles among different particle types. There was statistically significant variation at P<0.001 (Table 5).

Identification of MPs polymers: A specific amount of microplastic objects were utilized for Fourier-transform infrared (FTIR) analysis. As noted by Veerasingam *et al.* (2020), a range of polymer types were identified, encompassing PA (polyamide), PE (polyethylene), PVC (Polyvinyl chloride), PC (Polycarbonate), PP (Polypropylene), PET (Polyethylene terephthalate), and EVA (Ethylene vinyl acetate).

MPs polymer identification in feed sample (A1, A2, and A3)

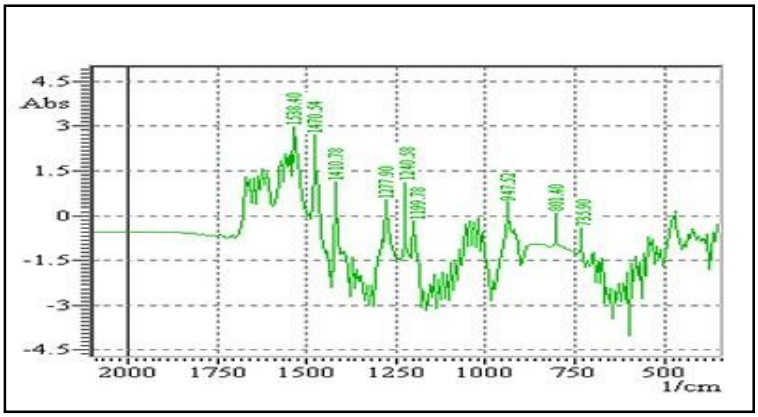

Figure 15: FTIR analysis data of some microplastic items of sample (A1, A2, and A3).

Sample Name	Description	Number	Percentage (%)
A1 A2 A3	Total particle measured	40	100
	Total polymer identified	38	95
	PA	14	35
	PE	7	17.5
	PVC	6	15
	PC	4	10
	PP	3	7.5
	PET	2	5
	EVA	2	5
	Total unidentified particle	2	5

Table 6: MPs polymer composition in sample (A1, A2, and A3) identified by FTIR.

A comprehensive examination was conducted on 40 microplastic items, out of which 38 were successfully recognized. One item remained unidentifiable. As per this analysis, PA (polyamide) or nylon emerged as the prevailing polymer, comprising the highest proportion at 35%.

MPs polymer identification in feed sample (F1, F2, and F3)

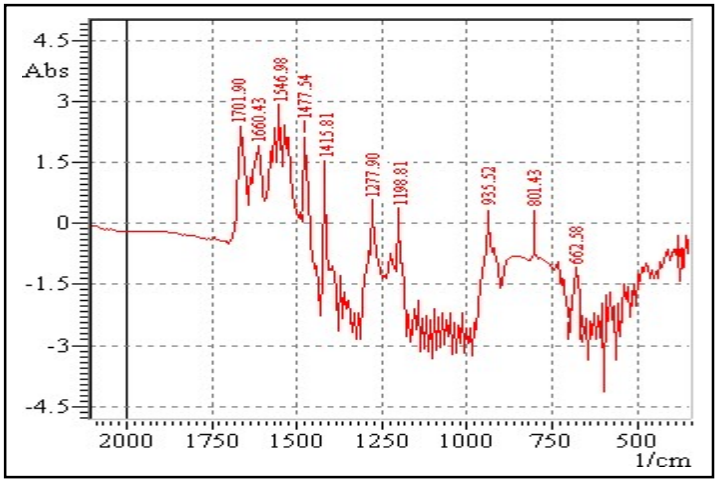

Figure 16: FTIR analysis data of some microplastic items of sample (F1, F2, and F3).

A comprehensive examination was conducted on 46microplastic items, out of which 45 were successfully recognized. One item remained unidentifiable. As per this analysis, PA (polyamide) or nylon emerged as the prevailing polymer, comprising the highest proportion at 42%.

Sample Name	Description	Number	Percentage (%)
F1 F2 F3	Total particle measured	46	100
	Total polymer identified	45	97.8
	PA	19	42
	PC	7	15
	PE	6	13
	PVC	5	11
	PP	3	6.5
	EVA	3	6.5
	PET	2	4.5
	Total unidentified particle	1	2.2

Table 7: MPs polymer composition in sample (F1, F2, and F3) identified by FTIR.

MPs polymer identification in feed sample (P1, P2, and P3)

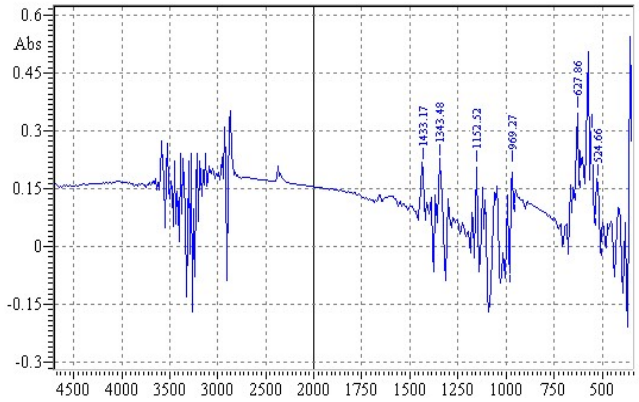

Figure 17: FTIR analysis data of some microplastic items of sample (P1, P2, and P3).

In the process of examination, a grand total of 45 microplastic items underwent scrutiny, out of which 42 items were successfully recognized and other items remained unidentifiable. According to the outcomes of this analysis, the prevailing polymer was once again PA (polyamide) or nylon, making up the largest share at 35%.

Sample Name	Description		Number	Percentage (%)
P1 P2 P3	Total particle measured		45	100
	Total polymer identified		42	93.4
	PA		16	35
	PC		7	16
	PE		6	15
	PVC		5	12
	PP		3	6.7
	EVA		3	6.7
	PET		2	4.5
	Total unidentified particle		3	6.7

Table 8: MPs polymer composition in sample (P1, P2, and P3) identified by FTIR.

MPs polymer identification in feed sample (N1, N2)

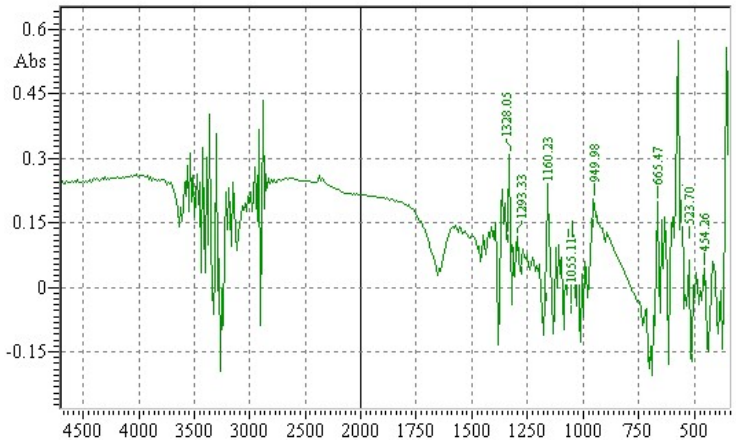

Figure 18: FTIR analysis data of some microplastic items of sample (N1, N2).

A total of 47 microplastic items were examined where 44 items were identified while 3 item could not be identified. According to this analysis, PA (polyamide) or nylon was also the most dominant polymer (39%).

Sample Name	Description	Number	Percentage (%)
N1 N2	Total particle measured	47	100
	Total polymer identified	44	97.8
	PA	18	39
	PC	7	15
	PE	6	13
	PVC	5	11
	PP	3	6.4
	EVA	3	6.4
	PET	2	4.3
	Total unidentified particle	3	6.4

Table 9: MPs polymer composition in sample (N1, N2) identified by FTIR.

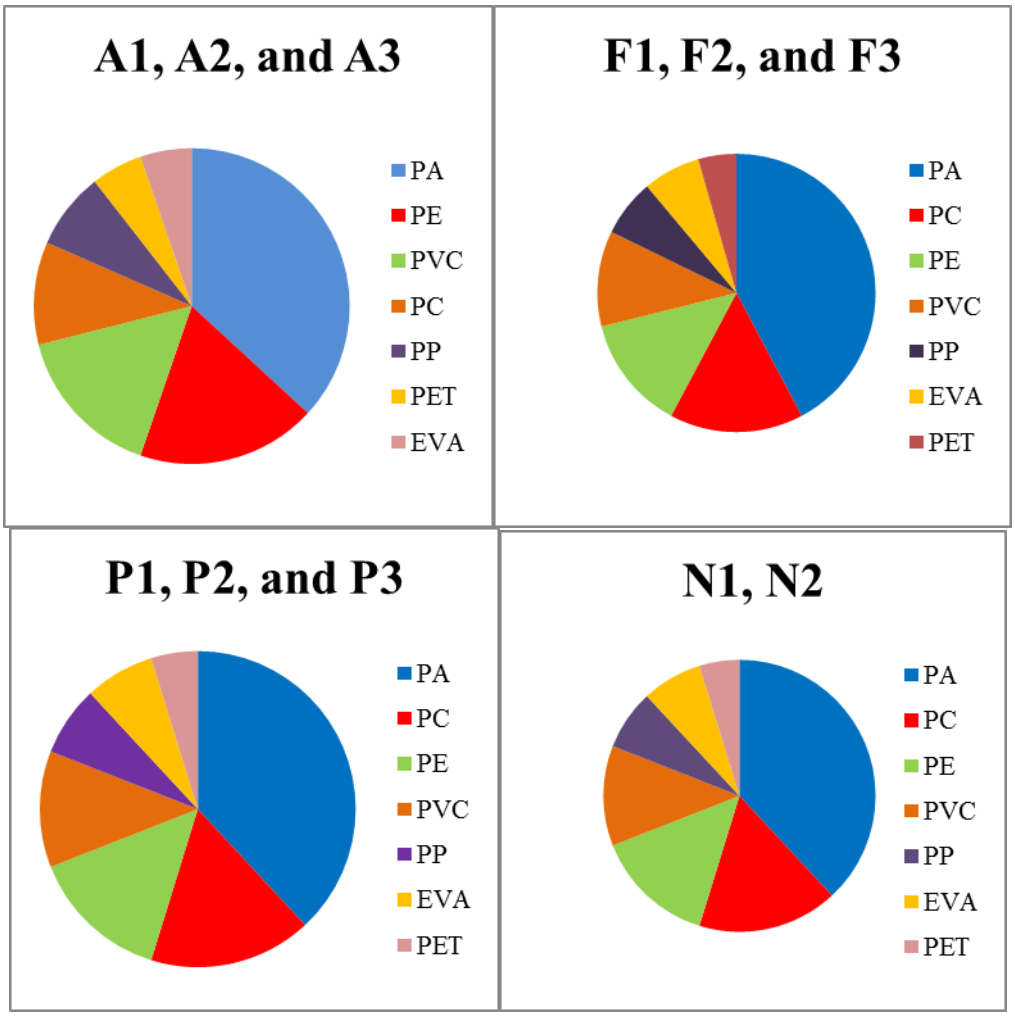

Figure 19: Composition of different MP polymers.

Discussion

The presence of microplastics within freshwater environments and aquaculture systems is a significant sustainability concern (Parvin *et al*., 2021; Rahman *et al*., 2022). Studies support the idea that the threat of microplastic contamination extends to aquaculture fish feed in Bangladesh. In one study, microplastics were separated from catfish feed using peroxide oxidation, density separation with NaCl, and filtration with a 0.22 m pore size cellulose nitrate filter. Another investigation centered on marine-derived commercial fish meal, a key ingredient in fish feed, and was conducted in Iran. In this research, microplastics were extracted through potassium hydroxide (KOH) oxidation, followed by density separation utilizing sodium iodide (NaI), and filtration via a Whatman filter with an 8 µm pore size (Hanachi *et al.,* 2019). Yet another study assessed aquaculture feed to discern the contamination pathway for farmed fish. Aquaculture feedstocks bought from stores, like fishmeal and soybean meal, were broken down with KOH and separated by density with ZnCl2. Particles were looked at with microscopy and spectroscopy (Walkinshaw *et al.,* 2022). We successfully trialed NaCl flotation to extract microplastics from fish feed. A simple overflowing technique provided the highest recovery rates of spiked microplastics; 108 of the potential microplastics in our samples were 601 to 1000 µm, highlighting the importance of recovering smaller microplastics and the suitability of our method. This present study investigated the presence of microplastics in commercially available fish feed within the five brands (pre-starter, starter, and grower) from Aturar depo, Hathazari, and Khatunganj local markets. The presence of microplastics was evident across all brands, with a collective total of 331 particles detected within 13 feed samples, weighing 585g. The average particle count in the five commercial feeds for various fish markets was approximately 567±296.18 particles per kilogram. A comprehensive quantification of primary microplastics influx and secondary microplastics generation in the marine environment remains limited globally and locally. Scant data is available regarding the diverse contributions of various plastic types and their associated chemicals, along with temporal variations. This hampers the ability to predict future trends in the potential impact of microplastics on fisheries and aquaculture. Hanachi *et al.,* (2019) detected particles ranging in size from 452 µm to 161 µm in four commercial fish meals. The size range of those particles was 158 µm to 810 µm. Rahman *et al.,* (2022) identified microplastic particles in commercial fish feed collected from ten fish farms, where the size range of detected particles was 10 µm to 88 µm, and the identified particles were fiber, film, and fragments, where fibers were the dominant category. The present study found particles of 942.8±128.12 µm in size in seven commercially available fish feeds in Bangladesh. Here size range of those particles is 192 µm to 2696 µm. In the current study, it was discovered that particle counts per kg are lower and particle size is larger in fish feeds. However, Rahman *et al.,* (2022) detected a high number of particles with smaller sizes. The variation in particle number and size is due to the use of different detection instruments and methods. For example, in the present study, a mortar pestle was not used to make powder from the samples, while Rahman *et al.,* (2022) used an electric blender, which might be the cause of the smaller particle amount. On the other hand, in this work, cellulose filter paper was used with a pore size of 20 µm, whichcan separate particles larger than 180 µm, and Rahman *et al.,* (2022) used a cellulose nitrate filter with a pore size of 0.22 µm, which can separate very small particles.

A study showed that fish meal contained MPs like fragments, films, pellets, and fiber, where fragments were the most dominant (67%) category of particles (Hanachi *et al*., 2019). According to Rahman *et al.,* (2022), commercial fish feed samples contained particles like fiber, film, and fragments, where fibers were the dominant category. Walkinshaw *et al.,* (2022) detected three different types of particles, like fibers (82.5%), fragments (16.8%), and films (0.8%), in fishmeal and soybean meal. In the present study, seven types of particles (fiber, film, fragments, foam, pellets, micro beads, and nurdles) were detected in commercial fish feeds, where fiber is the highest in

percentage (52%), followed by film (21%), fragment (15%), pellet (9%), foam (2%), micro beads (0.61%), and nurdles (0.31%).

The particle types are following the trend:

Fibers> Films> Fragments> Pellet> Foams> Micro beads> Nurdle

Here, it is found that almost all the studies discussed here found that fiber is a common and dominant particle type present in fish feeds and meals that originated from different areas and different raw materials. Rahman *et al.,* (2022) reported five different colors of particles in fish feed and flesh samples, and the identified particle colors were blue, red, black, brownish, and translucent. There were three different colors of particles detected in fish feed ingredients: fishmeal and soybean meal. The most common color of particle was blue (70%), followed by red (11.8%) and black (6.5%) (Walkinshaw *et al*., 2022). There were eight different colors of particles found in this study, and brown (24%), black (22%), blue (17%), red (16%), green (14%), white (4%), yellow (2%), and transparent (0.61%) had the highest color abundance. The color distributions of particles were as follows: brown, black > blue> red> green > white >yellow> transparent. One-way ANOVA results showed there was statistically significant variation among and between the feed brands and company type in terms of particle size and color, sample form, and particle size at $p<0.001$. An ANOVA test (Duncan Multiple Range Test) was performed, which showed that there was a significant difference in mean between different brands ($p < 0.05$) in the feed sample for particle size (Table 2) and color (Table 4). Polyamide (PA), a prevalent type of commodity plastic, finds extensive use in both household and industrial contexts, ranging from clothing items to fishing equipment. Over time, these materials tend to sink into sediment due to their inherent negative buoyancy (Andrady, 2015; De Sá *et al.,* 2018). Notably, PA stands out as one of the frequently identified types of microplastics (MPs) discovered in the digestive tracts of fish, as observed along the southeastern coast of India (Sathish *et al.,* 2020) and the Atlantic coast of Morocco (Maaghloud *et al*., 2020). Likewise, PA is a commonly detected component in environmental samples obtained from various locations, such as the Great Lakes (Driedger *et al.,* 2015) and Lake Garda in Italy (Imhov *et al.,* 2016). In this study, the identification of MPs polymers was done by FT-IR, where the percentage of PA (polyamide) was higher than any other polymer.

Conclusion

Microplastics, tiny particles, are a growing environmental contaminant that affects the worldwide ecology. This pollutant has entered the human food chain through fish, shrimp, turtles, and crabs. Microplastics from various sources have also contaminated inland water systems with aquaculture species. Bangladesh, the fifth-largest aquaculture producer, heavily uses commercial fish diets. Research shows that aquaculture systems contain microplastics from artificial fish meals. Thus, this study examines microplastics in Bangladeshi commercial fish diets. The emerging environmental contaminant is microplastics. This contaminant affects the entire ecosystem and is reported worldwide. Microplastics in fish, shrimp, turtles, crabs, and other aquatic species have penetrated the human food chain. Microplastics from various sources have been identified in inland water aquaculture species. Bangladesh ranks 5th in aquaculture production, and commercial fish diets are widely employed to improve fisheries. Artificial fish feed is a source of microplastics in aquaculture, according to research. Thus, this study extended microplastics assessment in Bangladeshi commercial fish feeds. Five commercial fish feed samples from three developmental stages were purchased from local stores. Particles were recognized under a microscope in these samples following the NOAA microplastic assessment technique. The study convincingly shows microplastic particles in Bangladeshi commercial fish diets. Interestingly, all fish feed samples included microplastic particles. In 585g of feed samples from five brands, 331 particles

were found. The average microplastic abundance was 570±231 particles per kilogram. This study shows that commercial fish feed causes microplastics in Bangladeshi aquaculture fish. Based on eating behavior and patterns, future studies should determine how often fish eat microplastics. Experiments on how microplastics influence fish physiology and how they reach consumers through the food chain might be useful. Understanding these implications is critical given the high protein content of aquaculture fish. Analysis of feed components and production processes could also reveal the sources of microplastics in fish feed. Plastics are essential to modern life and serve many of our requirements, but they also threaten the environment and all of its components. Since it is hard to stop using plastic products, recycling them safely and scientifically and taking safeguards may lessen microplastic contamination. In addition, the government should ensure efficient waste disposal, consistent monitoring of industrial effluent plants, and rigorous compliance with legislation. Public awareness is also crucial. Otherwise, microplastic contamination will be hard to eradicate, and the Bay of Bengal will become a vast plastic storage facility.

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