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Preliminary Study on Abundance of Microplastic in Sediments and Water Samples Along the Coast of Pakistan (Sindh and Balochistan)-Northern Arabian Sea

Quratulan Ahmed[1,*], Qadeer Mohammad Ali[1], Levent Bat[2], Aysah Öztekin[2], Sehrish Memon[1], Azizullah Baloch[1]

[1]University of Karachi, The Marine Reference Collection and Resources Centre, Karachi, 75270 Pakistan.
[2]Sinop University, Fisheries Faculty, Department of Hydrobiology, 57000 Sinop, Türkiye.

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Corresponding Author
Tel.: +923322483260
E-mail: quratulanahmed_ku@yahoo.com

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Abstract

Plastic material dominates our life and accordingly, it dominates the environment as a pollutant. Pakistan coasts are facing with plastic pollution problem like the rest of the world. The number and types of microplastics found in sea water and sediment samples from 25 locations along the Arabian Sea coast of Pakistan were explored in this study. The results of the present study show that the region is under a high pollution from microplastics. Microplastic abundance in seawater was found as mean 582.12±246.14 particle. L-1 and in sediment samples was mean 987.40±617.06 particle.kg-1 dry sediment. Microplastic concentration was maximum in Manora both seawater and sediment samples. Fibers were major contribution to total microplastics, up to 99% of all samples both seawater and sediment samples.

Introduction

Litter pollution is one of the most important problem of our day and plastics are the dominant type of litter, which are one of the most considerably used products in the world and the increasing amount of use of this material pose a significant management problem (Thompson et al., 2009). As a result of this, the accumulation and fragmentation of plastics in the environment emerge as one of the most important problems in recent times (Barnes et al., 2009), finally all plastic particles smaller than 5 mm defined as microplastics (Arthur et al., 2009).

Recently microplastics definition is suggested by Frias and Nash (2019) as "*any synthetic solid particle or polymeric matrix, with regular or irregular shape and with size ranging from 1 µm to 5 mm, of either primary or secondary manufacturing origin, which are insoluble in water*". Microplastic pellets (or nurdles) used in industrial manufacturing and microbeads found in personal care products are examples of primary microplastics, while secondary microplastics are created by the breakdown of bigger plastics (Cole et al., 2011; Hidalgo-Ruz et al., 2012; Rogers, 2020). In all types of environment around the world contaminated with microplastics (Eriksen et al., 2013; Desforges et al., 2014; Mathalon and Hill, 2014). The presence and distribution of microplastics along the coasts is a growing problem worldwide.

Pakistan has yet to adequately recognize the problems of marine litter and microplastic pollution. The majority of marine litter originates on land, from sewage flow, beach visitors, poor waste management, commercial fishing, shipping, and other industrial

activities like ship breaking (Qaimkhani, 2018). In Pakistan, all large cities have great hurdles in dealing with the problem of urban trash (Qaimkhani, 2018). There are limited investigations conducted on marine litter (Qari and Shaffat, 2015; Ali and Shams 2015) and microplastic pollution in the region (Balasubramaniam and Phillott, 2016; Irfan et al., 2020). Based on this, this investigation had been carried out to reveal the current microplastics pollution in this region for the first time in such a wide area. The goal of this study was to look at the number and types of microplastics found in seawater and sediment samples collected from 25 locations along the Arabian Sea coast of Pakistan.

Material and Methods

Survey Area

Pakistan coast which has approximately 1000 km coastline to Arabian Sea extending east to west, from the Indian border to the Iranian border (Figure 1).

Microplastic surveys conducted along the Pakistan coast during 2020.Sediments and water samples were collected from twenty-five sampling stations along the coast of Pakistan. Detailed information about the stations is given in the Table 1. 15 of the stations are located in the Sindh province (Stations 1-15) and 10 are located in the Balochistan province (Stations 16-25). Sindh has a total of 266.5 kilometers of coastline between the Indian borders at Sir Creek in the Indus Delta on the east and the Hub River beachfront on the west. From the Hub River in the east to the Iranian border near Jiwani in the west, the Balochistan Coast runs for 734.5 kilometers (Qaimkhani, 2018).

Sampling and Analyzing

During the survey, 1-liter surface-water were collected in glass bottle was immersed in water with its exterior attached to floats to keep the top at a depth of 5 cm. Sediment samples were obtained with a metal spoon from the top 5-10 cm of the sediment, and 1 kg sediment samples were taken in glass bottles with seawater at the same locations. Until analysis, all samples were kept at 4°C.

Seawater samples were passed through filters with three different mesh size (500 µm, 250 µm, and 55 µm). Material remaining on the filters were dried and stored for further analysis.

Sediment samples were dried for three days at 65°C to achieve a consistent weight. Density separation process applied to sediment samples. In a glass beaker, 200 g of each dried sediment sample was deposited, and 500 mL of saturated $NaCl^-$ solution (density 1.2 $g.cm^{-3}$) was added. The suspension was decanted into a 150 mL glass beaker after being manually agitated for 2 minutes and settling for 2 hours. Treatment with 20 mL 30 percent H_2O_2 at 65°C for 24 hours destroyed organic materials in the solution. The solutions were passed through filters with three different mesh size (500 µm, 250 µm, and 55 µm) and the filters were dried and kept in preparation for further examination.

The dried filters were investigated using a Stereo Microscope. Each filter was observed under microscope, and microplastic particle amount, shape, color, and size are all documented.

Microplastics were categorized according to types (fiber, fragment, film, foam and beads) (Figure 2). Microplastics samples were kept in separate vials after allocation and counting.

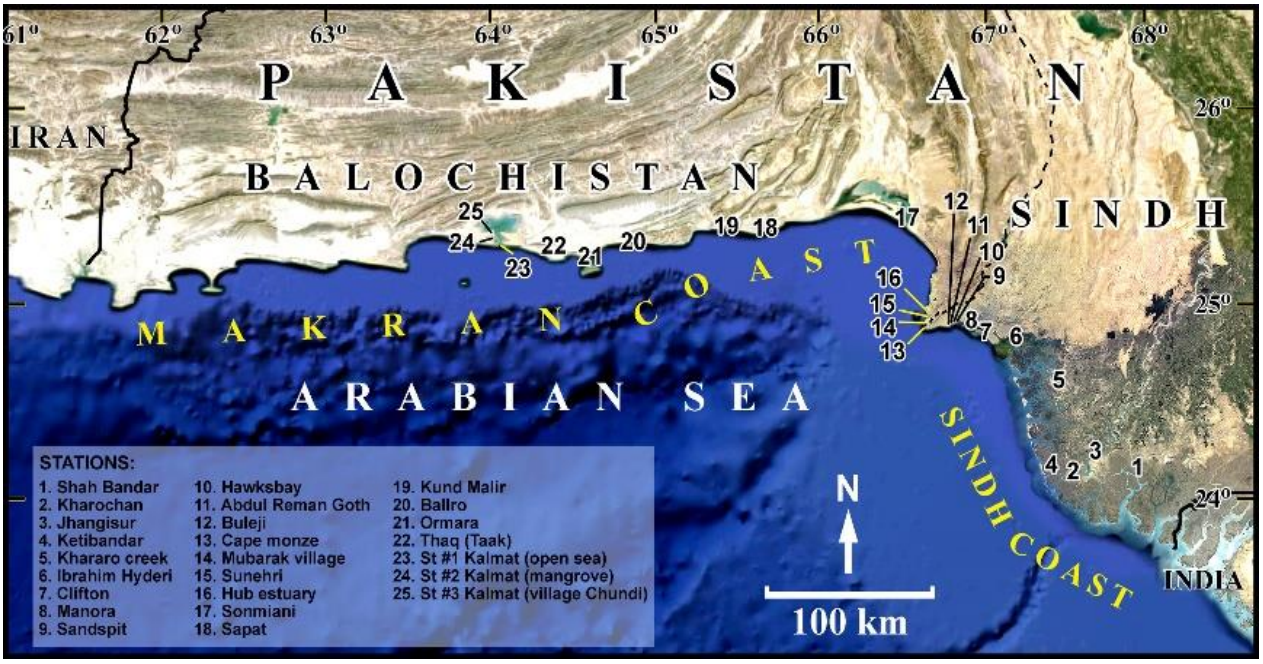


Figure 1. Survey area

Quality assurance and quality control

During the entire procedure, special precautions were taken to prevent contamination. Wherever possible, non-plastic components were employed. Contamination was avoided by cleaning and drying all containers three times with distilled water before use. Distilled water was used to rinse all of the filters. To avoid airborne contamination, the laboratory was sealed during sample handling and analysis, and cotton lab coats and gloves were always worn. During the drying and suspension process, aluminum foil was always used to cover the filters and solutions.

Data Analysis

Abundances were recorded as particle. L^{-1} for seawater and particle.kg^{-1} dry sediment for sediment samples. The IBM Statistic Package for Social Science was used for statistical analysis (SPSS). Statistical analysis was performed by grouping the microplastic in the stations according to the province (Sindh or Balochistan) where the stations are located and the population degree (Urban or Rural) of the stations. The significance of differences between the province and between the population degree being determined by Student's t-test (p=0.05). Prior to statistical analyses, the log transformation was applied the data.

Table 1. Sampling stations along the Pakistan Coast

No	Localities	Latitude and Longitude	Morphology	Population Degree	Recreational Usage	Seawater abundance (particle.L^{-1})	Sediment abundance (particle.kg^{-1})
St.1	Shah Bandar	24°07’13.2’’N 67°55’05’’E	Muddy (Indus deltaic area)	Rural	No	464	0
St.2	Kharochan	24°04’30’’N 67°34’42’’E	Muddy (Indus deltaic area)	Rural	No	569	1155
St.3	Jhangisur	24°04’55’’N 67°36’19’’E	Muddy (Indus deltaic area)	Rural	No	517	1110
St.4	Ketibandar	24°07’40.1’’N 67°22’31.6’’E	Muddy (Indus deltaic area)	Rural	No	883	2080
St.5	Khararo creek	24°32’48’’N 67°27’43’’E	Muddy (Indus deltaic area)	Rural	No	315	630
St.6	Ibrahim hyderi	24°47’03’’N 67°08’28’’E	Creek area muddy	Urban	No	686	1280
St.7	Clifton	24°47’24’’N 67°02’41’’E	Sandy	Urban	Yes (Very High)	778	1710
St.8	Manora	24°47’55.8’’N 66°57’56.2’’E	Rocky	Urban	Yes (Very High)	1096	2645
St.9	Sandspit	24°49’04’’N 66°56’28’’E	Sandy	Urban	Yes (Very High)	888	1105
St.10	Hawksbay	24°51’33.3’’N 66°51’55.0’’E	Sandy	Urban	Yes (Very High)	604	700
St.11	Abdul Rehman Goth	24°50’22’’N 66°49’02’’E	Rocky + sandy	Urban	Yes (High)	846	735
St.12	Buleji	24°50’24.1’’N 66°49’21.2’’E	Rocky beach	Urban	Yes (Very High)	939	795
St.13	Cape monze	24°50’02’’N 66°39’24’’E	Rocky + sandy	Rural	Yes (Low)	394	645
St.14	Mubarak village	24°50’44’’N 66°39’35’’E	Rocky + sandy	Rural	Yes (High)	481	1170
St.15	Sunehri	24°52’44’’N 66°40’57’’E	Rocky + sandy	Rural	Yes (High)	554	895
St.16	Hub estuary	24°55’25’’N 66°43’28’’E	Estuary (sandy)	Rural	No	251	475
St.17	Sonmiani	24°27’07’’N 66°33’36’’E	Bay	Urban	Yes (High)	941	2090
St.18	Sapat	25°25’01’’N 65°51’50’’E	Sandy	Rural	No	383	850
St.19	Kund Malir	25°23’29’’N 65°27’27’’E	Rocky + sandy	Rural	Yes (Moderate)	296	450
St.20	Ballro	25°19’36’’N 64°53’20’’E	-	Rural	No	477	510
St.21	Ormara	-	Rocky	Urban	Yes (Moderate)	351	650
St.22	Thaq (Taak)	25°16’11’’N 64°30’21’’E	Rocky + sandy	Rural	Yes (Moderate)	267	475
St.23	Kalmat (open sea)	25°19’36’’N 64°02’22’’E	-	Rural	No	750	1490
St.24	Kalmat (Mangrove)	25°20’23’’N 64°03’46’’E		Rural	No	331	460
St.25	Kalmat (Village chundi)	25°23’58’’N 64°02’31’’E		Rural	No	492	580
					Mean	582,16	987,40
					SD	246,17	617,06

Results

Abundance of microplastics

During the study, in total, 14554 microplastics were found in sea water and 4900 microplastics were found in sediment samples.

Microplastics were found at all stations in sea water (Figure 3). Microplastic abundance in seawater was found as mean 582.12±246.14 particle. L^{-1}. Microplastic concentration was minimum in Hub estuary (St.16: 215 particle. L^{-1}) and maximum in Manora (St.8:1089 particle. L^{-1}). When the stations were evaluated to their provinces, the concentration of microplastics in the Sindh province (667.6±894.57 particle. L^{-1}) was significantly higher than the concentration found in the Balochistan province (453.9±225.75 particle. L^{-1}; $p < 0.05$). When the survey stations are evaluated according to population status, urban regions (782.78±242.38 particle. L^{-1}) had significantly higher microplastics concentration than rural regions (469.31±167.01 particle.L^{-1}; $p < 0.05$).

Microplastics were identified in all but one of the stations' sediment samples (St.1: Shah Bandar) (Figure 3). Microplastic abundance in sediment samples was mean 987.40±617.06 particle.kg^{-1} sediment Microplastic concentration was found as maximum in Manora (2645 particle.kg^{-1} sediment). When the stations were evaluated to their provinces, the concentration of microplastics in the Sindh province was mean 1110.33±645.01 particle.kg^{-1} sediment, and Balochistan province was mean 803.00±552.47 particle.kg^{-1} sediment ($p>0.05$). When the survey stations are evaluated according to population status, urban regions (1281.67±728,00 particle.kg^{-1} sediment) had higher microplastics concentration than rural regions (821.88±494.57 particle.kg^{-1} sediment; $p>0.05$).

When the abundance of microplastics was examined, high amounts of microplastics were found in both marine environments (seawater and sediment). Sindh province was found to be more polluted than Balochistan province and also urban regions had higher microplastics concentration than rural regions both sediment and seawater samples. The highest microplastic amounts was found in Manora (St.8) both sediment and seawater samples. It was seen that the stations with high microplastic concentration in seawater also contain high microplastic concentration in the sediment, and the stations with low microplastic concentration also contain low microplastics concentration in the sediment. (Figure 3).

Types of microplastics

Microplastics were found in 5 categories (fiber, fragment, film, foam and Beads-Figure 3). Fibers were the predominant type in both sediment and seawater samples. Beads and films were found at the same stations in sediment and seawater and more fragments were found in sediment samples.

In seawater samples, dominant microplastic type was fiber (99.77%) in all station and followed by fragment, film, foam and beads with small proportion (Figure 3). Fibers are the predominant MP type found at

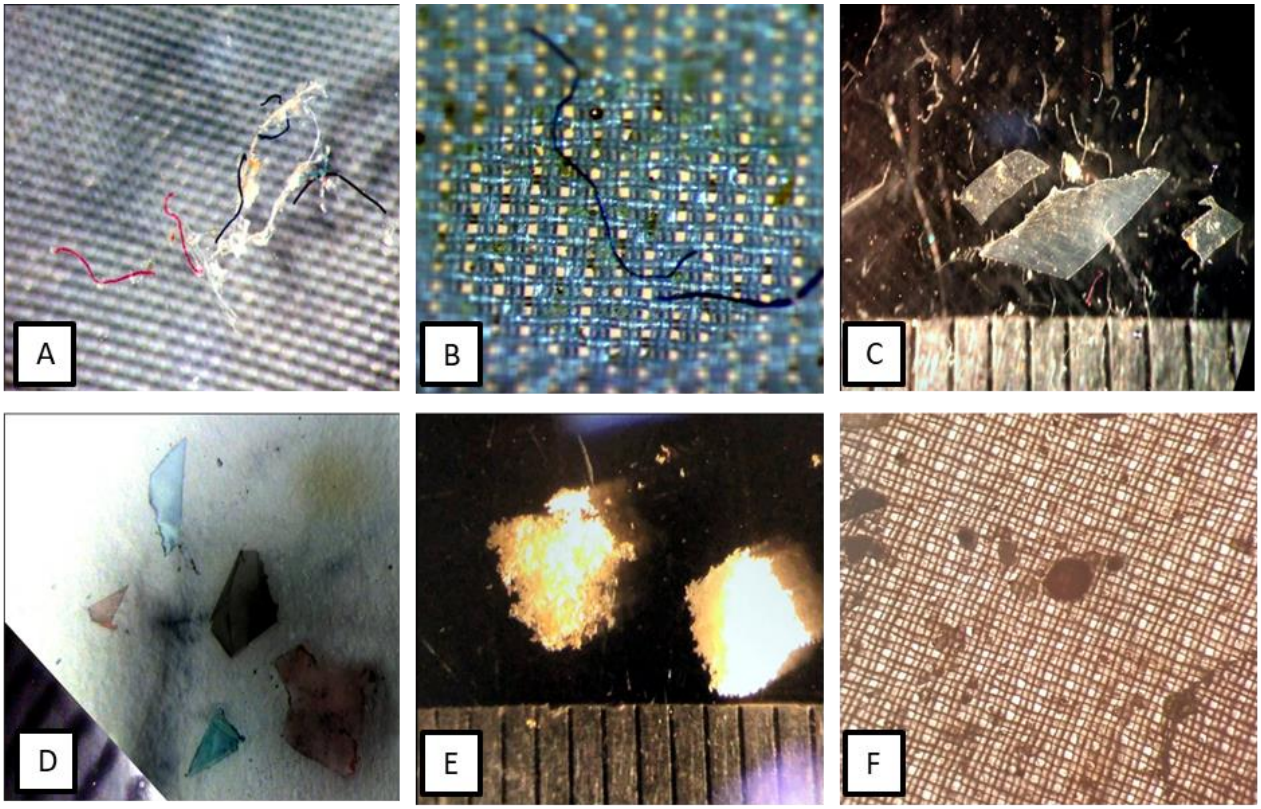
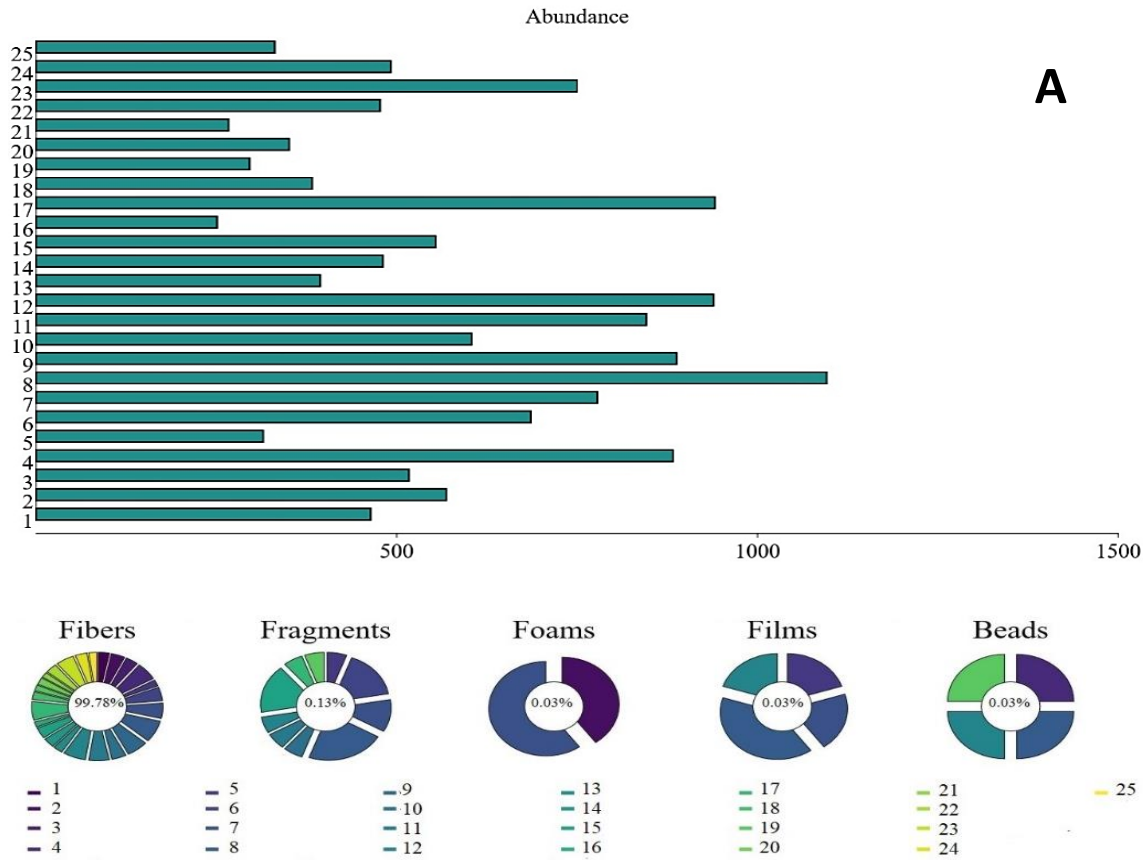


Figure 2. Types of microplastics in sampling stations (A,B: Fibers, C: Films, D: Fragments, E: Foams, F: Bead)



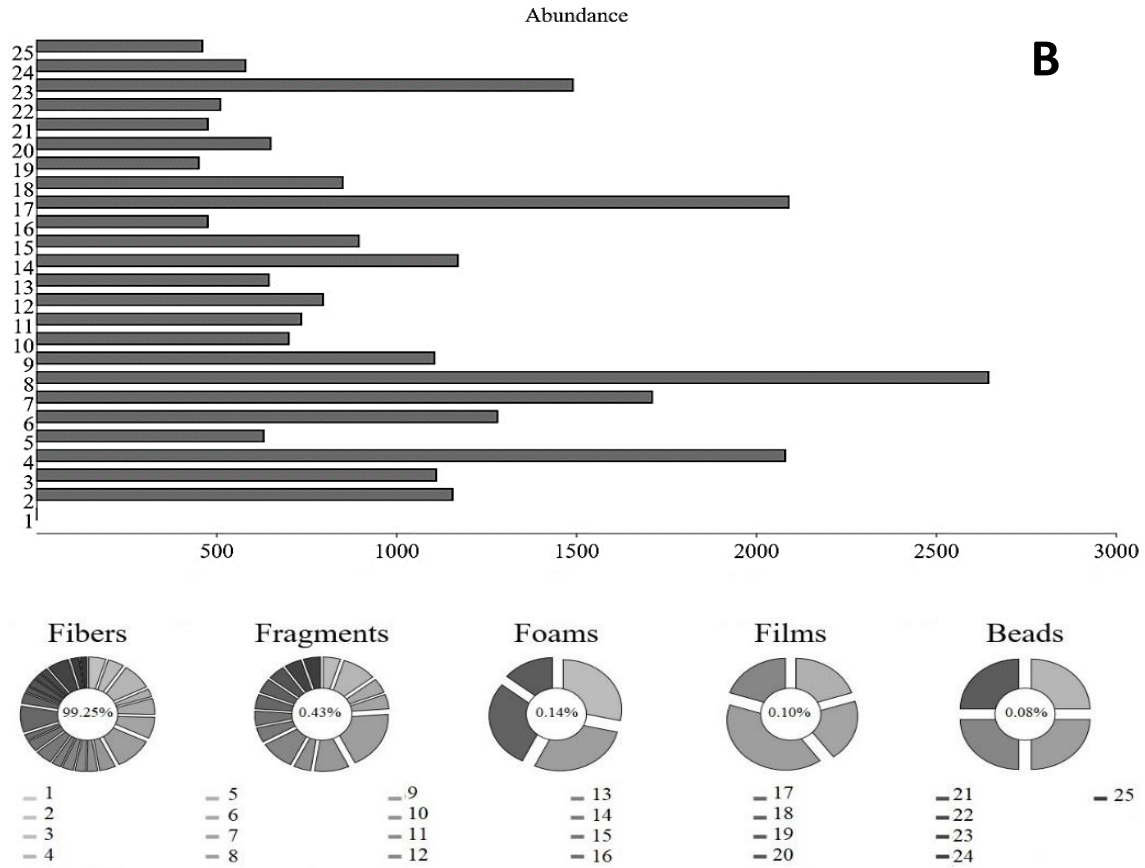


Figure 3. Abundance and types of microplastics in sampling stations [Seawater: abundance-particle.L^{-1} (A), Sediment: abundance-particle.kg^{-1} sediment (B).

all stations, while other types of plastic have been found at a few station (Fragments in St.5,6,7,8,10,11,12,15,17 ,19; Foams in St.2,7; Films in St. 5,7,8,12; Beads in St.4,8,12,19).

Dominant microplastic type was fiber (99.24%) in all station and followed by fragment, film, foam and beads with small proportion in sediment samples (Figure 3). Fibers were found at all stations (exceptional St.1), while other microplastic types of plastic have been found at a few stations (Fragments in St.3,4,6,7,8,9,10,12,14,15,17,18,20,23,24; Foams in St.23,8,18,19; Films in St. 5,7,8,12; Beads in St.4,8,12,19).

Microplastics are filtered with 3 different mesh size filter during laboratory analysis and in seawater samples 35.53% of microplastics were 500 µm filter, 21.57% of microplastics were 250 µm filter, 42.90% of microplastics were 55 µm filter. In sediment samples 33.19% of microplastics were 500 µm filter, 22.82% of microplastics were 250 µm filter, 43.98% of microplastics were 55 µm filter.

Discussion

The present study is a preliminary investigation on abundance of microplastic in sediments and water samples along the coast of Pakistan (Sindh and Balochistan)-Northern Arabian Sea. Microplastics amount (particle/l in seawater samples and particle/kg dry sediment in sediment samples) and types (fibers, fragments, films, foams and beads) were investigated in 25 locations along the Pakistan coast. There is very limited investigation on microplastic pollution in the Pakistan coast (Balasubramaniam and Phillott, 2016; Irfan et al., 2020-Table 2). A preliminary investigation on microplastic from beaches conducted in the Indian Ocean by Balasubramaniam and Phillott (2016). In this study Hawkesbay Beach researched in Pakistan and results of this study showed that there was 12 microplastic fibers in 25 g sand (480 fibers.kg^{-1}). Another investigation was conducted by Irfan et al. (2020) and they researched the abundance and distribution microplastics in the Ravi, Lahore. The results of the research showed that investigated Freshwater-system was contaminated with microplastics, both in sediment and in surface-water. The investigations carried out in the surrounding environment were given in the Table 2.

The results of the present study show that the region is under a high pollution from microplastics (Table 2). Microplastic abundance in seawater was found as mean 582.12±246.14 particle. L^{-1} and in sediment samples was mean 987.40±617.06 particle.kg sediment^{-1}. Microplastic concentration was maximum in Manora (located south of the Port of Karachi, Sindh) both seawater and sediment samples. Bilges, washings, and cleaning from engine rooms/floors of vessels are the sources of litter pollution in the Manora canal, which occur during loading and unloading at ports (Qaimkhani, 2018). Approximately 2,500 ships and 200 oil tankers are said to pass through the Manora Channel each year, bringing cargo to Karachi (Qaimkhani, 2018).

When the stations were evaluated to their provinces, the average amount of stations in the Sindh was higher than the Balochistan both seawater and sediment samples. Sindh is more populous than Balochistan besides there is poor disposal system in Sindh. Karachi which is the industrial and commercial center of the country, located on the coast of the Sindh province. Environmental degradation along Pakistan's coastline, particularly the Karachi city harbor areas, has a major impact on millions of coastal residents and the marine ecosystem (Qaimkhani, 2018).

Fibers were detected as predominant shape of microplastics in the marine environment (sediments: Mathalon and Hill, 2014; Nel and Froneman, 2015, water-coloumn: Bagaev et al., 2017, surface-water: Lusher et al., 2014; Dubaish and Liebezeit, 2013). During the research, all samples were dominated with the fibers having considerable abundance (up to 99% both seawater and sediment). The similar result was reported from the previously conducted study in Hawkesbay Beach in Pakistan (Balasubramaniam and Phillott 2016) and many other studies conducted in surrounding environment (Naji et al., 2017; Tiwari et al., 2019). According to Irfan et al. (2020), a large amount of fibers in the water can be linked to residential activities like washing clothes, which is the main sources of fibers into sewers (Kang et al. 2018; Wang et al. 2017), but the majority of pieces in the sullage carrier's water can be connected to the degradation of surrounding discarded municipal rubbish.

The effluent from washing machines is discharged into the local sewer system in nations with sewage infrastructure, which plays a critical role in the fate and movement of microfibres into the environment (Napper and Thompson, 2016). As a result, the massive amount of fibers released when clothing is washed is anticipated to contribute significantly to environmental microplastic contamination (Napper and Thompson, 2016). Qaimkhani (2018) stated that untreated water in the amount of 450 million gallons is dumped into the sea every day in Karachi and other coastal cities because no sewage treatment plant is operational (in December 2017 hearing before the Supreme Court).

It has been reported that microplastics are present in all types of environments around the world (Desforges et al., 2014; Eriksen et al., 2013; Free et al., 2014; Aytan et al., 2019). Microplastic consumption has been studied a variety of aquatic organisms from zooplankton to marine mammals (Sun et al., 2017; Karlsson et al., 2017; Lusher et al., 2015; Trifuoggi et al., 2019; Thomas et al., 2020). Plastics can be treated with a variety of chemicals during production (Andrady and Neal 2009; Napper and Thompson 2018), and they can also adsorb and concentrate pollutants from the environment (Teuten et al., 2009). As a result, there is growing concern about organisms consuming microplastics.

Conclusion

MPs pollution is predominant in all Pakistan coast. Large quantities of microplastics were encountered at all sampled stations (excluding only Shah Bandar's sediment sample). Fibers were major contribution to total MPs like many other regions all over the world.

The number of studies in the region is very limited and needs improvement. Marine litter and the problem of microplastic pollution has not yet been adequately recognized in Pakistan. Strict measures should be taken to reduce this pollution.

Ethical Statement

No ethical statement declared.

Funding Information

No financial support was used in this study.

Table 2. Studies on microplastic pollution

Location	Sampling Area	Abundance	Mp Types	References
Persian Gulf, Iran	Littoral Sediment	0-125±25 particles.kg^{-1} dry sediment	Fibers (88%) Films (11.2%) Fragments (0.8%)	Naji et al., 2017
Chabahar Bay, Gulf of Oman	Littoral Sediment	262±17 particle.kg^{-1}	Fragments (32.22%) Pellet (27.37%) Fibers (26.26%) Film (14.15%)	Hosseini et al., 2020
	Seawater	218 ± 17 particle.L^{-1}	Fibers (42.54%) Fragments (28.66%) Film (18.24%) Pellet (10.57%)	
Chabahar Bay, Gulf of Oman	Seawater	0.49 ± 0.43 particle.m^{-3}	Fibers (32.7%) Fragment (26.7%) Paint Flake (25.8%) Pellets (14.87%)	Aliabad et al., 2019
Northern part of Oman Sea	Littoral Sediment	138.3±4.5-930.3±49.1 particles.kg^{-1}	Frangments (32.9%) Fibers (29.9%) Films (26.8%) Pellets (10.4%)	Kor et al., 2020
Girgaon Mumbai (Arabian sea coast), Tuticorin, and Dhanushkodi (Bay of Bengal coast), India	Beach Sediment	Mumbai : 220±50 particles.kg^{-1}) Tuticorin : 181±60 particles.kg^{-1} Dhanushkodi:45±12 particles.kg^{-1}	Fibres (51%) Granules (40%) Films (9%)	Tiwari et al., 2019
Lahore, Pakistan	Freshwater system	Water: 16,150 ± 80 microplastics.m^{-3}	Water: Fragments (56.1%) Fibers (38.6%), Sheets (2.5%), Foams (2.2%) Beads (0.6%)	Irfan et al., 2020
		Sediment: 40,536 ± 202 microplastics.m^{-2}	Sediment Fragments (83.1%) Fibers (11.8%), Foams (3.4%) Sheets (1.3%) Beads (0.4%)	
Hawkesbay Beach, Pakistan	Beach Sediment	12 partilce.25 g sand^{-1}	Fibers	Balasubramaniam and Phillott 2016
Arabian Sea, Pakistan	Sediment	987.40±617.06 particle.kg^{-1}	Fibers (99.25%) Fragment (0.43%) Foams (0.14%) Films (0.10%) Beads (0.08%)	This study
	Seawater	582.12±246.14 particle.L^{-1}	Fibers (99.77%) Fragment (0.13%) Films (0.03%) Foams (0.03%) Beads (0.03%)	

Author Contribution

QA conceptualization, planned the study, coordinated sampling, work in the field and laboratory, helped young researchers; QMA organised, supported laboratory facilities; LB and AÖ wrote original draft, literature collection made tables / figures and analysed data; SM and AB carried out the sampling. All authors read and approved the final manuscript.

Conflict of Interest

All authors declared that they had no known competing financial interests or personal relationships that seemed to affect the work reported in this article. All authors followed the ethical responsibilities of this journal.

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