Proceedings of the 5th International Conference on Civil Engineering for Sustainable Development (ICCESD 2020), 7~9 February 2020, KUET, Khulna, Bangladesh (ISBN-978-984-34-8764-3)

OCCURRENCE OF MICROPLASTICS AT SHIP BREAKING AND RECYCLING ZONE OF BANGLADESH

Md Wahidul Haque[1], Tasneem Zafar[2] and M Mosharraf Hossain*[3]

[1]MS student, Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong 4331, Bangladesh, email: wahidulhaque7@gmail.com
[2]MS student, Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong 4331, Bangladesh, email: sameenez.ifescu@gmail.com
[3]Professor, Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong 4331, Bangladesh, email: mosharaf@cu.ac.bd

***Corresponding author**

ABSTRACT

Microplastic (MPs) has emerged as a global concern causing ubiquitous contamination of marine environment by tiny plastic particles. MPs are increasingly entering the food chain and subsequently into the human digestive system. Bangladesh is blamed for contributing MPS into the marine ecosystem through the Bay of Bengal. However, the country has not yet focused on this issue. On the other hand, Bangladesh is the global leader in open beaching ship breaking and recycling industry (SBRI) on the Sitakunda-Bhatiary shore of the Bay of Bengal. The role of SBRI in MP contamination of the Bay of Bengal is yet to be explored. This study evaluated the abundance, distribution, and characteristics of microplastics in the soils from SBRI. Samples were collected from 0-10, 10-20 and 20-30 cm depths at three zones viz., beaching, cutting and storage zones of five ship breaking yards (SBYs) and a control site at Kattali sea beach. MP fragments, between 0.3 to 5 mm, from the soil samples, were extracted following NOAA protocol for sediments. The fragments were analyzed under an optical microscope and by using ImageJ software and FTIR was used for the polymeric identity of the fragments. The study revealed an abundance of microplastics in the soils from SBYs with 217 MP particles per kg on an average compared to 127 MP particles per kg at the control site. Abundance varied among zones with respective ranges of 50-460, 80-410 and 70-330 for beaching, cutting and storage zones. Overall, the MP particles found in the ship breaking yard were mostly plastic fragments (45%) and fibers (40%). The respective ranges of plastic and polythene fragments were 10-260 and 10-50 pieces per kg of soil from SBYs compared to their respective values of 10 and 20-30 pieces in control. Fibers were the most abundant form of microplastic particles at beaching zone while at cutting and storage zones plastic fragments dominated. Microplastic particles from SBYs were mainly Transparent (22%) and Red & Black (10%) in color unlike particles in the control sample which were mostly Transparent or Grayish. Transparent particles were most abundant in the beaching and cutting zones and Green in the storage zone. The second most abundant color was Black and Red respectively at beaching and cutting zones while it was Transparent and Gray at the storage zone. In terms of shape, 45% of microplastic particles were irregular shaped, 18% elongated, 17% rectangular without variations between SBYs and control samples. In terms of abundance, respective zone sequences of irregular shaped, elongated and rectangular particles were storage>beaching>cutting, cutting>storage>beaching and storage>cutting>beaching. Among the microplastic particles, ~71% were in the size range of 0.3 to 1 mm and about ~28% were in the range of 1- 1.70 mm in SBYs as in the control. Respective size ranges of plastic particles at beaching, cutting, and storage zones were 0.33-1.45, 0.3-1.81 and 0.3-2.54 mm. FTIR indicated presence of Polyethylene (PE), Polyethylene terephthalate (PET), Polypropylene (PP), Polyvinylchloride (PVC), Polyurethane (PU), Polystyrene (PS) with PVC and PU occurring only in SBY samples. The result indicated elevated microplastic contamination of the coastal environment by SBRI with the exclusive contribution of PVC and PU. Therefore, SBYs should be directed to adopt MP control measures while breaking ships.

Keywords: *Microplastic, Ship breaking yards, Plastic pollution, Marine pollution.*

1. INTRODUCTION

Plastics in the environment are either macro- or micro-plastics based on their size (Barnes et al, 2009). There are varying opinions in classifying plastic fragments into microplastics, for example, less than 10mm diameter (Graham & Thompson, 2009), 2-6mm (Derraik, 2002), less than 2mm (Mark et al, 2010), smaller than 5.0 mm in size. Microplastic (MP) has become a global concern as exemplified by the UN environment's adoption of 'Beat Plastic Pollution' as the main theme of World Environment Day 2018. Unabated use of plastics all over the world at scale made MPs ubiquitous especially in the marine environment leading to damages of the marine ecology. In 2017, globally almost 350 million tonnes of plastics entered economic flow which was around 15 million tonnes higher than in 2016 (PlasticsEurope, 2018). About 15-31% of MPs in the oceans are primary MPs from laundering of synthetic clothes (35% of primary microplastics); abrasion of tires through driving (28%); intentionally added microplastics in personal care products, for example, microbeads in facial scrubs (2%) while 69-81% are secondary MPs (European Parliament, 2018).

As the MPs are increasing, in recent years MPs were extracted from sediment cores collected in Japan, Thailand, Malaysia, and South Africa. Variety of polymers, including polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terphthalates (PET), polyethylene-polypropylene copolymer (PEP) and polyacrylates (PAK) were identified in the sediment. Most of the microplastics which size were in the range of 315 lm–1 mm. The abundance of microplastics in surface sediment varied from 100 pieces/kg-dry sediment in a core collected in the Gulf of Thailand to 1900 pieces/kg-dry sediment in a core collected in a canal in Tokyo Bay (Matsuguma et al., 2017). MPs have been extensively detected in sea, freshwater, land environment and organisms (He et al., 2018). Polypropylene, nylon, PVC MPs were found in Belgian beaches (Claessens et al, 2011) in the Belgian beaches and estuarine and subtidal sediments around Plymouth, UK (Thompson et al., 2004). PS and PMMA acrylic fibres MPs are accumulating in marine habitats (Mark et al., 2011). PE, PP, PS, Nylon, PVA, and acrylonitrile butadiene styrene (ABS) have been recently identified in Singapore's coastal environment (Ng & Obbard, 2006).

Ship Breaking and Recycling Industry (SBRI) is a hugely profitable industry with a great environmental cost and Bangladesh has recently become the ship breaker in the world surpassing India in terms of gross tonnage (Express, 2018). Shipbreaking activities in Bangladesh are concentrated in Sitakund (Bhatiary to Barwalia), just north of Chittagong city on the Bay of Bengal. And most of the activities are performed in open beach sediment. Hazardous waste coming from the ship breaking yard includes asbestos, oil pollutants, persistent organic pollutants, Polycyclic Aromatic Hydrocarbons (PAHs), Polyvinyl Chloride (PVC), PCBs (Polychlorinated Biphenyls) and electrical equipment (Hossain & Islam, 2006; Jobaid et al, 2014) may easily contaminate the soil. MP fragments were found in a ship-breaking yard in the Arabian sea (Reddy et al, 2006). They found PU, nylon, PS, polyester, and glass wool in extracts from sediments which are normally used in the construction of ships and the making of associated components such as insulating materials, fabrics, packaging, etc. Therefore, during the ship dismantling process at Alang-Sosiaya (Reddy et al., 2006). Tiwari and her colleagues (2019) found Microplastic concentrations in beach sands were varied from 45 ± 12 MP kg^{-1} to 220 ± 50 MP kg^{-1} of dry sand of Indian coast (Tiwari et al, 2019). In an Indian ship-breaking yard, the highest concentration of microplastic was 89 mg kg^{-1}, whereas, in UK beach, the microplastic concentration was 9 kg^{-1}. Though many aspects of pollution from SBRI have been performed - the role of SBRI in MP pollution is yet to be investigated. This study addressed this research gap by analysing MPs in samples of soils from SBRI.

2. METHODOLOGY

2.1 Study Area

Soil samples were collected from five Ship Breaking Yards (SBYs) in Bhatiary, Chittagong, Bangladesh on May 2018. A control sample was collected from Kattoli Sea Beach which was not affected by ship breaking activities and is located in a similar geography compared to SBYs. In each yard, samples were taken from three zones – Beaching zone, Cutting zone and Storage zone. At each zone, the samples were taken from three depths *viz.*, 0-10 cm, 10-20 cm and 20-30 cm. For the analysis, the samples from three depths were made into a composite sample.

Table 1: GPS locations of soil samples collected from SBYs

Yard	Zone	Latitude	Longitude
1	Beaching	22.43522	91.73264
	Cutting	22.4352	91.73308
	Storage	22.43531	91.73344
2	Beaching	22.46905	91.71942
	Cutting	22.46926	91.71972
	Storage	22.46914	91.72024
3	Beaching	22.47972	91.71319
	Cutting	22.4798	91.7134
	Storage	22.47981	91.71373
4	Beaching	22.48392	91.71123
	Cutting	22.48402	91.71147
	Storage	22.48407	91.71198
5	Beaching	22.5169	91.68879
	Cutting	22.51702	91.68885
	Storage	22.51729	91.68891
Control	Beaching	22.35087	91.75723
	Cutting	22.35088	91.75782
	Storage	22.35085	91.7586

2.2 Materials and Methods

This separation of MPs from the soil matrix was done following adapted National Oceanic and Atmospheric Administration (NOAA) protocol for quantifying synthetic particles in waters and sediments. According to NOAA, this method can be used for the analysis of plastic debris include hard plastics, soft plastics (e.g., foams), films, line, fibres, and sheet in bed sediments. Moreover, this method is applicable for the determination of many common plastics including polyethylene (0.91-0.97 g/mL), polypropylene (0.94 g/mL), polyvinyl chloride (1.4 g/mL), and polystyrene (1.05 g/mL) (Masura et al, 2015). In this study, 0.3-5mm size plastic fragments were considered as microplastics. In brief, the samples were weighted and 100g of the samples were dried at 105°C for overnight. Then the dried soils were crashed using morter and pastle and sieved through a 5-mm metal sieve to discard the particles larger than 5-mm. Finally, the samples were subjected to density separation in 5M NaCl (aq.) solution in a beaker overnight to isolate the plastic debris through flotation. The floating solids were separated from the denser undigested mineral components using a density separator and transferred through a custom 0.3-mm sieve.

MPs that were collected on the 0.3-mm sieve were subjected to wet peroxide oxidation (WPO) after drying by using 20ml 30% Hydrogen peroxide (H_2O_2) in the presence of a 20ml 0.05M Fe(II) catalyst to digest organic matter. In this process, the plastic debris remains unaltered. Then the WPO mixture was again subjected to density separation in 5M NaCl to isolate the plastic debris through flotation. The floating solids were collected in a petri dish and dried at 60°C for 10-15 minutes or until the sample dryness. An optical microscope with 10X lens was used to take images of MPS to determine their sizes, shapes and colours beside other parameters. ImageJ software was used to determine the shape, length, area and perimeter of the microplastic particles. Fourier-Transform Infrared Spectroscopy (FTIR) was used to confirm the polymeric identity of the microplastic particles. The working flow chart is given below:

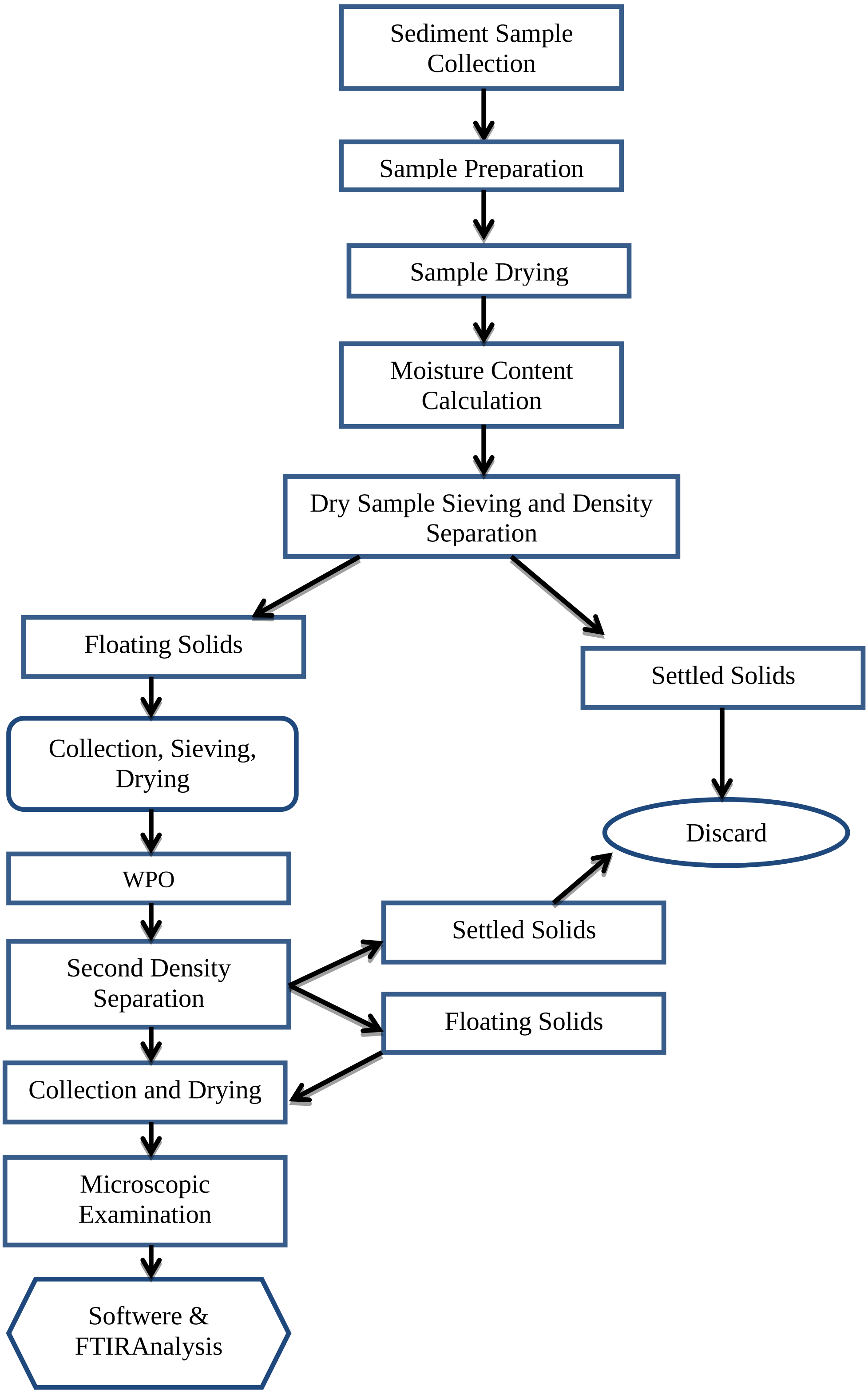


Figure 1: Flow Diagram of Working Process

3. RESULTS AND DISCUSSION

3.1 Number of Microplastics

MPs were found in all the SBY samples. The total number of microplastics particles in SBY samples was around 217 MP particles per kg compared to 127 in control indicating significant enrichment of microplastic in the SBYs. The number of particles varied among Beaching, Cutting and Storage zones (Figure 3.1) and the respective ranges were 50-460, 80-410 and 70- 330. In the control site the range was 80-160. In Belgian coastal waters total MPs count was as high as 390 particles per kg dry sediment (Claessens et al., 2011). Beijiang River littoral zone showed 178±69 to 544±107 MPs particles per kg sediment (Wang et al., 2016). In Indian coast, MPs concentrations in beach sands varied from 45±12 to 220±50 MP per kg sand (Tiwari et al., 2019). At Changjiang Estuary in China the mean MP concentration was 121±9 particles per kg (Peng et al., 2017). Compared to these reports, SBYs seems to substantially contribute in MPs enrichment in beach soil which may ultimately find their ways into the global oceanic circulation through the Bay of Bengal.

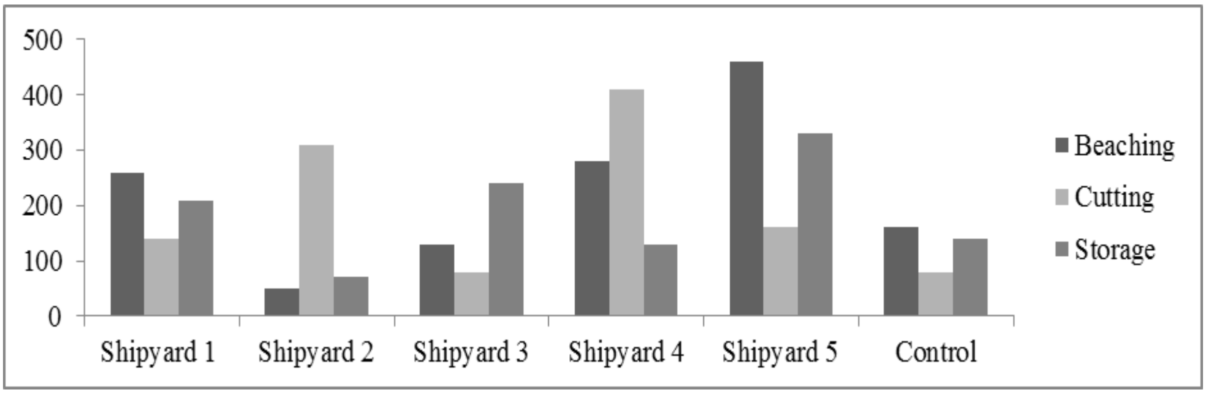


Figure 2: Total Number of Microplastics (Per Kg Soil)

3.2 Types of Microplastics

Several forms of MPs were found in soil samples from ship breaking. Plastic fragments, Polythene fragments, Pellets, Foams, and Fibers were the main forms. Plastic fragments and fibres were the most abundant form. Overall, the number of plastic fragments varied from 10-260 pieces, polythene fragments varied from 10-60 pieces, foam 10-50 pieces and fibre 10-340 pieces per kg soil in SBY. But in the control the number of plastic fragments is around 10 pieces, Polythene fragments varied from 20-30 pieces, foam 10-20 pieces and fibre 30-120 pieces per kg soil. In the Beaching zone, fibres were most abundant followed by plastic fragments whereas in the Cutting zone and Storage zone, plastic fragments were the most abundant form followed by fibres. In the beaching zone, fibers > plastic fragments > polythene fragments > foams. In the cutting zone, plastic fragments > fiber > foam > polythene whereas it is plastic fragments and foams > polythene and fiber in the control. In the storage zone, plastic fragments > fiber > polythene > foam whereas it is fiber > polythene and foam > plastic fragments in the control. In contrast, it was fiber > polythene > plastic and foam in the control.

At a glance, 1450 out of 3260 (~45%) of total microplastics found in SBY were Plastic fragments, 40% (1310 out of 3260) was Fibers, 9% (300 out of 3260) was Polythene fragments and 6% (200 out of 3260) was Foams (Figure 3.3a). On the other hand, 63% was fibers, 18% was Polythene fragments, 11% was Foams and 8% was Plastic fragments in the control (Figure 3.3b). In the beaching zone, around 46% of total microplastics was Fibers, 41% was Plastic fragments, ~10% was Polythene, and ~3% was Foam. In the cutting zone, around 45% was Plastic fragments, ~42% was Fibers, ~7% was Foam and ~5% was Polythene fragments. And in the storage zone, ~48% was Plastic fragments, ~32% was Fibers, ~12% was Polythene fragments and ~8% was Foams.

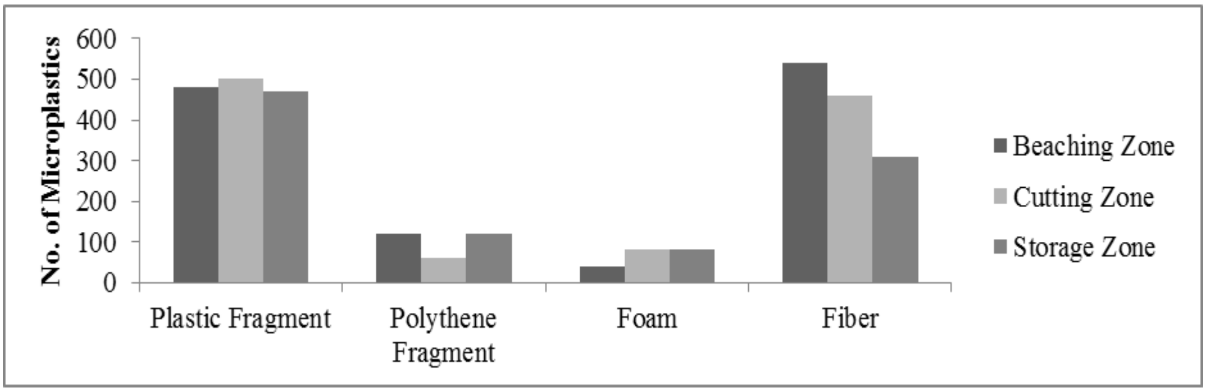
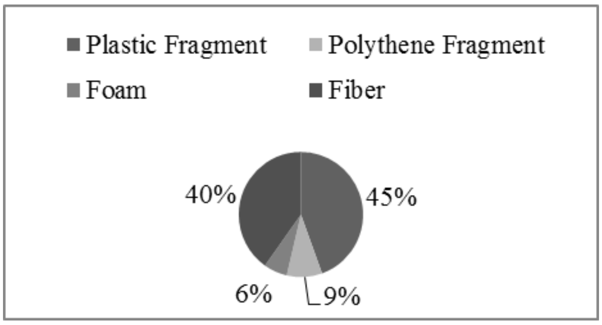


Figure 3: Types of Microplastics in different zones

In the Channel of Bizarte in Northern Tunisia the dominant shape of microplastic was fibre (88.88%) (Abidli et al, 2017). In Browne coastal areas, the proportions of polyester and acrylic fibres used in clothing were dominant (Browne et al., 2011). In the pelagic zone and sedimentary habitats, plastic fragments and fibres were accumulated (Thompson et al., 2004). In Belgian harbours, Polypropylene, nylon, polyvinyl alcohol Fibres were the most common types of particles found (Claessens et al., 2011). On the southeast coast of Shanghai fiber (93%) were the most abundant types. Comparison with these sites clearly indicated unique characteristic of SBYs in terms of forms of MPs released.



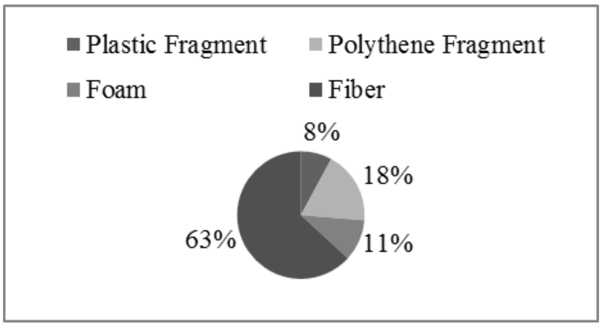


Figure 4 (a): Abundance of Microplastics in SBY (b) Abundance of Microplastics in Control

3.3 Color

In this study, Transparent microplastic particles were the most abundant both in ship-breaking yard and control samples. In the SBY the color abundance varies from Transparent > Red > Black > Green > Gray > Grayish > Yellow > Reddish > Blue > Brownish > Brown > Bluish > Golden > White > Greenish. On the other hand, in the control the color abundance varies from Transparent > Grayish > Reddish > Greenish > White, Green, Blue > Yellow. Black, Red, Reddish, Blue, Bluish, Yellow color particles were not found in the control. In SBY around 22% microplastics were transparent compared to around 47% in the control. About 10% of particles were Black, Red and Green in the SBY whereas 16% was Greyish and 11% was Reddish in the control. Black particles were absent in the control indicating less permanence of microplastics in the soil of control. Transparent particles were most abundant in the beaching and cutting zones and Green in the storage. However, the second most abundant color of microplastic particles was Black, Red respectively at beaching, cutting zone while it was Transparent and Grey at storage zones. In the Beaching zone, the abundance of microplastics by color was Transparent (25%) > Black (19%) > Grayish (12%) > Red, Yellow (~8%) > Blue, Green, Brownish (~5%) > Reddish, Gray, Golden, White (~3%) > Bluish (2%). In the Cutting zone the sequence was Transparent (24%) > Red (15%) > Reddish (14%) > Yellow (8%) > Blue, Green, Gray (~6%) > Brown, Grayish (~5%) > Black (4%), Bluish (2%), Golden (1%). And in the Storage zone the sequence was Green (18%) > Transparent and Gray (16%) > Black and Red (~7%) > Blue and Yellow (~6%) > Brown and Grayish (~5%) > Brownish (4%) > Bluish (3%) > Reddish and Greenish (~2%) > Golden (1%).

In the Channel of Bizarte in Northern Tunisia microplastic color were white blue green red and black (Abidli et al., 2017). At a Brazilian beach, plastic pellets/nibs were mainly white or pearly, bluish/greenish and brownish (Spengler et al., 2008).

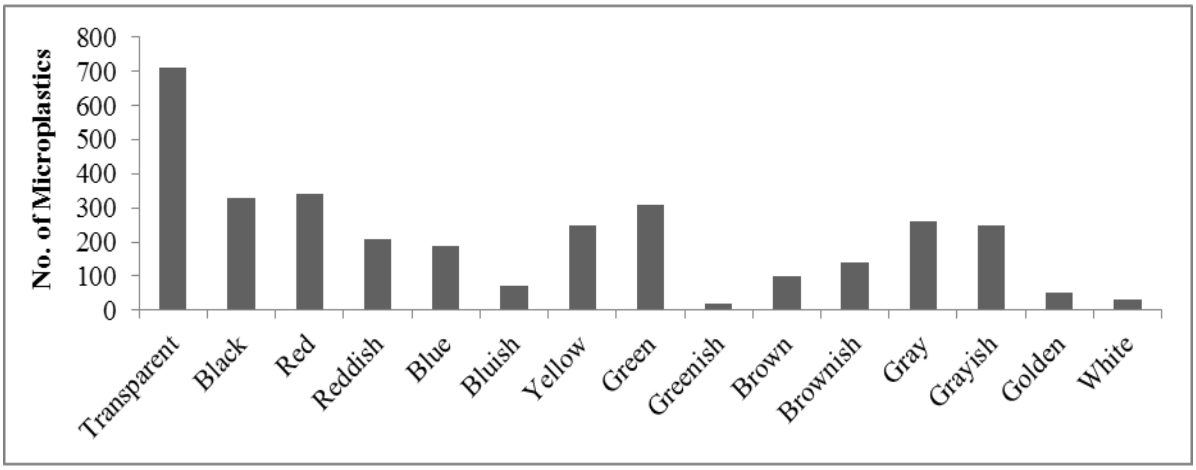


Figure 5: Total Color abundance in SBY

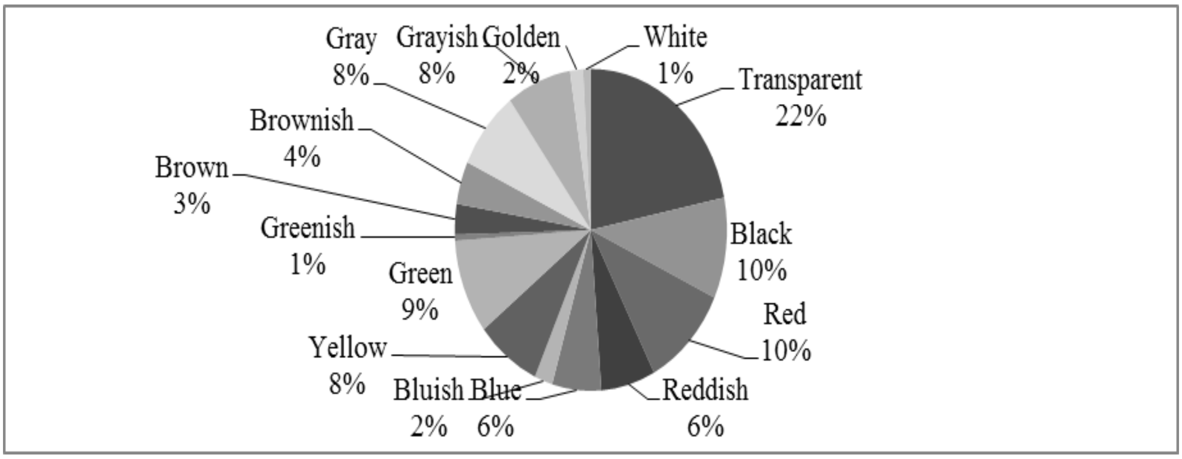


Figure 6: Total Color Percentage in SBY

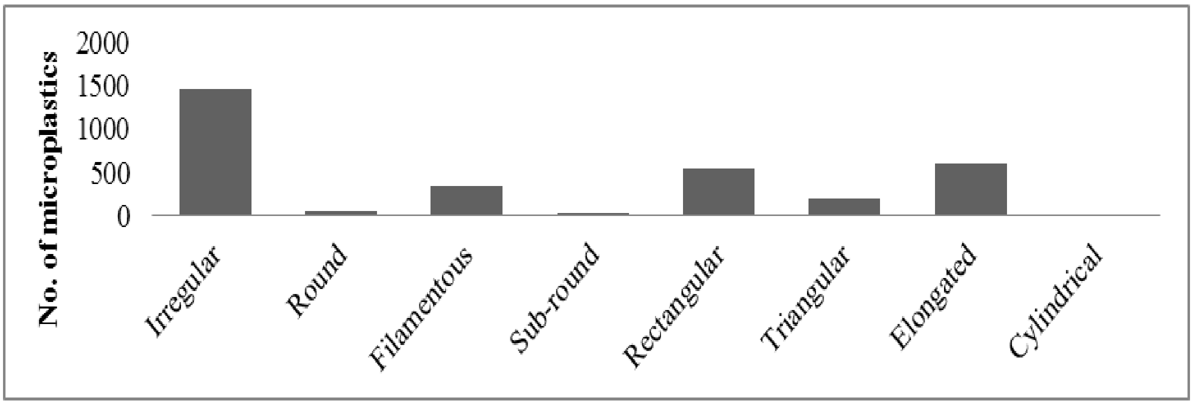


Figure 7: Total Shape-wise distribution of microplastics in SBY

3.4 Shape

Most of the microplastics were irregularly shaped followed by elongated shape both in SBY and control. In the SBY soil the abundance of microplastics on the basis of their shapes were as follows: Irregular > Elongated > Rectangular > Filamentous > Triangular > Round > Sub- round > Cylindrical. It was Irregular > Elongated > Rectangular > Filamentous > Sub- round in the control. Round, Triangular and Cylindrical shape particles were absent in the control.

Among the particles occurred in SBY soils, around 45% were irregularly shaped, ~18% elongated, ~17% rectangular, ~10% filamentous, ~6% triangular, ~2% round and ~1% in cylindrical and sub-round shape. On the other hand, in the control 47% was irregular in shape, ~26% elongated, ~13% rectangular, ~11% filamentous, ~3% sub- round.

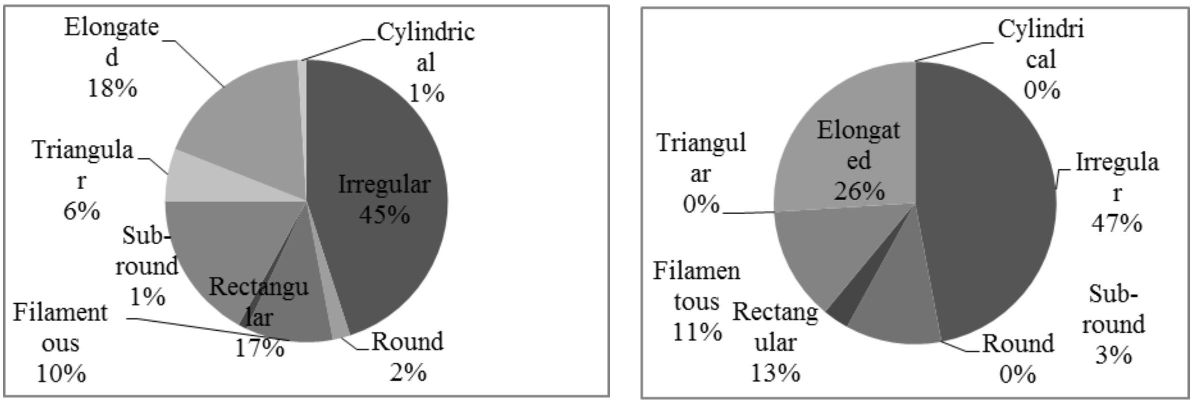


Figure 8: Shape-wise distribution of microplastics in SBY and Control

In the Beaching zone shape-wise distribution of microplastics was as follows Irregular (48%) > Filamentous (16%) > Elongated (14%) > Rectangular (13%) > Triangular (7%) > Round (2%). Sub-round and cylindrical shaped was not found here. In the Cutting zone shape-wise distribution of microplastics was as follows Irregular (35%) > Elongated (25%) > Rectangular (18%) > Filamentous (10%) > Triangular (6%) > Sub- round (3%) > Round (2%) and Cylindrical (1%). And in the storage zone, Irregular (53%) > Rectangular (19%) > Elongated (15%) > Triangular (5%) > Filamentous (4%) > Sub- round, Round and Cylindrical (1%) particles were found.

3.5 Size

Around 71% particles' size was in the range of 0.3 to 1mm, around 28% was in the range of 1-1.7mm, and around 1% was in the range of 1.7- 2.4mm and 2.4- 3.1mm. No particles > 2.54mm were found. On the other hand, around 76% of particles showed sizes is in the range of 0.3 to 1mm, around 24% was between 1- 1.7mm. In control all particles were below 1.7mm in size. Respective size ranges for Beaching, Cutting and Storage zones were 0.33-1.45 mm, 0.3-1.81 mm and 0.3-2.54 mm.

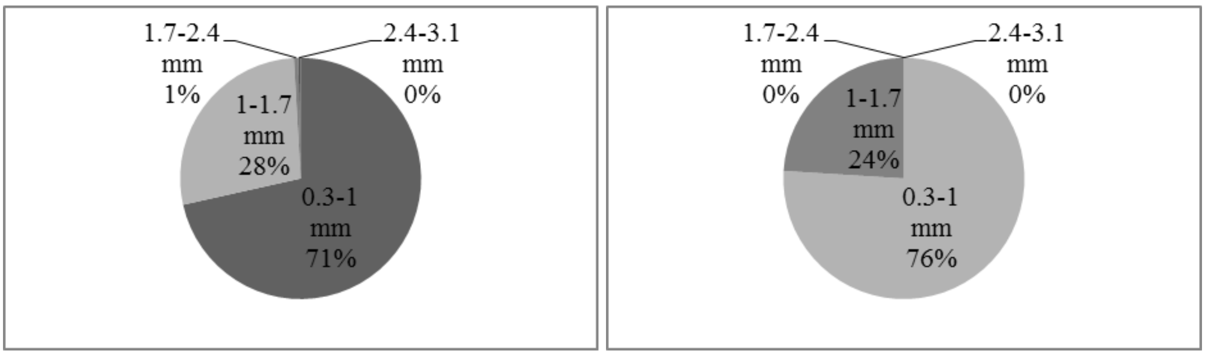


Figure 9: Size-wise distribution of microplastics in SBY (left one) & Control (right one)

3.6 FTIR Analysis

FTIR identified the microplastic particles as Polyethylene (PE), Polyethylene terephthalate (PET), Polypropylene (PP), Polyvinylchloride (PVC), Polyurethane (PU), Polystyrene (PS). Among these particles Polyvinylchloride (PVC) and Polyurethane (PU) were found only in the ship breaking yard indicating characteristic enrichment of SBYs soil by ship breaking activities. In Nordeerney, PP, polyethylene, PET, PVC, PS and PA were identified (Dekiff et al, 2014).

4. CONCLUSIONS

Microplastic is a relatively new issue and it is a matter of concern all over the world. Though Bangladesh is one of the vulnerable countries, there is a dearth of studies on this issue specially in context of Ship Breaking and Recycling Industries (SBRI). This study aimed to find the contribution of SBRI on MP enrichment of beach sediment for the first time by following NOAA protocol. This study revealed high abundance of microplastics in the sediments from SBYs in Bangladesh with ~ 217 MP particles per kg of soil from SBYs on an average compared to 127 particles per kg at the control site. The abundance of MP particles varied among the zones with respective ranges of 50-460, 80-410 and 70-330 for beaching, cutting and storage zones. Overall, the particles found in the SBYs were mostly plastic fragments (45%) and fibers (40%). The respective ranges of plastic and polythene fragments were 10-260 and 10-50 pieces per kg of soil from SBYs compared to their respective values of 10 and 20-30 pieces in control. At beaching zone fibers were the most abundant form of microplastic particles. In contrast, at cutting and storage zones plastic fragments dominated. Microplastic particles from SBYs were mainly Transparent (22%) and Red & Black (10%) in color unlike particles in the control sample which were mostly Transparent or Grayish. Transparent particles were most abundant in the beaching and cutting zones and Green in the storage. However, the second most abundant color of microplastic particles was Black, Red respectively at beaching, cutting zone while it was Transparent and Gray at storage zones. Shapewise, 45% of microplastic particles had an irregular shape, 18% were elongated, 17% rectangular and it was almost similar between SBYs and control samples. In terms of abundance, respective zone sequences of irregular shaped, elongated and rectangular particles were storage>beaching>cutting, cutting>storage>beaching and storage>cutting>beaching. Among the microplastic particles, ~71% were in the size range of 0.3 to 1 mm and about ~28% were in the range of 1- 1.70 mm in the SBY. This is almost the same in the control. Respective size ranges of plastic particles at beaching, cutting and storage zones were 0.33-1.45, 0.3-1.81 and 0.3-2.54 mm. The analyzed particles were identified as Polyethylene (PE), Polyethylene terephthalate (PET), Polypropylene (PP), Polyvinylchloride (PVC), Polyurethane (PU), Polystyrene (PS). Among these particles Polyvinylchloride (PVC) and Polyurethane (PU) found only in the ship breaking yard. Therefore, the described microplastic fragments originated both from sea sediments and directly from the ship-breaking activities at the site. The comparison between control and ship breaking yard samples reveals the contribution of ship breaking in microplastic contamination. As Polyvinylchloride (PVC) and Polyurethane (PU) found only in the ship breaking yard so their source should be identified including their concentration. And their impact should be identified including the counter measure. Though the study deals with a limited number of samples, it may provide baseline information about the distribution, types, colours, shapes, area coverage, the perimeter of microplastics of the soils of ship breaking yard, Bangladesh. As Polyvinylchloride (PVC) and Polyurethane (PU) found only in the ship breaking yard and were absent in control, care must be taken during ship breaking while handling the materials which may contains these plastics.

ACKNOWLEDGEMENTS

This research was supported by research grant from the Research and Publication Cell of the University of Chittagong awarded to Dr Mohammad Mosharraf Hossain.

REFERENCES

Abidli, S., Toumi, H., Lahbib, Y., & El Menif, N. (2017). The First Evaluation of Microplastics in Sediments from the Complex Lagoon-Channel of Bizerte (Northern Tunisia). https://doi.org/10.1007/s11270-017-3439-9

Barnes, D. K. A., Francois, G., C., T. R., & Morton, B. (2009). Accumulation and fragmentation of plastic debris in global environments. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), 1985–1998. https://doi.org/10.1098/rstb.2008.0205

Browne, M. A., Galloway, T. S., & Thompson, R. C. (2010). Spatial Patterns of Plastic Debris along Estuarine Shorelines. Environmental Science & Technology, 44(9), 3404–3409. https://doi.org/10.1021/es903784e

Browne, M. A., Crump, P., Niven, S. J., Teuten, E., Tonkin, A., Galloway, T., & Thompson, R. (2011). Accumulation of Microplastic on Shorelines Woldwide: Sources and Sinks. Environmental Science & Technology, 45(21), 9175–9179. https://doi.org/10.1021/es201811s

Claessens, M., De Meester, S., Van Landuyt, L., Clerck, K., & Janssen, C. (2011). Occurrence and distribution of microplastics in marine sediments along the Belgian coast. 62. https://doi.org/10.1016/j.marpolbul.2011.06.030

Dekiff, J. H., Remy, D., Klasmeier, J., & Fries, E. (2014). Occurrence and spatial distribution of microplastics in sediments from Norderney. 186C. https://doi.org/10.1016/j.envpol.2013.11.019

Derraik, J. G. B. (2002). The pollution of the marine environment by plastic debris: A review. Marine Pollution Bulletin, 44(9), 842–852. https://doi.org/10.1016/S0025-326X(02)00220-5

European Parliament. (2018, November 22). Microplastics: Sources, effects and solutions. Retrieved February 20, 2019, from European Parliament website: http://www.europarl.europa.eu/news/en/headlines/society/20181116STO19217/microplastics-sources-effects-and-solutions

Express, T. F. (2018, July 12). Challenges before ship-breaking industry. The Financial Express. Retrieved from https://www.thefinancialexpress.com.bd/editorial/challenges-before-ship-breaking-industry-1531411490

Graham, E. R., & Thompson, J. T. (2009). Deposit- and suspension-feeding sea cucumbers (Echinodermata) ingest plastic fragments. Journal of Experimental Marine Biology and Ecology, 368(1), 22–29. https://doi.org/10.1016/j.jembe.2008.09.007

He, D., Luo, Y., Lu, S., Liu, M., Song, Y., & Lei, L. (2018). Microplastics in soils: Analytical methods, pollution characteristics and ecological risks. TrAC Trends in Analytical Chemistry, 109, 163–172. https://doi.org/10.1016/j.trac.2018.10.006

Hossain, Md. M., & Islam, M. (2006). Ship Breaking Activities and its Impact on the Coastal Zone of Chittagong, Bangladesh: Towards Sustainable Management.

Jobaid, Md. I., Khan, M. M., Haque, A. K. M. K., & Shawon, I. A. (2014). Ship Recycling and Its Environmental Impact: A Brief Overview of Bangladesh (Vol. 16). https://doi.org/10.9790/487X-161013137

Masura, J., Baker, J., Foster, G., and Arthur, C. (2015). Laboratory Methods for the Analysis of Microplastics inthe Marine Environment: Recommendations for quantifying synthetic particles inwaters and sediments. National Oceanic and Atmospheric Administration.

Matsuguma, Y., Takada, H., Kumata, H., Kanke, H., Sakurai, S., Suzuki, T. and Newman, B. (2017). Microplastics in Sediment Cores from Asia and Africa as Indicators of Temporal Trends in Plastic Pollution (Vol. 73). https://doi.org/10.1007/s00244-017-0414-9

Ng, K. L., and Obbard, J. (2006). Prevalence of microplastics in Singapore’s coastal marine environment. 52. https://doi.org/10.1016/j.marpolbul.2005.11.017

Peng, G., Zhu, B., Yang, D., Su, L., Shi, H., and Li, D. (2017). Microplastics in sediments of the Changjiang Estuary, China (Vol. 225). https://doi.org/10.1016/j.envpol.2016.12.064

PlasticsEurope. (2018). Plastics- the Facts 2018: An analysis of European plastics production, demand and waste data. Retrieved from www.plasticseurope.org

Reddy, M. S., Basha, S., Adimurthy, S., & Ramachandraiah, G. (2006). Description of the small plastics fragments in marine sediments along the Alang-Sosiya ship-breaking yard, India. Estuarine, Coastal and Shelf Science, 3–4(68), 656–660. https://doi.org/10.1016/j.ecss.2006.03.018

Spengler, A., Silva-Cavalcanti, J. S., Ivar do Sul, J. A., Araújo, M. C. B., Costa, M. F., & Tourinho, P. S. (2008). Microplastics on the strandline: Snapshot of a Brazilian beach.

Thompson, R. C., Olsen, Y., Mitchell, R. P., Davis, A., Rowland, S. J., John, A. W. G., and Russell, A. E. (2004). Lost at Sea: Where Is All the Plastic? Science, 304(5672), 838–838. https://doi.org/10.1126/science.1094559

Tiwari, M., Rathod, T. D., Ajmal, P. Y., Bhangare, R. C., and Sahu, S. K. (2019). Distribution and characterization of microplastics in beach sand from three different Indian coastal environments. Marine Pollution Bulletin, 140, 262–273. https://doi.org/10.1016/j.marpolbul.2019.01.055

Wang, J., Peng, J., Tan, Z., Gao, Y., Zhan, Z., Chen, Q., and Cai, L. (2016). Microplastics in the surface sediments from the Beijiang River littoral zone: Composition, abundance, surface textures and interaction with heavy metals. 171. https://doi.org/10.1016/j.chemosphere.2016.12.074