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Microplastics in soil-like-material obtained during mining of a municipal solid waste dumpsite

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ABSTRACT

Plastics are widely cited as one of humankind's greatest inventions; however, the increase in global production and lack of plastic waste management has created a new emerging contaminant known as Microplastics (MPs). Landfills/dumpsites are frequently used as viable options to dispose of plastic trash, which eventually can be a new source and hotspot for MPs. The present study evaluates the presence of MPs in soil-like-material (SLM) obtained while mining an MSW open dumpsite in Delhi (India). After removing the organic matter by the Fenton reagent, the MPs were extracted using the dual-density separation technique (NaCl and $ZnCl_2$). MPs were identified and characterized based on size, shape, and color; FTIR and Raman Spectroscopy were used to determine the polymer types. The results indicate the significant presence of MPs in SLM, and almost 70% of MPs were less than 425 µm. The MPs concentration ranged from 3750 items/kg to 7050 items/kg in SLM, where items refer to discrete pieces of MPs. Fiber and fragment were the dominant shapes, and most MPs were either white/transparent or brown. The spectral analysis indicated that polyethylene, PET, and polypropylene were the main identified polymers. The findings of this study suggest that open dumpsites could be a source of MPs and that without a liner and cover system, MPs may migrate to the surrounding environment and contaminate nearby surrounding.

Keywords: Microplastics, Dumpsites, Soil like material, Municipal solid waste, FTIR

1 INTRODUCTION

Due to its affordability, cost-effectiveness, and variety of applications, plastics have become an integral part of society, increasing worldwide plastic production to 390.7 million tonnes in 2021 (Plastic's Europe, 2021). Figure 1 depicts the upward trend in global plastic production. However, inadequate waste management, legislation, and public ignorance caused much chaos around the globe and constituted a new threat to the environment and human beings, known as microplastic pollution. Microplastics (MPs) have not yet been given a precise definition. However, in the scientific community, they are typically considered tiny bits of plastic ranging in size from 1 µm to 5 mm (Geyer et al., 2017; Su et al., 2019; Horton & Barnes, 2020). Due to their large specific surface area and affinity towards heavy metal and organic contaminants, MPs can act as a vector for their transmission, negatively impacting aquatic and terrestrial ecosystems (Hüffer et al., 2019; Wu et al., 2020). MPs are detected in different ecosystems throughout the globe, and its recent discovery in the blood (Leslie et al., 2022), lungs (Mahadevan & Valiyaveettil, 2021; Jenner et al., 2022), and breastmilk (Ragusa et al., 2022) raise a high alarm that humans are not isolated from the threat. Although numerous studies on the harmful effects of MPs on aquatic ecosystems have been presented, much less is known about their fate, transport, and adverse effects on Soil (Song et al., 2022; Yuan et al., 2022). Recent studies indicate that exposure to MPs can cause tissue damage, oxidative stress, and change in gene expression in fish (Rochman et al., 2013), while humans may experience oxidative stress, cytotoxicity, neurotoxicity, and immune system disruption (Gouin et al., 2022; Liu et al., 2019; Schirinzi et al., 2017). However, these studies are still in the nascent stage.

According to the US Environmental Protection Agency (USEPA, 2018), 35.68 million tonnes of plastic garbage were generated in 2018, and landfills held 26.97 million tonnes of it. This demonstrates that

75.66% of plastic trash is dumped in municipal solid waste (MSW) landfills (Yadav et al., 2020). Landfills/dumpsites are considered a new source and hotspot of MPs as they receive a large amount of MSW, which is a primary and secondary source for MP pollution (Puthcharoen & Leungprasert, 2019; Tun et al., 2022). Due to poor waste management, lack of resources, and non-engineered landfills, most MSW waste is dumped in open dumpsites. These vast waste mountains without any protective liner and a cover system can contaminate the nearby environment (Hölzle et al., 2022).

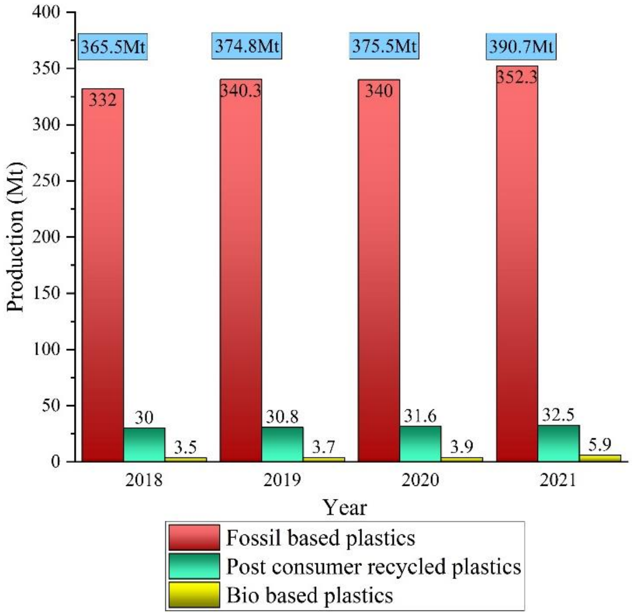

Figure 1. Increase in Global production of plastics.

According to the Central Pollution Control Board (CPCB) report in 2019, India generated 9.46 million tonnes of plastic waste and out of which only 3.51 million tonnes (37%) was collected and treated; in addition, the country's per capita plastic waste generation has nearly doubled over the last five years. The leftover plastic waste was either littered or dumped in landfills or open dumpsites, leading to environmental pollution and health hazards. Landfill mining is currently adopted throughout the globe to reduce the load on dumpsites and provides opportunities to recover energy, recyclables, reusables, and other valuables. Many researchers assessed the feasibility of soil-like material (SLM) or landfilled mined fractions (LMF) in terms of Heavy metals, salts, and organic contaminants; however, the presence of MPs is not extensively studied (Datta et al., 2021). The direct implication of this SLM material for various applications increases the chance of MPs pollution, creating a potential adverse impact (Somani et al., 2020). Therefore, the objective of the current study is to document the presence of MPs in SLM, followed by its characterization based on size, shape, color, and polymer. The study serves as a benchmark for understanding the role of dumpsites and SLM for MPs pollution and paves the way for future remediation guidelines.

2 MATERIAL AND METHODOLOGY

2.1 Site description

India's capital, New Delhi, is home to three enormous mountains of garbage located in the neighborhoods of Okhla, Ghazipur, and Bhalswa; for the current study, SLM material was collected from Okhla dumpsites situated at 28.5122° N, 77.2833° E. The site has been operational since 1996 and was declared exhausted in 2010. The dumpsite has exceeded its capacity, grown to a height of 55 meters, thrice the permissible limit, and was permanently decommissioned in 2018 (CPCB report, 2021). About 6 million tonnes of legacy trash are housed in the dumpsite, with a surface area of 186,155 square meters. Fig 2 represents the location of the dumpsite.

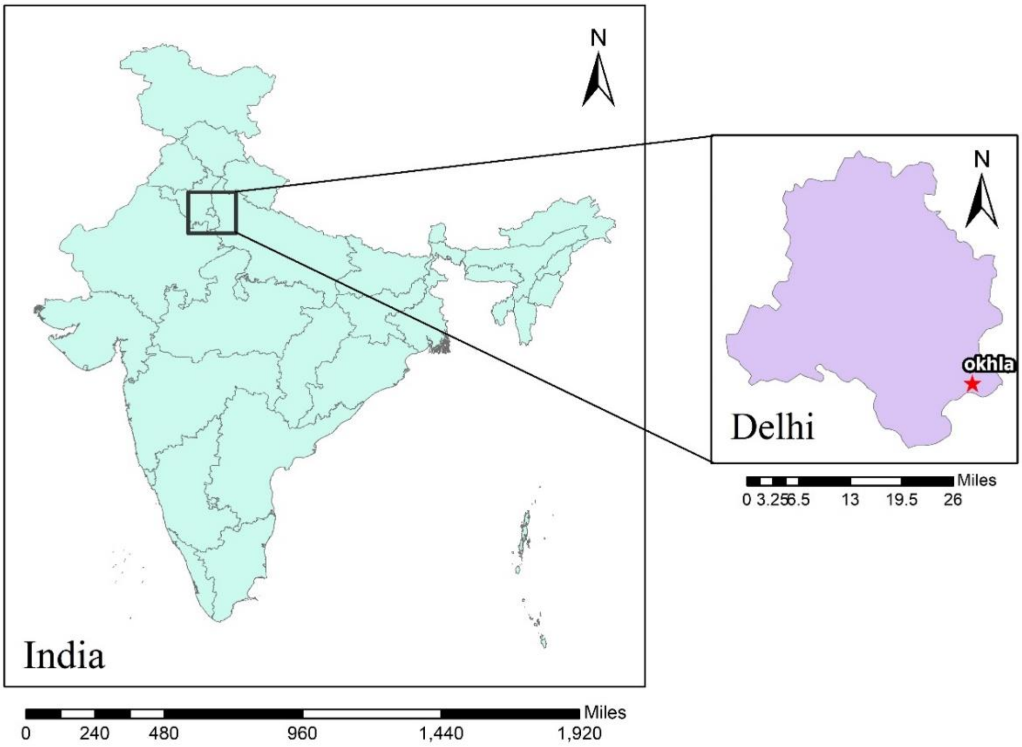

Figure 2. Location of the dumpsite in Delhi, India

2.2Sample collection

The National Green Tribunal (NGT), a government authority, has ordered mining operations to alleviate the burden on dumpsites. Trommels of 6 mm and 30 mm sieves were installed at different locations on the site. Legacy waste was separated into three different size categories (<6 mm, 6mm to 30 mm, and >30 mm), with waste equivalent to <6 mm being employed for the current investigation. The 6 mm minus fraction was collected from four locations to get a representative picture of the whole dumpsite. Fig 3 illustrates the sampling locations. The legacy waste was further sieved to 4.75 mm and named SLM fractions.

Figure 3. *Sampling location (A, B, C, and D) of legacy waste at dumpsite*

2.3 Extraction of microplastics

Initially, 100 gm of SLM was wet sieved, with a 75 µm sieve size to prevent any loss of MPs. The entire sample was later oven-dried for 24 hrs at 60ºC, below the continuous operating temperature of most polymers reported in MPs worldwide, to avoid any morphological changes (Sujathan et al., 2017). The dried SLM was further sieved with 4.75 mm, 1 mm, 0.425 µm, and 75 µm to collect four different size fractions. The samples were analyzed, and MPs were extracted by following the procedure of Goli et al., (2022) and Wan et al., 2022) with slight modifications. About 5 gm of dried SLM material of individual fractions was taken and transferred to a 250 ml glass beaker.
The traditional Loss on Ignition (LOI) method operated at 450 ºC -500º C, which may damage the MPs. Therefore, the wet peroxide oxidation method using the Fenton reagent was adopted to digest the soil organic matter. The Fenton reagent solution was prepared in the laboratory using 30% hydrogen peroxide and 0.05 M Fe (II) solution. The beaker was placed on a hot plate at around 60ºC, and the Fenton reagent was added until no foam was present at the surface. The production of reactive hydroxyl radicals breaks down the soil's organic matter. The reaction was exothermic; the solution could spread out of the beaker if not appropriately monitored. Moreover, maintaining the temperature below the operating temperature is needed to ensure only soil organic matter is digested and prevent any damage to microplastic. After removing organic matter, the residue was transferred to a saturated NaCl solution (1.2 gm/cc) followed by a ZnCl2 solution (1.55 gm/cc) for density separation. The solution was placed overnight for sedimentation, and the floating components were passed through vacuum infiltration using nylon membrane filters (2.55 µm pore size, 47 mm diameter). The Density separation was performed three times, and the Dual-density separation method was adopted to increase the removal efficiency of the MPs.The residue was dried and transferred to Petri dishes for further visual inspection and characterization. Fig 4 represents the layout of the analysis. All suspected MP particles collected on the filter paper were visually analyzed under a stereo microscope. The abundance, shape, size, and color of MPs were recorded. The MPs were further characterized based on shape, size, and color. The polymers' spectra were identified using FTIR-ATR and Raman Spectroscopy and matched with standard spectral libraries. All the tests were done in triplicates. Double distilled water, laboratory-grade chemicals, reagents, and equipment were used throughout the analysis for higher accuracy.

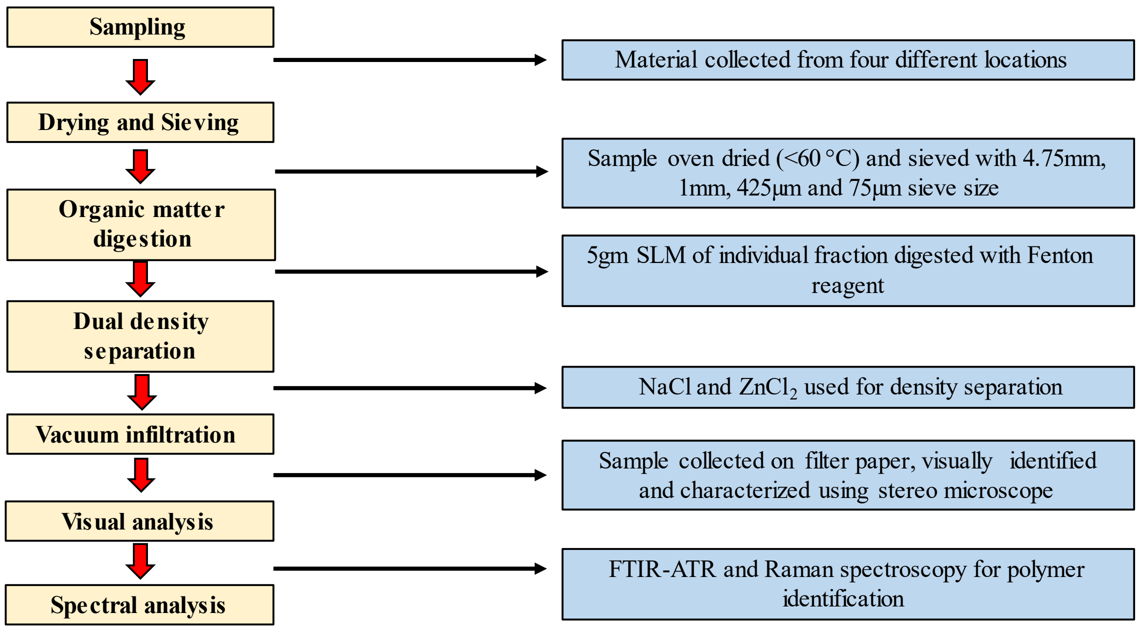

Figure 4. Flow chart of the analysis

3 RESULTS AND DISCUSSION

3.1 Abundance of MPs in SLM

The results indicate that MPs were detected in all the SLM samples. The abundance of MPs in different locations (A, B, C, and D) with corresponding size ranges is shown in Fig 5. The unit for MP concentration is defined as (items/kg), where items refer to discrete pieces of MPs. The concentration varied from 3750 items/kg to 7050 items/kg. The respective percentage size distribution in SLM is summarized in Table 1. The results depict that the concentration of MPs increased with decreasing size; additionally, it was reported that 70% of MPs have a size less than 425 µm. Large amounts of small-size MPs in SLM indicate a high degree of weathering and could potentially threaten the nearby environment (Udovicki et al., 2022; Yuan et al., 2022). The presence of MPs at all four sites demonstrates that MPs are distributed over the dumpsites, and the variation in concentration is related to the heterogeneous dispersion of MSW. These results are lower than those reported in refuse samples (Puthcharoen & Leungprasert, 2019; Su et al., 2019b Afrin et al., 2020). The variation in concentration can be attributed to the age of the dumpsite (Wan et al., 2022). The presence of MPs indicates that dumpsites could be a viable source of MPs, and unbound use of SLM can potentially create a problem in the future once the impacts and hazards of MPs are more clearly understood.

3.2 Characteristics of MPs detected in SLM

Based on their shapes, the identified MPs were categorized into fibers, fragments, films, foams, and non-detectable (ND). Fig 6 represents the percentage distribution of MPs shapes among the four locations and size fractions. The results indicate that SLM consists of all shapes; however, fibers and fragments are dominant compared to films and foams. It was reported that the percentage of fibers and fragments shapes MPs increases with a decrease in size among all four locations. The distribution in shapes of MPs implies the presence of various sources or a high degree of weathering of plastics due to physical, chemical, or biological processes. The shapes of MPs play a vital role in transportation, and Fiber and fragments can travel a longer distance(Goeppert & Goldscheider, 2021; Han et al., 2022). The detected MPs were further categorized based on color. Fig 7 represents the distribution of MPs with color. Brown, white, and transparent MPs are more in number compared to black, blue, and red. The color of MPs is primarily derived from parent material and can help identify the source of MPs (Pastorelli et al., 2014). Fig 8 shows photographs of detected MPs during the analysis.

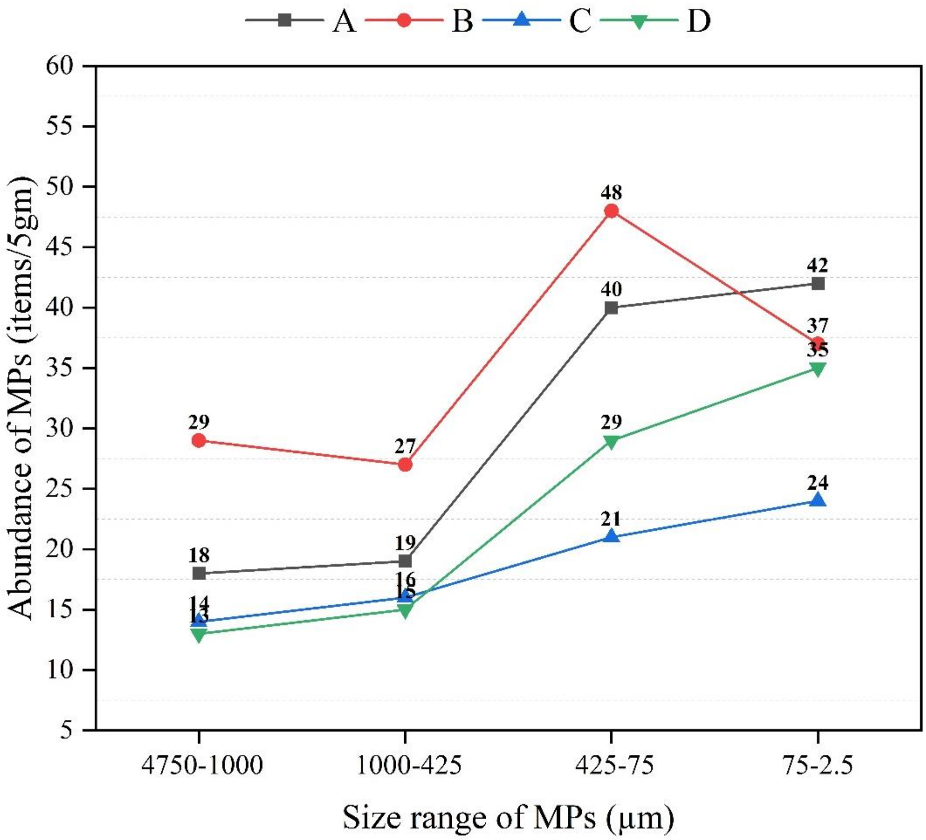

Figure 5. *Abundance of MPs in SLM at different locations with size range*

Table 1. *Summary of test analysis for different locations*

Sr No	Sample location	Size range (µm)	Size distribution (%)	Abundance (items/kg)
1	A	4750-1000	15.12	5950
		1000-425	15.96	
		425-75	33.61	
		75-2.5	35.29	
2	B	4750-1000	20.56	7050
		1000-425	19.14	
		425-75	34.04	
		75-2.5	26.24	
3	C	4750-1000	18.66	3750
		1000-425	21.33	
		425-75	28.12	
		75-2.5	31.89	
4	D	4750-1000	14.13	4600
		1000-425	16.3	
		425-75	31.52	
		75-2.5	38.04	

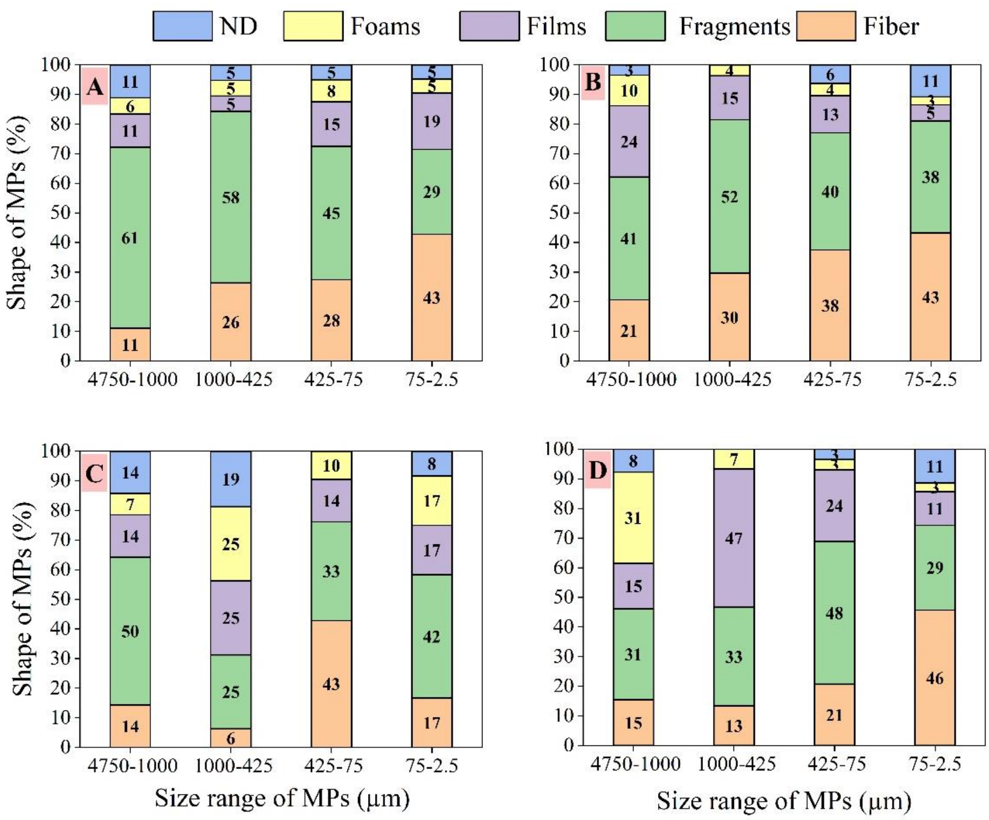

Figure 6. *Distribution of MPs particles with shapes and size range among different locations (A, B, C, and D)*

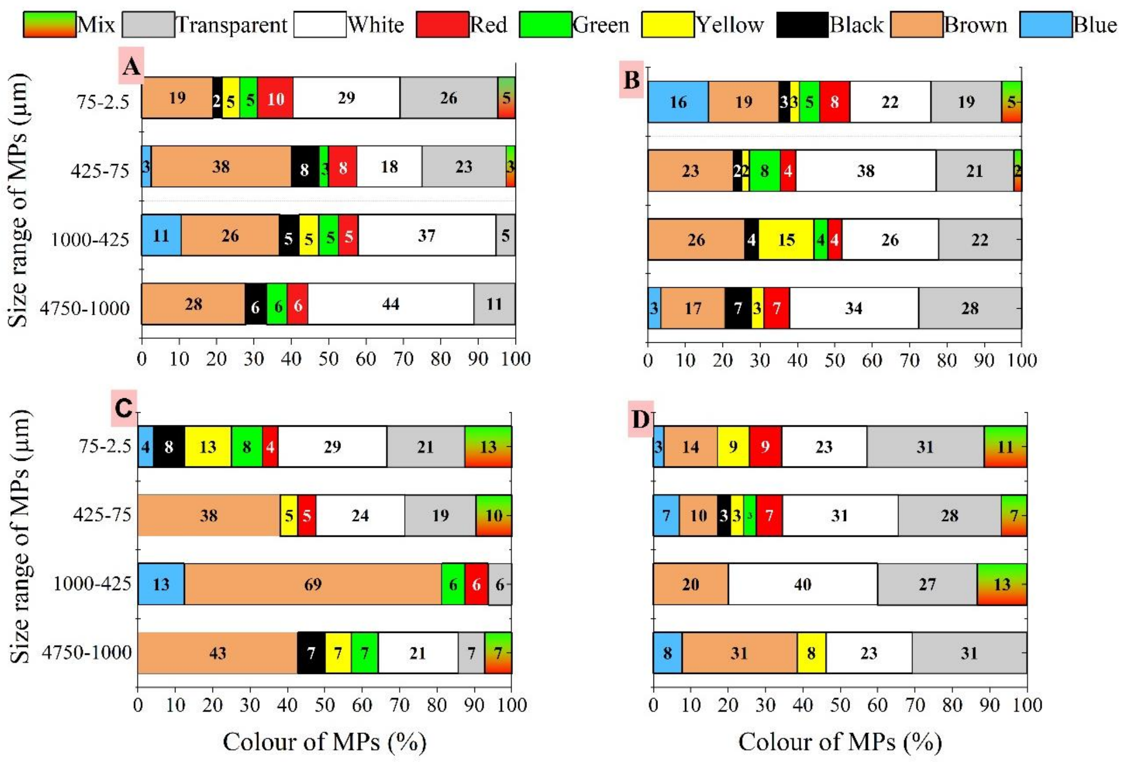

Figure 7. *Distribution of MPs particles with color and size range among different locations (A, B, C, and D)*

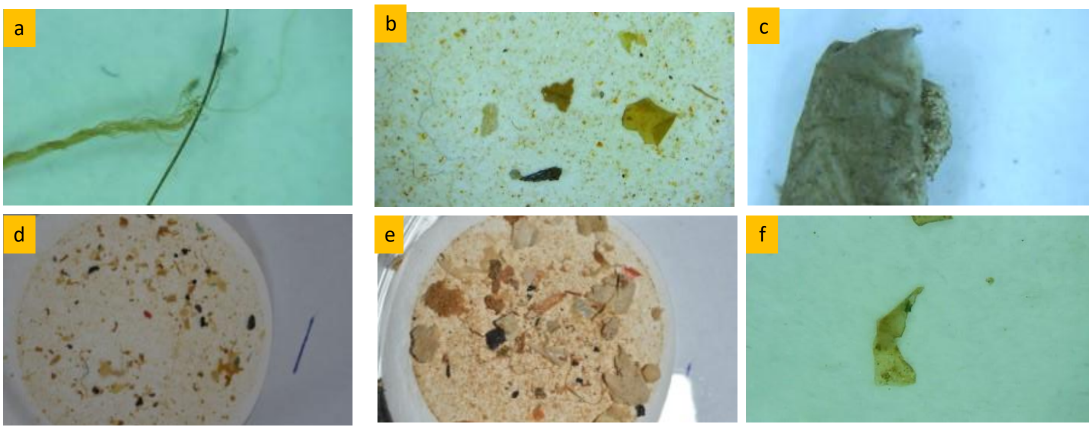

Figure 8. *Photographs of MPs particles during analysis (a) fiber, (b,c f) fragments and films, (d,e) MPs pieces placed on filter paper.*

3.3 Polymer identification using spectroscopy

The polymer composition of MPs detected in SLM was analyzed via Fourier transformation infrared spectroscopy (FTIR-ATR) and Raman spectroscopy. Several polymers were identified, including polyethylene, polyethylene-terephthalate (PET), polystyrene, polypropylene, and polyester. Polyethylene (39%) and PET (22.2%) are the dominant ones. SLM material consists of many white and transparent plastic sheets made of polyethylene, while PET and polyester are widely used to manufacture plastic bottles and covers. The presence of colored MPs also indicates their presence. Figure 9 represents the distribution of identified polymers. The spectrum obtained is matched with the standard available online libraries, and a high matching percentage is used to validate the type of polymers.

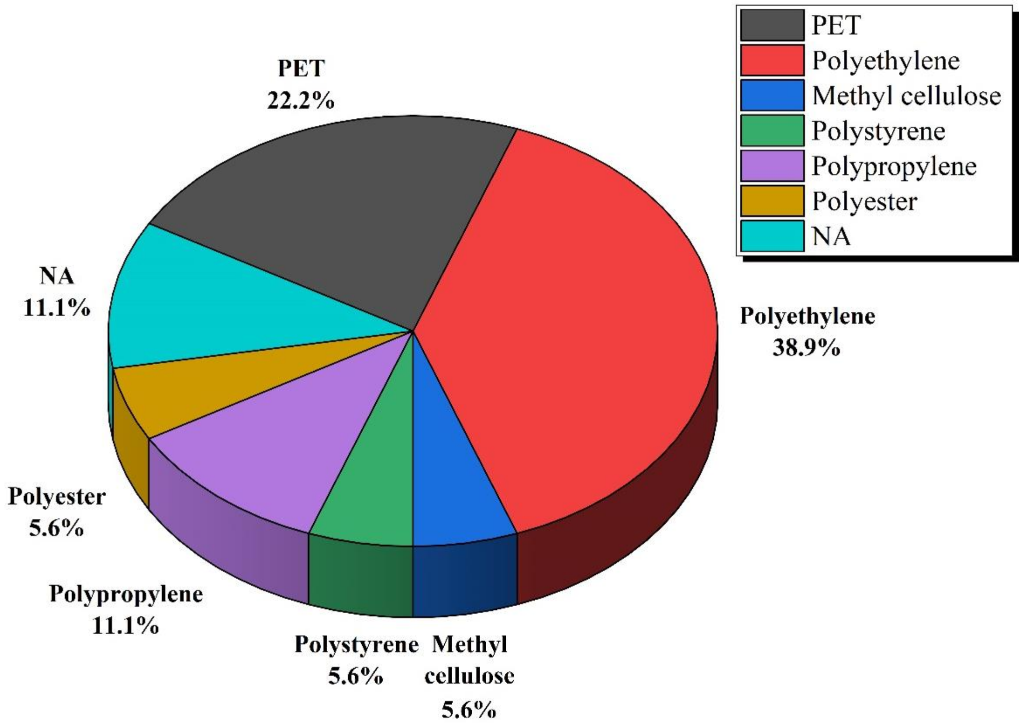

Figure 9. *Polymer composition identified in SLM*

4 CONCLUSIONS

The current study assesses the MP content in SLM material mined from the legacy waste of an open dumpsite. The following findings can be drawn from the analysis.

1. MP in SLM mined from legacy waste implies that SLM is a vital source of plastic pollution, and its direct unbound application can enhance the spread of MPs to the environment.
2. The abundance of MPs in SLM ranged from 3750 items/kg to 7050 items/kg. MPs were detected in all size fractions; however, the concentration of MPs varies with size.
3. The morphological characteristics indicate that Fiber and fragments are the primary shapes, and brown, white, and transparent are the predominant colors of MPs.
4. Polyethylene and polyethylene terephthalate are the prevailing identified polymers, followed by polyester and polystyrene.

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