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Research Article

Microplastics in Indoor Dust Collected from Healthcare Units: Occurrence and Exposure Assessment

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Abstract

Microplastics are one of the dominant environmental pollutants that have been found in various environments due to the widespread use of plastic products. The present study was designed and conducted with the aim of investigating the abundance of microplastics in settled dust in healthcare wards with a health risk assessment approach. In this study, 30 settled dust samples from different healthcare wards were examined. The samples were prepared, digested, and extracted in the laboratory. Optical microscopy was used to identify and determine the physical properties of microplastics, and SEM-EDX was used to determine their surface morphology and chemical composition. The polymer composition of microplastic particles was also determined using a Raman spectrometer. The results of this study showed that the abundance of microplastics in settled dust was 4358 pieces per 10 grams, with the highest abundance at 636 sampling stations and the lowest contribution of 18 sampling stations. The most common color, shape, and polymer type of microplastics were white (37%), fiber (65%), and polyvinyl chloride (30%), respectively, and the predominant size of microplastic particles in the sample was between 10 and 1000 µm (55%). The results of this study have a direct relationship with the type of equipment and devices used in the wards, type of ventilation, cleaning methods, and hygiene practices. This study provides new insights into microplastic contamination in assessing the risk associated with deposited dust in healthcare units. Furthermore, the findings are useful for controlling exposure and improving microplastic contamination reduction steps in health management in healthcare facilities.

Keywords

Health Risk Assessment, Monte Carlo Simulation, Microplastics, Dust

1. Introduction

Microplastics (MPs) are tiny plastic particles that enter the environment due to human activities, the breakdown and erosion of plastic materials, as well as industrial processes. These particles, with a size of less than 5 mm, can spread rapidly in ecosystems and have significant negative impacts on human health and the environment. In urban environments, settled dust serves as a vital indicator for assessing air pollution con-

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ditions and, due to the high concentration of MPs, has significant detrimental effects on the ecological quality of the environmen [1]. t. One of the places where microplastics may accumulate is hospital surfaces, and especially the dust contained in them. Hospitals, as major healthcare centers, with a sensitive population including patients, nurses, and doctors, must be carefully managed in terms of hygiene and safety. In these environments, microplastic pollution can lead to serious health complications, especially in people with weakened immune systems. Microplastic particles can carry harmful chemicals and microorganisms and can trigger various diseases in humans [2]. MPs are important in dust due to their accumulation and carcinogenic properties and can cause numerous health and environmental problems. The risks from MPs vary in different environments and depend on the specific conditions. The routes of exposure to MPs are through ingestion, inhalation and skin contact, while most exposure occurs through inhalation and ingestion [3]. Among the most important health risks from MPs entering the body of people through food, water and inhalation are oxidative stress and cytotoxic effects, metabolic disorders, immune system disorders, neurotoxic effects and hormonal disruptions. The potential effects of MPs on the health of people at risk depend on the way they enter the body and their location. They can cause various diseases such as lung damage, asthma, acute and chronic poisoning, developmental toxicity, reproductive and locomotor toxicity, neurotoxicity, genotoxicity and cytotoxicity, increased antioxidant defense, colon cancer and persistent contamination in the human body [4]. So far, much research has focused on the detection of microplastics in dust in indoor spaces such as homes, mosques, universities, hospitals and operating rooms. Study hospital as one of the important medical centers in Yazd province, needs research on the frequency of microplastics and the assessment of related health risks due to the high volume of patient visits and attention to health issues. The aim of this study is to investigate the frequency of microplastics in dust deposited in the medical departments of this hospital, with a health risk assessment approach. Measuring the level of microplastic pollution and analyzing the risks related to it can provide valuable information in improving health conditions and promoting the health of patients and staff. Recently, several studies have been conducted in this area, which have shown that microplastics can act as a carrier for toxins and bacteria and pose significant health risks [1]. Therefore, the identification and assessment of these particles in sensitive environments such as hospitals is of particular importance. Therefore, the characteristics of microplastics in dust deposited in healthcare units were investigated in this study to help understand the presence of microplastics in indoor spaces. Although this research can be conducted separately on other environmental issues, it suggests 1) analyzing the abundance, morphology, color, size, and composition of microplastics in dust collected in different healthcare units of Yazd hospitals in Iran and 2) assessing the annual exposure to microplastics for different age groups of the population.

2. Materials and Methods

2.1. Study Area and Sample Collection

During December 2024 and April 2025, 30 dust samples were collected from healthcare units in Yazd province, central Iran. Yazd city, with its hot and dry climate, is considered one of the medical and cultural hubs of Iran. For this purpose, approximately 2 to 5 grams of dust were collected from 15 healthcare units. Dust samples were obtained using a brush, a steel duster, and a metal broom. After each use, the sampling equipment (brush, duster, and duster) was washed with deionized water. The collected samples were then transported to the laboratory and a 5 mm sieve was used to remove coarse foreign matter and other interfering factors.

2.2. Sample Preparation

Following the filtration of the dust samples through a 5 mm diameter metal sieve, 1 g of each sample was transferred to 100 mm beakers and 30 ml of H_2O_2 solution (30%, v/v) (Merck, Germany). Subsequently, organic matter was added to each for digesting. The sample was added and allowed to complete the oxidation reaction (about ten days). The samples were transferred to a drying oven (BF55E, FG, Iran) at 50°C for 24 hours. Then, to separate the MPs, the density separation method was used via a saturated solution NaI (Merch, Germany) with a 1.6 g/cm3 density. Thus, To each sample, 25 ml of the prepared NaI solution was added and mixed for two minutes to dislodge any adhered particles, and then it was left to settle for thirty minutes. After separation, the particles' supernatant was filtered through filter paper (Whatman, Maidstone, Kent, UK) with a 1-3 µm pore size. Afterward, the filter papers were moved to a glass Petri dish and kept in clean cabinets to dry at ambient temperature. Ultimately, glass petri dishes containing filter papers were examined to identify and measure MPs [21].

2.3. MP Detection and Quantification

2.3.1. Optical Analysis

An optical microscope was used to examine the separated parts [22]. The identified MP's quantity, shape, size, and color were among the visual properties assessed using a binocular microscope with a magnification of around 100x [6, 23]. Tools such as tweezers, needles, and color detection are commonly used to identify MPs [7, 21]. Usually, MPs lack tissue and cellular structure. The diameter of these particles is constant throughout their lifetime, their color does not change, and they are not twisted or shiny [1, 8].

2.3.2. Micro-Raman Analysis

Chemical composition analysis of the microplastics was conducted using micro-Raman spectroscopy (Lab Ram HR, Horiba, Japan). Since accurate detection of MPs is not possible only by visual methods, a Raman spectrometer was utilized to validate prior analyses and determine the types of polymers present. The spectrometer laser used in this study had a wavelength of 785 nm. In addition, samples were examined at 50X magnification. Finally, the composition of the polymer was determined by comparing the reference spectra with the spectra obtained by Raman [11, 19].

2.3.3. SEM-EDS Analysis

During the final stage of MPs analysis, the surface morphology of the identified particles was examined using a scanning electron microscope (SEM) in conjunction with an X-ray diffraction (EDX) unit. For this purpose, A TESCAN-VEGA2 measuring device (TESCAN, Czech Republic) and an EDX spectrometer were used. The MPs were placed onto the adhesive and conductive carbon tape, and to avoid sample charging, a thin layer of gold was deposited onto the particle surfaces using a Q150R-ES instrument (Quorum Technologies, England). The SEM-EDX method is typically utilized to assess polymers' structure and elemental composition once identified [12, 24].

2.4. Human Intake of MPs

Inhalation and ingestion are considered the first routes of exposure to MPs [25, 26]. In this study, the inhalation routes of MPs were estimated as follows:

$$\beta = \frac{Af}{12\times \mathrm{Ap}} \times 10^4 \tag{1}$$

$$Dr = \frac{n\times\beta}{\mathrm{exposed\ \ days}} \tag{2}$$

The coefficient β, which denotes the sampling surface, is defined as 12 cm for the filter paper, Ap represents the Petri dish's area, and Af is considered the filter paper's total area. Dr indicates the deposition rate (MPs/m^2/day), and n indicates the estimated count of MPs present in each sample. The amount of daily inhaled MPs (items/kg-BW/day) was determined utilizing the following formula [19, 26]:

$$EDI(inhalation) = \frac{Dr\times F\times IR}{1.2\times \mathrm{BW}} \tag{3}$$

IR denotes the inhalation rate (m^3/day), BW stands for body weight (kg), and the constant factor of 1.2 represents the air volume (m^3) per square meter of sampling area. This measurement was calculated by deducting the Petri dish height (1.2 m) from the standard indoor height (2.4 m). The following formula was used to calculate the daily intake of MPs from indoor dust inhalation [19, 24, 27]:

$$Drw = \frac{0.0113\times Dr}{\mathrm{Wdp}} \tag{4}$$

$$EDI(ingestion) = \frac{Dr\times F\times SIR}{1000\times \mathrm{BW}} \tag{5}$$

In this formula, Drw represents the deposition rate of MPs. Wdp is particle weight, and SIR is indoor dust absorption rate (mg/day). 0.0113 defines the (12 cm) transformation factor to 1 m^2 area [9, 19, 28]. Table 1 also mentions the amounts of SIR, IR, BW, and F according to the studied age groups extracted from the data of the EPA Exposure Factors Guide (USEPA2011). (28)(29).

Table 1. *Indoor dust ingestion rate (mg/day) and inhalation rate according to, age categories, and average body weight.*

Groups	F	BW(kg)	IR(m3/day)	SIR(m^3/day)
Teenagers	0.88	53	14	20
Adults	0.88	63	13.3	20

2.5. Quality Control (QC)

In this research, we used cotton gowns and nitrile gloves to prevent the transfer of pollution and protect particles from environmental pollutants. Plastic equipment was strictly avoided when collecting samples. Samples were securely placed in glass containers and covered with aluminum foil to avoid any contamination transfer, and then they were transported to the laboratory. Before and during the operation, all work surfaces were disinfected using 70% alcohol to stop airborne particles and cross-contamination. Glass containers and equipment were carefully cleaned using distilled water, and liquids and solvents such as ethanol, distilled water, and KOH solution were filtered using filter paper. In addition, during all steps, the laboratory door was closed to prevent contamination.

2.6. Statistical Analysis

Microsoft Excel 2021 and IBM SPSS 26.0 software were used to perform a detailed statistical analysis. Kolmogorov-Smirnov (K-S) tests were used to check the normality of the data. Descriptive statistical methods were used to accurately examine the microstructures present in the dust deposited in the hospital healthcare units. In each case, significance was determined using a p value of < 0.05.

3. Results and Discussions

3.1. The Abundance of Microplastics in Indoor Dust of Various Hospital Healthcare Units

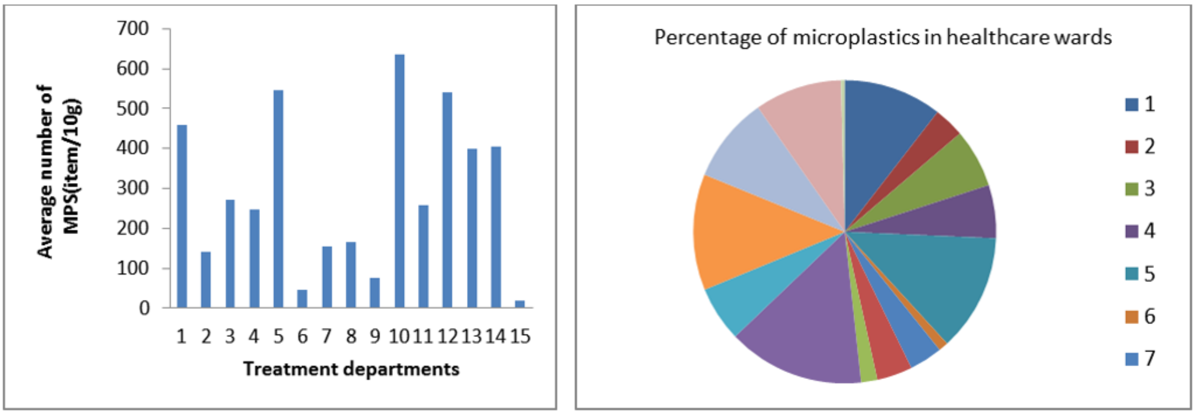
In this study, particulate matter was observed in all 30 dust samples from hospital healthcare units. The frequency and mean of particulate matter detected in dust samples collected from hospital healthcare units are shown in Table 2 and Figure 1.

In total, 4358 particulate matter were observed in the collected samples. The frequency of some of the particulate matter samples identified with different shapes, sizes, and colors is shown in Figure 2. The lowest mean value was found in units where the face was washed and disinfected regularly (healthcare units 15) with levels of 34 items per milligram, and the highest mean presence of microplastics was found in a unit where ventilation and cleaning and disinfection were inadequate (treatment unit 10 with 636 items per milligram (Table 2 and Figure 1)). According to Table 2, the mean (± standard deviation) levels of microplastics in dust from different hospital healthcare units is 98 items per milligram. The lowest number of MPs was observed in ward 15 (with an average of 2 items/10g). In contrast, the highest number of MPs was observed in ward 8 (with an average of 98 items/10g). Microplastics were found in all units. However, it cannot be definitively determined which unit contained more microplastics, because the types of microplastics detected in the hospital units studied varied. The differences in the level of microplastics in different healthcare units can be attributed to the materials and equipment used in hospitals, which are mainly plastic. These include disposable gloves and masks, plastic syringes and needles, medical equipment and supplies, laboratory containers, and others [30]. Also, the structure of the hospital, staff activities, waste management methods, unit disinfection methods, unit structure, and the specific management of each hospital are effective in the frequency of nosocomial infections [14, 15, 31].

It should be noted that few studies have been conducted on indoor dust particles from different hospital healthcare units for comparison with this study. In a study conducted in Shiraz and Bushehr, the number of indoor dust particles in hospitals, schools, kindergartens, and mosques was reported to be 1212 to 1362 particles per gram, which is almost similar to the levels of particulate matter detected in the present study. In both Bushehr and Shiraz, kindergartens showed the highest mean concentrations of particulate matter. On average, this number was 121 (particles per gram) in Bushehr kindergartens and 104 (particles per gram) in Shiraz kindergartens [16, 19]. The atmospheric and environmental dynamics of particulate matter are influenced by the vertical concentration gradient of pollution, wind speed, wind direction, precipitation, and ambient temperature [32]. Ventilation systems in healthcare units may be the reason for the accumulation of particulate matter in indoor dust [17, 33]. The concentration and size range of suspended particles in indoor dust are influenced by the number of occupants and types of human activities [34].

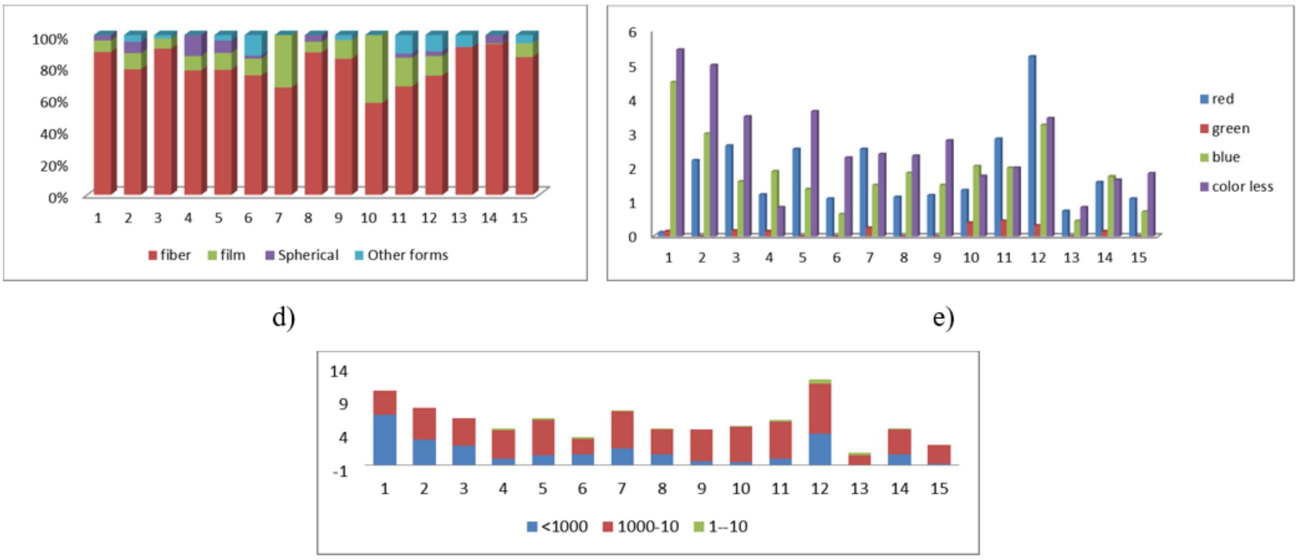
Table 2. *Quantity, mean, and standard deviation of identified MPs in the studied stations.*

wards	Number of MPs	Percentage of MPs (%)
1	458	26
2	142	8
3	272	18
4	247	17
5	545	39
6	45	4
7	154	10
8	165	98
9	76	6
10	636	32
11	257	13
12	540	25
13	398	24
14	405	24
15	18	2
total	4358	100



a) b)

Figure 1. Average number of microplastics detected in settled dust in the treatment units of Meybod hospital, Yazd (a), (b).



f)

Figure 2. Shape (d), color (e), and size (f) of particulate matter suspended in settled dust in the treatment units of Imam Jafar Sadeq Hospital, Meybod, Yazd.

3.2. Physical Characteristics (Shape, Color, and Size) of MPs

Microplastics are a diverse range of pollutants in different forms, including spherical particles, fibers, and films. They contain complex compositions including polymeric materials and chemical mixtures [35]. In addition, microplastics can provide a suitable substrate for the growth and proliferation of microorganisms, including harmful pathogens, and pose a risk to human and habitat health [34, 52]. The present study showed that microplastics were observed in different shapes, colors, and sizes. The study identified fibers as the most common form of microplastics. The frequency of microplastic shapes identified included fibers (79%), films (14%), and spheres (3%), with other shapes (4%) (Table 3 and Figure 2(a)). Our study results are inconsistent with studies conducted in Shiraz and Bushehr, Iran, on indoor dust in homes, mosques, hospitals, kindergartens, and universities, where the primary form of microparticles is fibers [36]. In a study by K. Sharafdin et al., fibers were also found to be the most prevalent form of microplastics both indoors and outdoors in different locations in Islamabad, Pakistan, which is consistent with our study [29, 37]. In another study in Surabaya, Indonesia, that examined microplastics in indoor dust, fibers were the most abundant form observed, accounting for 85% of microplastic particles [38]. The predominant form of microplastics can originate from synthetic clothing fabrics, plastic bags, or discarded plastic products. This form results from the crushing of plastic bags or packaging and has the lowest density [39]. The colors of microplastics detected in dust samples from healthcare units were as follows: white 37% > blue 28% > red

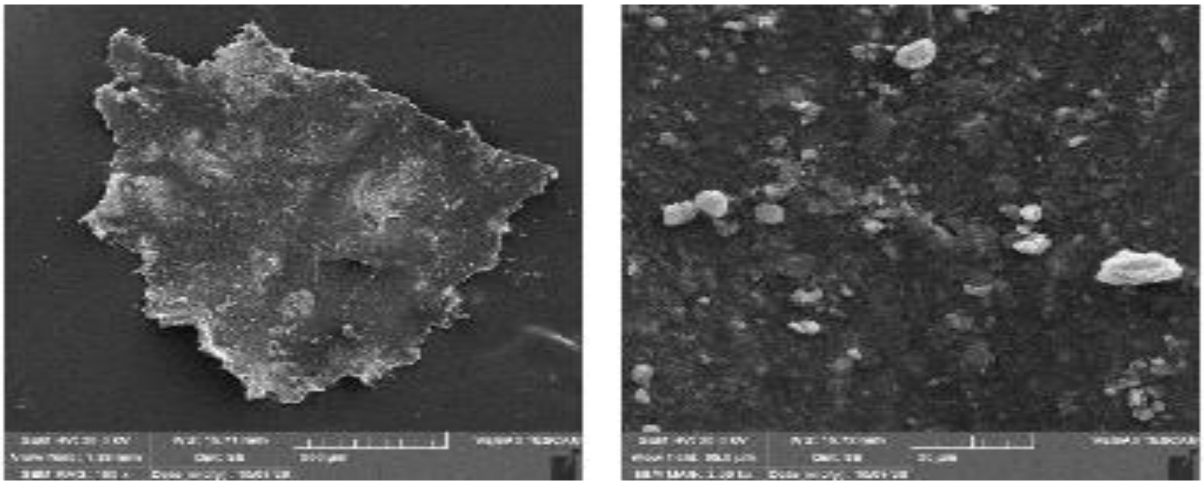
27% (> green 2%) (Table 3 and Figure 2(b)). The most common color was white, which is in contrast to some previous studies [20, 40]. In the study by Zhang et al., blue was the second most abundant color in indoor dust, which is consistent with our study [41]. The white color of the particulate matter observed in dust samples from healthcare units can be attributed to hospital equipment and consumables such as plastic bags, masks, gloves, syringes, gowns, and others [30]. The size of plastic particles is a key factor affecting their environmental fate and interactions in living organisms [42]. The size of the particulate matter observed in the samples ranged from <10, 10–1000, and >1000 μm (Table 3 and Figure 2(c)). The size of most of the observed particulate matter was 10–1000 μm. The results of this study are consistent with the findings of Xiaoyu Zhai et al., who found that the average size of particulate matter in the office, laboratory, dining hall, and dormitory was 66.85, 46.96, 96.71, and 54.07 μm, respectively [43]. In contrast to the findings of this study, Kashfi et al. (2020) reported that most of the fine particles detected in indoor dust in Bushehr and Shiraz, Iran, were larger than 1000 μm [18, 19].

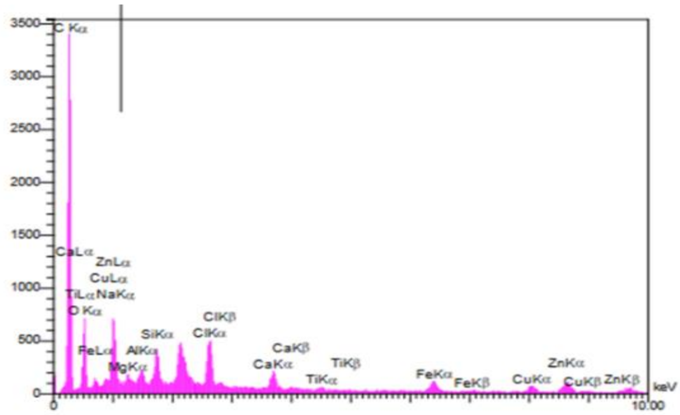
Table 3. *Physical characteristics (shape, color, and size) of MPs in the studied stations.*

wards	shapes				color				size		
	Fiber	film	Other forms	Spheri-cal	blue	Green	red	White/transparent	<10	10-1000	>1000
1	10.1	0.82	0	0.38	4.5	0.15	0.12	5.45	7.5	3.57	0
2	6.16	0.79	0.33	0.56	3	0	2.22	5	3.75	4.8	0
3	6.45	0.45	0.15	0	1.6	0.17	2.65	3.5	2.86	4.15	0
4	3.45	0.4	0	0.58	1.9	0.15	1.22	0.85	0.95	4.18	0.32
5	6.25	0.85	0.27	0.62	1.38	0	2.55	3.65	1.45	5.25	0.35
6	3.20	0.45	0.55	0.08	0.65	0	1.10	2.30	1.6	2.35	0.02
7	6.06	2.96	0	0	1.5	0.25	2.55	2.4	2.45	5.6	0.16
8	5.9	0.44	0	0.28	1.85	0	1.15	2.35	1.55	3.70	0.16
9	5.45	0.75	0.20	0	1.5	0	1.20	2.8	0.55	4.80	0
10	3.45	2.55	0	0	2.05	0.4	1.35	1.76	0.38	5.30	0.15
11	4.7	1.25	0.8	0.18	2	0.45	2.85	2	0.87	5.6	0.32
12	10.1	1.68	1.38	0.39	3.25	0.32	5.25	3.45	4.65	7.55	0.60
13	1.85	0	0.15	0	0.45	0	0.74	0.85	0	1.45	0.36
14	5.9	0.03	0	0.32	1.75	0.15	1.58	1.65	1.50	3.82	0.15
15	4.2	0.42	0.25	0	0.72	0	1.1	1.84	0.15	2.88	0

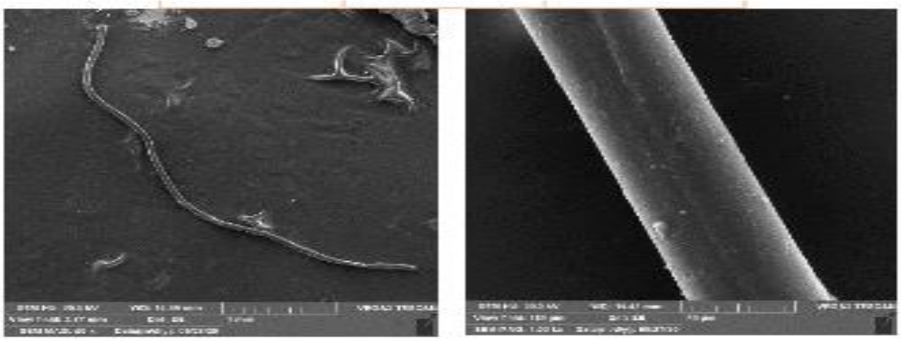
3.3. Polymer Types of MPs

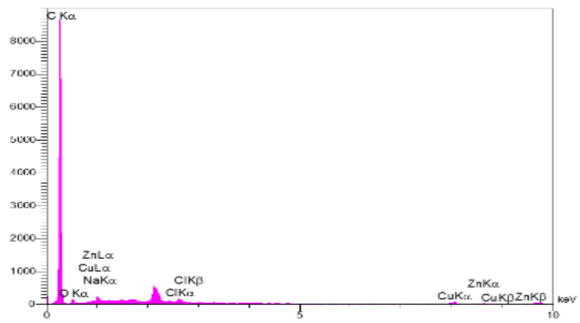
Raman analysis is a spectroscopic technique that allows the identification of the components present in a sample [44]. This technique is widely used to identify different types of MPs [45, 46]. To identify the types of MPs identified, 11 MPs were randomly selected and Raman spectroscopy was used to analyze them. Figure 3 shows the different types of MPs identified by Raman spectroscopy and the Raman spectra for the specific polymers found in the corresponding MPs. The diversity of MPs was similar, with polyvinyl chloride (27%) being the most abundant polymer identified and all polymers having the same amount (18%). In a study in Lima, the most common type of MPs observed in PP dust was identified [5]. In another study in the UK, PET, PP, PE, nylon, PTFE, EVA, and PVA were reported as the main polymers in surgical environments [20]. PE, PVC, and PP are widely used in the production of tubing and fittings, syringes, blood bags, bandages, breathing tubes, laboratory equipment, syringes, surgical masks, plastic bags, and many other products [47-49]. PET and PS are also temporarily used in pharmaceutical bottles, sterile containers, laboratory containers, pharmaceutical packaging, and more [50, 51].



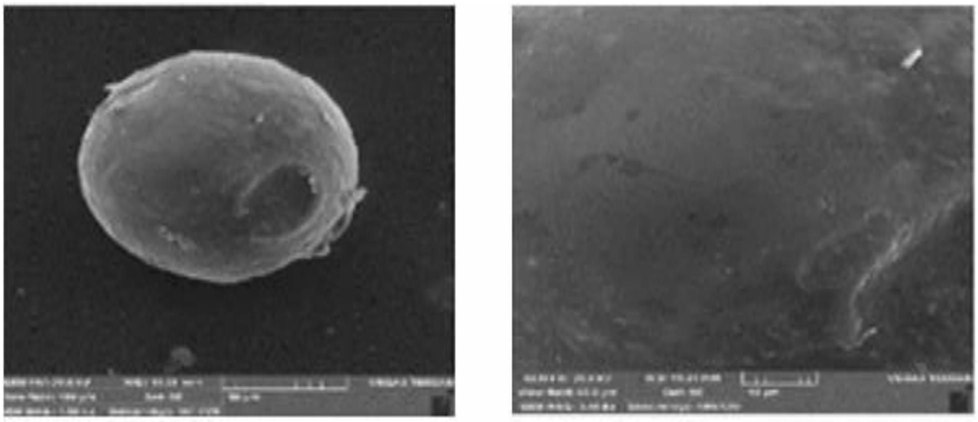


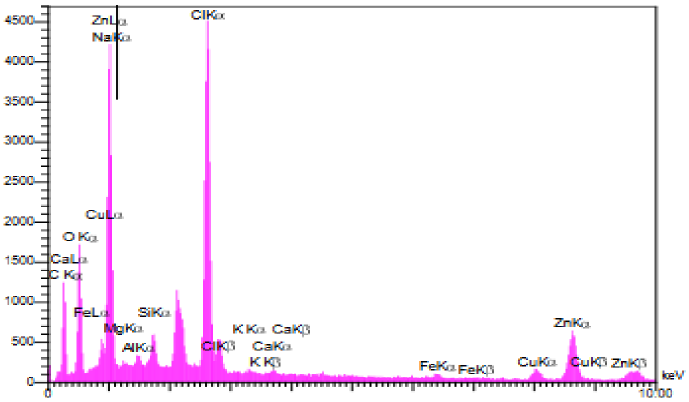
Elt	W%	A%
C	68.21	78.71
O	19.69	17.05
Na	0.73	0.44
Mg	0.80	0.46
Al	0.81	0.41
Si	1.14	0.56
Cl	1.75	0.68
Ca	0.99	0.34
Ti	0.35	0.10
Fe	1.29	0.32
Cu	1.29	0.28
Zn	2.95	0.62





Elt	W%	A%
C	89.96	93.53
O	7.01	5.47
Na	0.93	0.50
Cl	0.51	0.18
Cu	1.14	0.22
Zn	0.45	0.09





Elt	W%	A%
C	41.03	57.78
O	24.58	25.99
Na	8.96	6.60
Mg	0.69	0.48
Al	0.69	0.44
Si	1.05	0.63
Cl	9.27	4.42
K	0.27	0.12
Ca	0.24	0.10
Fe	0.26	0.08
Cu	1.34	0.36
Zn	11.62	3.01

Figure 3. *Images and Raman spectra of some polymers identified in MPs in dust deposited and SEM images and EDS analysis result of representative MPs (with different shapes) in hospital treatment units.*

3.4. Elemental Analysis

SEM-EDS is a potent combination of techniques for rapid morphological analysis and quantitative and qualitative elemental analysis of MPs. A standard SEM microscope with low voltage and low current mode is used to examine MPs (52). directly. Based on SEM-EDS analysis, Findings showed that MPs are characterized by a considerable prevalence of carbon (C) and oxygen (O) elements. In addition, a small percentage of other elements, such as K, Fe, Cl, Al, Ca, Mg, Na, and Si, were also detected in MPs (Fig. 4). In the study of Mrs. Kashfi et al., a significant proportion of carbon (C) and oxygen (O) elements were identified in MPs in different internal places of Bushehr and Shiraz cities. The elements of nitrogen (N), phosphorus (P), iodine (I), chlorine (Cl), aluminum (Al), calcium (Ca), magnesium (Mg), sodium (Na), and silicon (Si) detected were likely the result of plastic additives or residues that adhered to the surfaces of microplastics [19]. The diverse composition of MPs can be derived from multiple sources, such as using plastic materials, medical equipment, industrial and non-industrial activities, hospital procedures, waste disposal, environmental interactions, and more [53, 54].

3.5. MPs in This Study Area Compared with Other Locations

Table 4 compares the abundance and concentration of microplastics (MPs) in indoor dust of the medical units of Hospital in Yazd city with other similar studies in different parts of Iran and the world. As can be seen, the abundance of microplastics in this study, despite the smaller number of samples taken, had more microplastics than similar articles. The common size range of microplastics in indoor dust identified in this study was 10 to 1000 μm, which is different from the ranges observed in other research efforts. The shape of most microplastics in this study and other studies was fibers. The predominant color of microplastics in this study was white, which is consistent with recent studies. The main element of microplastics in this study was also similar to other previous studies, C and O. Also, in most studies, polyvinyl chloride (PVC) was identified as the most common polymer in indoor dust samples.

Table 4. Characteristics MPs in indoor dust in this study compared to other study.

Study area	Sampling location	Sample number	Abundance of MPs	Dominant size(µm)	Major Color	Major Shapes	Major Elemental	Major Polymer types
Curent study	Hospital(cured ward)	30	4358MPS/g	10-1000	white	fiber	Carbon, oxygen	PVC
(20)	Hospital(surgical)	28	1233±2364 mps m-2 day-1	10-250µm	clear	Fragment		PE, PET, PP, Nylon
(19)	Residential house, mosque, hospital, kindergarten, university	30	1212-1362 mps particles	1000µm>	White/transparent	fiber	Carbon, oxygen	PE
(40)	university		131-2659 mps particles	120-2222µm	Black, transparent, blue, red	fiber	Carbon, oxygen fuorine	Polymide, PP
(56)	Apartment, offices, bissines hotels, university	242	62-3861 mps/g	201-1000µm	Black, red, white, transparent, green	fiber		Polyester, PE, PP
(26)	house	32	22-6169 mps/g	200-400µm	Black	fiber		PE, PET, PA, PVC
(53)	schools	28	195mps.g of dust-1	500-1000µm	White-transparent	fiber	Carbon, oxygen	PET.PP
(57)	Apartement office, pastry shope, gift shop, paintshop		104×1.1 $mp/m^2/day$	1000-5000µm		fiber		polyesters

3.6. Human Exposure to MPs

People can come into contact with microplastics through the air they breathe and the food they digest. Due to their persistence, size range, and complex composition, microplastics may have special properties, such as a wider range of potential toxicity, compared to other environmental particles [13]. Table 5 presents the EDI values of microplastics from inhalation and ingestion of settled dust in different healthcare units in Meybod Hospital, Yazd Province, for different age groups. In all different healthcare units of the hospital, EDI from ingestion and inhalation was more common in adolescents than in adults. The hospital with poor ventilation and cleaning, as well as equipment used in the department that was mostly of plastic origin, was exposed to higher levels of microplastics. It should be noted that the exposure levels in different healthcare units for infants, toddlers, and children are very low. Therefore, EDI values were not calculated for these specific age groups. The higher daily intakes calculated for adolescents in these settings are likely attributable to their lower body weight compared with other adult groups [24]. These findings support research conducted in Australian homes with the highest EDI from dust intake in the 18–64 year age group [10]. In another study conducted in indoor environments in Shiraz and Bushehr, ingestion and inhalation of dust resulted in higher EDI in adolescents than in adults [19]. In another study in Australia, the mean annual intakes of MPs from ingestion and inhalation in Australian homes were reported to be 2.4 and 0.2 (mg/kg body weight/year), respectively [24]. In another study conducted in China, the EDI from indoor dust inhalation was reported to be as follows: adults (0.23 MPs/kg body weight/day) and university students (0.22 MPs/kg body weight/day). High exposure to MPs through inhalation of dust in hospital care units is an important route of exposure for individuals. Therefore, specific management strategies are needed to minimize MPs in these units and more accurate scientific methods are needed to calculate the daily intake (EDI).

Table 5. *Estimated daily intake of particulate matter through ingestion and inhalation of indoor dust (number of items/kg body weight/day) for adolescent and adult groups in particulate matter in settled dust in the treatment units of Imam Jafar Sadeq Hospital, Meybod, Yazd.*

wards	Teenagers		Adults	
	Inhalation	Ingestion	Inhalation	Ingestion
1	3.85	1.50×10^{-5}	3.2	1.3×10^{-5}
	3.52	1.30×10^{-5}	2.8	1.17×10^{-5}
	4.25	1.63×10^{-5}	3.4	1.4×10^{-5}
2	2.3	1.01×10^{-5}	2.09	8.5×10^{-6}
	3.6	1.2×10^{-5}	3.1	1.26×10^{-5}
	3.2	1.1×10^{-5}	2.6	1.09×10^{-5}
3	2.15	1.02×10^{-5}	2.3	9.4×10^{-6}
	1.17	8.68×10^{-6}	1.8	7.3×10^{-6}
	1.05	7.42×10^{-6}	1.5	6.2×10^{-6}
4	6.2	2.52×10^{-6}	0.97	3.97×10^{-6}
	1.1	2.35×10^{-5}	5.2	2.15×10^{-5}
	2.6	4.75×10^{-6}	1.02	4.16×10^{-6}
5	2.15	1.02×10^{-5}	2.3	9.4×10^{-6}
	1.26	8.68×10^{-6}	1.8	7.3×10^{-6}
6	2.5	5.07×10^{-6}	1.06	4.35×10^{-6}
7	8.2	1.08×10^{-5}	2.09	8.54×10^{-6}
	1.85	3.06×10^{-5}	1.6	10.74×10^{-5}
8	6.1	2.37×10^{-5}	1.5	2.08×10^{-5}
9	7.1	1.15×10^{-5}	2.6	1.09×10^{-5}
	1.1	2.63×10^{-5}	5.8	2.38×10^{-5}
	1.8	7.78×10^{-6}	6.7	6.62×10^{-6}
10	1.2	1.28×10^{-6}	2.5	2.62×10^{-6}
11	1.3	3.75×10^{-6}	2.6	3.62×10^{-6}
12	1.9	4.68×10^{-6}	4.7	5.62×10^{-6}
13	2.5	5.55×10^{-6}	3.65	2.82×10^{-6}
14	1.8	6.48×10^{-6}	4.35	6.02×10^{-6}
15	0.8	1.06×10^{-6}	0.068	1.3×10^{-3}

4. Limitations and Ideas for Future Studies

Due to ethical constraints at the sampling site, sampling was not performed in some departments, such as endoscopy and cardiology, due to the lack of permission from the department head and the cardiac department being repaired [54]. Another limitation of this study was the lack of standardized sampling methods, as the settled dust collection method may not collect all the particulate matter present [24, 54]. Quantification and analysis of particulate matter requires a great deal of time and precision, and quantification of particulate matter by microscopy is a significant challenge due to the variation in visibility of these particles depending on magnification. Furthermore, particulate matter may show variations in size compared to what is expected, as they can potentially pass through filters

[19]. These limitations are needed for further studies.

5. Conclusion

This study investigated the amount of microplastics in dust collected in the medical units of Meybod Hospital, Yazd Province, Iran. It was found that most microplastics were detected in a unit with poor ventilation and cleaning. Most of the detected microplastics were between 10 and 1000 µm in size. Fiber was the most common form of microplastics observed in dust samples. Polyethylene was also the most abundant polymer type among the microplastic polymers detected in indoor dust. SEM-EDS analysis showed that the observed microplastics had a high percentage of C and O elements. The findings of this study also indicate that the type of hospital waste management and the type of service provided by the hospital facilities may affect the abundance of microplastics. Given the limited research conducted on these units, more attention is needed to minimize the release of microplastics from these facilities. It should be noted that the development and implementation of new policies in the field of waste management is essential to reduce environmental pollutants, especially particulate matter, to protect the health of the environment and humans, and to improve public health. It is also possible to reduce particulate matter in dust deposited in various healthcare units of hospitals and other hospital departments and similar places by measures such as the use of plastic alternatives, improving ventilation systems, and increasing personnel awareness.

Abbreviations

MPS Microplastics
EDI Intake Daily Estimate

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Author Contributions

Azra Ebrahimpour Meybodi: Data curation, Writing – original draft, Funding acquisition, Visualization

Ehsan Abouee Mehrizi: Supervision, Methodology, Project administration, Writing – review & editing

Hossein Arfaeinia: Conceptualization, Supervision, Validation, Writing – review & editing

Zahra Soltanianzadeh: Software, Resources, Visualization, Investigation

Mahdi Ghorbanian: Writing – review & editing, Validation, Software, Formal analysis, Project administration

Conflicts of Interest

The authors declare that they have no competing financial interests or known personal relationships that could influence the work reported in this article. Given the type of contaminant studied in the healthcare units, we apologize for mentioning the hospital name.

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