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Identification and Distribution of Microplastics in Road Dust and Urban Soils: A Study in The Southwest of Iran

Parisa Asban[1], Reza Dehbandi[2,3], Mohammad Javad Mohammadi[4,5], Saeed Ghanbari[6], Afshin Takdastan[7], Nematollah Jaafarzadeh Haghighifard[5*]

[1]Student Research Committee, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran
[2]Department of Chemical Engineering, University of Sciences and Technology of Mazandaran, Behshahr, Iran
[3]School of Geography, Earth and Environmental Sciences, University of Birmingham, Edgbaston, B152TT Birmingham, United Kingdom
[4]Department of Environmental Health Engineering, School of Public Health and Air Pollution and Respiratory Diseases Research Center, Medical Basic Sciences Research Institute, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran
[5]Environmental Technologies Research Center, Medical Basic Sciences Research Institute, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran
[6]Department of Biostatistics and Epidemiology, School of Health, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran
[7]Department of Environmental Health Engineering, School of Public Health and Environmental Technologies Research Center, Medical Basic Sciences Research Institute, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

Abstract

Background: Microplastics have increasingly been detected in various environmental matrices. The concentration and distribution of microplastics in these environments remain poorly understood, particularly across various land uses within a city. This study addressed this knowledge gap by investigating the distribution and characteristics of microplastics in both road dust and urban soil across different land uses in Shushtar City.

Methods: In this descriptive-analytical study, 38 samples were collected in the road dust and urban soil of the different land uses. Stereo-microscopy, micro-Raman spectroscopy, and SEM-EDX were employed for the identification of microplastics.

Results: The study revealed a significant presence of microplastics in both road dust and urban soil. Road dust consistently exhibited higher microplastic concentrations compared to urban soil. High-traffic areas had the highest microplastic concentration in road dust (86.33 particles per 10 g), followed by municipal services (87 particles per 10 g) and industrial areas (42.28 particles per 10 g). In contrast, green spaces exhibited the highest microplastic concentration in urban soil (16.40 particles per 10 g), followed by residential areas (15.46 particles per 10 g) and municipal services (16.40 particles per 10 g). The Kruskal-Wallis test did not detect statistically significant differences ($P > 0.05$) in microplastic concentration or characteristics between all land uses.

Conclusion: The findings suggest that waste management practices, prevailing wind directions, and atmospheric conditions, including dry and wet deposition, play pivotal roles in influencing microplastic sources in road dust and urban soils in Shushtar City, southwest Iran.

Keywords: Microplastic, Dust, Plastics, Soil

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***Correspondence to:**
Nematollah Jaafarzadeh Haghighifard,
Email: n.jaafarzade@gmail.com

Introduction

The increase in urbanization and the development of infrastructures have caused continuous changes in land use in urban areas of developing countries (1,2). As a result of this development, great stress has been entering the environment and decreasing the quality of urban environments (3). The accumulation of microplastics in road dust and soil can lead to constant diversity in the ecosystem (2,4,5). In urban environments, road dust can indicate the reflection of pollutants of soil, air, and water (6). Nowadays, plastics are one of the most widely used materials in the world. They have dramatically entered the human lifestyle and are used in various forms for household, commercial, industrial, and medical purposes. The increase and excessive production of plastic in recent decades have led to significant environmental pollution

(7,8). According to Plastics-Europe (2018), the annual production of plastics exceeded 348 million tons in 2017. It is estimated that by 2050, annual plastic production could increase to 33 billion tons globally (8,9). Plastic pieces with dimensions less than 5 mm are called microplastics (10,11). Soil is an excellent source of microplastics. The soil of urban areas is mainly a mixture of different materials with a surface layer of more than 50 cm (12). Microplastics exist in soils with different land uses, such as agricultural and industrial soil (13,14). Soil, dust, runoff, and rainfall are essential sources of microplastics in cities. Microplastics have primary and secondary sources. Primary sources enter the environment directly as plastic film and due to the cosmetic products and plastic industry (15,16). Secondary sources arise from the fragmentation of more considerable plastic waste due to mechanical abrasion, oxidation, and photothermal degradation (17,18). The fragmentation of plastics is in response to physical, chemical, and biological processes that lead to a decrease in the structural resistance of plastic parts (19,20). Globally, China has the highest consumption of plastic (30%) (21,22). Plastics are made of synthetic organic polymers, including polyethylene (PE), polystyrene (PS), polypropylene (PP), polyvinyl chloride (PVC), polyurethane (PUR), and polyethylene terephthalate (PET) (23). Microplastics in road dust in developing countries like Iran have caused many problems due to traffic load and industrial activities (20,24,25). Microplastics can cause toxicity due to the high surface-to-volume ratio and intrinsic toxicity of monomers (26). The high surface-to-volume ratio in microplastics can cause the absorption of pollutants and persistent organic pollutants (POPs) on their surfaces (27,28). Concerns about the potential threats of microplastics to aquatic organisms, birds, mammals, and even humans have increased by their entry into the food chain (29). Microplastics in the human body can probably cause breast cancer and disorders in the reproductive system of women and men (9). Recently, there has been much evidence of the presence of microplastics in the human body (30). Road dust and urban soil act as potential reservoirs for microplastics, potentially entering the food chain and disrupting ecosystems. However, the concentration and distribution of microplastics in these environments remain poorly understood, particularly across various land uses within a city. Existing research is often limited to studying microplastics in either road dust or urban soil individually. This study addresses this knowledge gap by investigating the distribution and characteristics of microplastics in both road dust and urban soil across different land uses in Shushtar City, southwest of Iran. Notably, this is the first study of its kind in the country, providing valuable baseline data for future research and environmental management strategies. The study was conducted on the contamination of microplastics in the soil and road dust of urban areas and showed that microplastics have a high concentration in these environments, and population density and increased traffic increase their concentration (28,31). This study aimed to identify and investigate the distribution of microplastics in road dust and urban soils in south southwest of Iran.

Material and Methods

This descriptive-analytical study was conducted in Shushtar city in the north of Khuzestan province, Iran. This city has an ancient history and civilization and served as the capital of Khuzestan province until 1979 (Figure 1).

The city has 14 world cultural heritage sites registered on the UNESCO list and is located on the slopes of the Zagros mountains (32). This city enjoys mild winters and autumns, characteristic of the Mediterranean climate. The geographical location of sampling points in Shushtar City in Khuzestan province is shown in Figure 1.

The warmest and coldest months of the year in the city are July and December, respectively (33). The average annual temperature is 27.2°C, and the average annual rainfall in this city is calculated to be 322 mm. The prevailing wind direction is from southwest to northeast, and the average wind speed is 5 m/s. Shushtar is considered one of the main agricultural areas in Iran, with its primary products including wheat, rice, corn, legumes, and vegetables (34).

Before the sampling campaign, the sample size was determined using MedCalc statistical software version 22.019, resulting in a final determination of 38 samples, with 95% confidence and 10% accuracy. In total, six different land uses in Shushtar city were randomly selected as sampling locations, including municipal services, residential, high traffic, green space, industrial, and recreational areas. A total of 38 samples were collected over one week following a month-long period without rain.

Road dust samples were generally found on the side of the road, sidewalks, and squares. The amount of 300 to 500 g is collected from each station from the side of the road, street, and squares using a wooden brush and stainless-steel dustpan. To collect the soil, about 1 kg of soil was collected from the 0-10 cm depth of each urban soil station using a stainless-steel shovel. After each sampling, the brush and shovel were thoroughly cleaned and washed with purified filtered water. The samples were then stored in paper bags and transferred to the laboratory for further analysis.

In the laboratory, first, the samples were transferred to a clean aluminum foil and dried in an oven at 40°C to 60°C for 48 to 72 hours until they reached a constant weight (35). During the drying process, the samples were covered with aluminum foil to prevent airborne microplastics from possibly entering the samples. To separate larger wooden/metal parts, tree leaves, cigarette

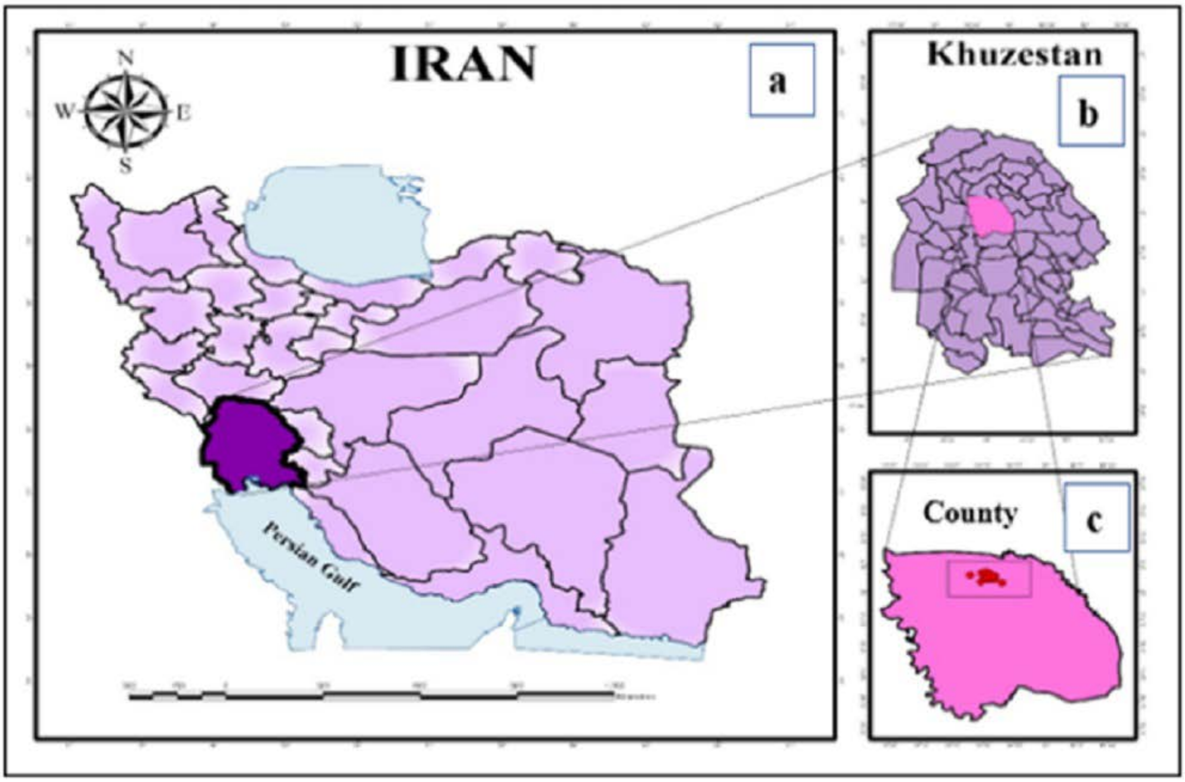

Figure 1. (a) Location of the Khuzestan province in Iran, (b) Location of the Shushtar county in Khuzestan province, (c) Geographical location of sampling points in Shushtar City

filters, glass, and other unnecessary materials, and to achieve the appropriate size fraction for the microplastics study (0-5 µm), the samples were passed through a 5 mm sieve. 50 g of soil and 10 g of road dust samples were selected from the sieved samples and put into a 1000 ml beaker for the digestion process (36,37). To the digest organic matter, 200 ml of 30% hydrogen peroxide (H_2O_2) solution was added to the samples. Moreover, the beakers were covered with aluminum foil until the produced bubbles disappeared. Then, the remaining materials were washed once with distilled water and dried in the oven. Zinc chloride solution ($ZnCl_2$) with a density of 1.7 g/cm^3 was added to the samples in a 1000 ml glass beaker (38). The samples were stirred with a stirring rod for 5 minutes and then left to stand for 24 hrs to allow the sediment to settle out. Afterwards. the supernatant of the solution was transferred to a 50 ml Falcon tube and put into a centrifuge at 2000 rpm for 7 minutes, and finally passed through a filter paper (Johnson standard filter, Garde 304) with a pore size of 10 microns using a vacuum pump (39). The flotation and extraction procedures were repeated three times to obtain the maximum percentage of microplastics from the samples. The filters were finally transferred to glass Petri dishes and dried in an oven at 60°C for 30 minutes to 1 hour.

The particles in the Petri dishes were carefully observed under a binocular stereo microscope (Olympus, BX41TF) with a maximum magnification of 200 times and identified and counted according to the instructions in the literature (2,37). A metal needle with a diameter of 250 µm and the ImageJ software were used to identify the microplastics. According to appearance, microplastics were divided into four groups of shapes, including fibers, fragments, plates, and spherule, in five colors, including yellow-orange, green-blue, black-gray, white-transparent, and red-pink, and four sizes of less than 250 µm, between 250 to 500 µm, between 500 to 1000 µm, and between 1000 to 5000 µm, respectively (40,41). In this study, the abundance of microplastics in both road dust and urban soil was reported as microplastics in 10 g (items/10 g). The polymer types of about 40 particles with different shapes, sizes, and colors were determined using a micro-Raman spectrometer (LabRAM HR, Horiba, Japan) with a 785 nm laser and a Raman shift of 400 to 1800 cm^{-1}. The micro-morphology and surficial chemical composition (including potentially toxic elements) of a selected number of separated microplastic particles were determined using a scanning electron microscope equipped with an energy-dispersive X-ray micro analyzer (EDS) device (SEM-EDX) (Tescan VEGA 3 microscope)

Quality assurance and quality control (QA/QC) procedures

Quality assurance and quality control procedures were followed during all sampling and laboratory processes and during extraction. At first, the glass containers used in different stages were soaked in 10% HNO_3 for 24 hours, and then, washed with filtered distilled water. The working surfaces of the laboratory were cleaned with ethanol. Metal and glass containers were cleaned with distilled water and used in all stages to prevent contamination with microplastics. Windows and doors were closed. White cotton lab coats, disposable latex gloves, and facemasks were used throughout the experiments and sample processes. All the reagents and solutions used were first passed through a filter paper with a diameter of 1-5 microns. To determine the possibility of microplastics entering the samples through laboratory materials and solutions, a control sample (blank test) was placed along with other samples in the test route, and no polymers were detected in the sample. All these cases for determining the relationship between the physical and chemical parameters measured in the soil with the concentration of microplastics.

Data analysis

Descriptive statistics and independent t-test, ANOVA, and Kruskal-Wallis test were used to analyze the data. The Kolmogorov-Smirnov test was used to check the normality of the data. Data analysis was done using Excel and SPSS version 22.

Results

Table 1 shows a statistical summary of the microplastics in road dust and urban soil in different land uses in Shushtar City. In total, 974 microplastics were identified in the street dust samples. The highest concentrations of MPs were observed at site S16 within the green space region (Beset park) with 134 particles per 10 g sample, and the lowest concentrations were found at site S13 within the residential areas (Kharman Khak) with 10 particles per 10 g sample. Among the land uses, the highest average concentrations of microplastics in street dust were found in the recreational regions, with an average of 87 particles per 10 g. In contrast, the lowest concentrations of microplastics were found in the residential area, with a mean of 40.75 particles per 10 g.

In total, 275 microplastics were identified among the urban soil samples. The highest concentration of microplastics (65.80 particles per 10 g) was observed at the S1 station located in Shahrivar 17 square, characterized by a high traffic load. The site exhibiting the lowest concentration, with 1.50 particles per 10 g of sample, was identified as S14 within the industrial zone at Sanat Park. Based on the land use type, the highest average concentrations of microplastics in urban soil were found in the high traffic area with 20.52 particles per 10 g, while the lowest average was found in the municipal service area with 2.60 particles per 10 g.

Figure 2 shows the microplastics distribution in road dust and urban soil samples in different land uses of Shushtar City. The results showed the importance of land use variability in the distribution of microplastics concentration in urban environments. As already mentioned, the highest concentration of microplastics in the road dust occurred in the recreational areas and municipal services areas, and the highest concentration of microplastics in the urban soil was observed in the high-traffic areas.

Microplastic shape

In terms of microplastics' shape, street dust and urban soil samples showed similar patterns (Figure 3). Table 2 shows the microplastics shapes in street dust were dominated by fibers (87%) and fragments (10%). Urban soil was dominated by fibers (95%), fragments (4%), and with only one identified sphere-like particle. In general, there appeared to be more fibrous microplastics in the urban areas.

Figure 4 shows that the high-resolution images of microplastic particles using SEM-EDS show that the surfaces of some microplastics are smooth and probably

Table 1. The statistical summary of the microplastics in road dust and urban soil in different land uses. All values are in particles per 10 g sample

Land use type	Sample type	Minimum	Maximum	Average	Standard Deviation (SD)
High Traffic	Road dust	21	69	42.28	19.86
	Urban Soil	6.20	65.80	20.52	25.46
Municipal Services	Road dust	21	107	64	60.80
	Urban Soil	2.60	2.60	2.60	-
Residential	Road dust	10	98	40.75	39.40
	Urban Soil	7.20	25.80	15.46	9.47
Green Space	Road dust	31	134	86.33	51.92
	Urban Soil	4	10.20	6.06	3.57
Industrial	Road dust	41	41	41	-
	Urban Soil	1.40	5	3.20	2.54
Recreational	Road dust	87	87	87	-
	Urban Soil	16.40	16.40	16.40	-

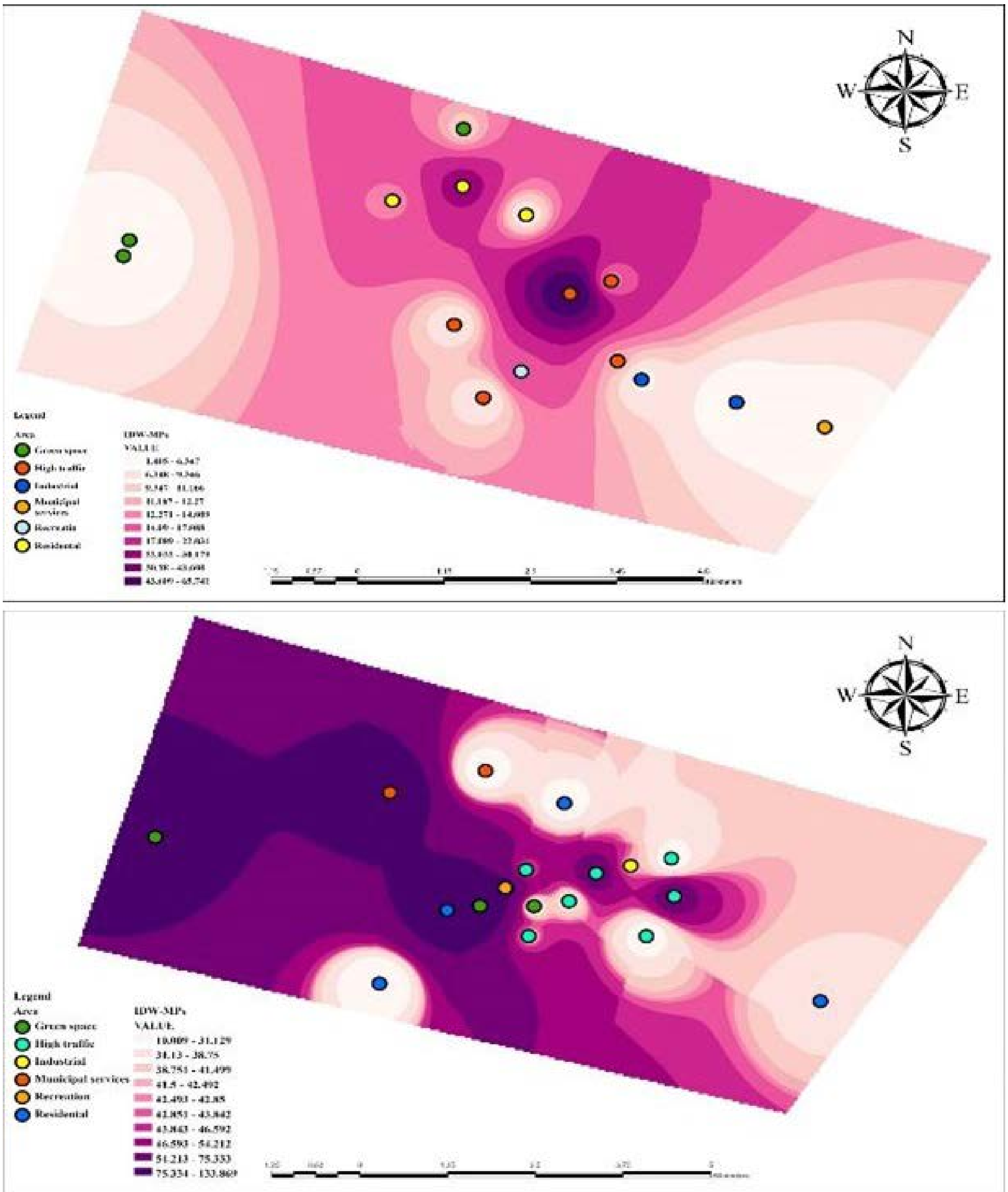

Figure 2. Distribution of microplastics in road dust and urban soil in different land uses of the Shushtar city; a: urban soil, b: road dust

indicate the primary sources for these microplastic particles (Figure 4).

Based on the results of visual inspection, several microplastic particles were selected for polymer identification by Raman micro-spectrophotometer (Figure 5). The Raman spectra of some microplastics identified in the road dust and urban soil are demonstrated in Figure 5a–d. High-density polyethylene (HDPE), polyethylene terephthalate (PET), and polyamide (PA) were the most abundant polymer types of microplastics in road dust. Also, polyethylene terephthalate (PET), polyvinyl chloride (PVC), polyurethane (PUA), and polystyrene (PS) were the four polymer types of microplastics in urban soil. The results of this study are consistent with those reported by Nematollahi et al (40). The reason for this consistency was the abundance of polyethylene terephthalate (PET) and polyamide (PA) in microplastics found in industrial and urban soils.

Discussion

The results of this study are consistent with the study of O'Brien et al in Australia, which focused on road dust and also found the highest abundance of microplastics in high traffic areas (42). The high concentration of microplastics in recreational areas can be attributed to two main reasons. First, the photo-degradation of children's playground equipment by high levels of sunlight radiation. The annual average of UV index in

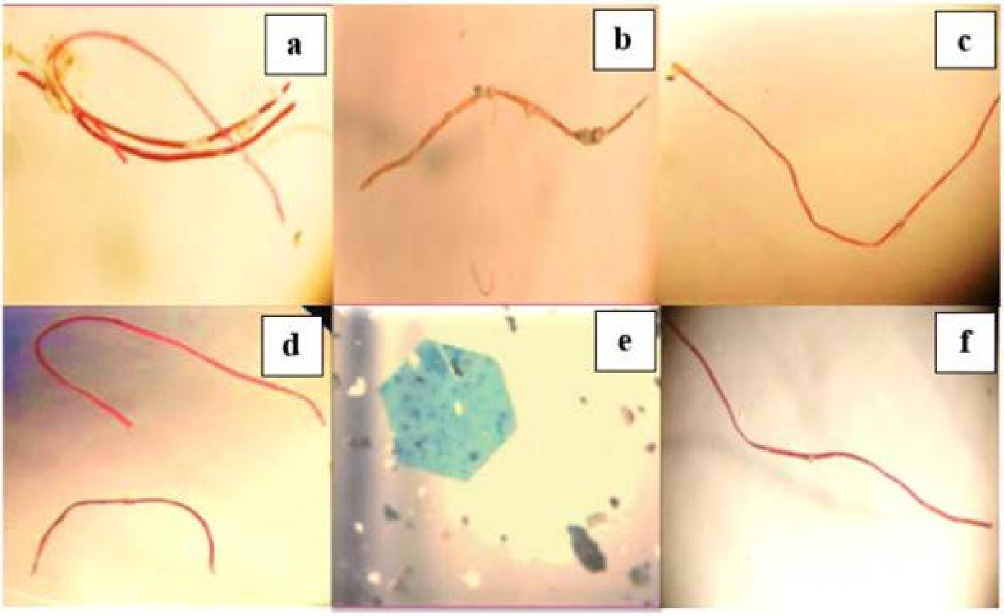

Figure 3. Stereomicroscopic images of fibrous (a, b, c, d, and f) and fragmented (e) microplastics in street dust and soil samples.

Table 2. The characteristics of microplastics (shape, color, and size range) in road dust and urban soil in different land uses. All values are in particles per 10 g sample

Characteristics of microplastics		High traffic	Municipal services	Residential	Green space	Industrial	Recreation
Fiber	Street dust	199	77	101	202	30	87
	Urban soil	99.60	0.60	40	9	3.20	16.20
Plate	Street dust	19	6	1	0	1	0
	Urban soil	0.20	0	1.50	0	0.20	0
Fragment	Street dust	51	13	2	16	0	0
	Urban soil	2.40	0	4.40	1.20	0.40	0.20
Spherule	Street dust	1	0	0	0	0	0
	Urban soil	0	0	0	0	0	0
White/Transparent	Street dust	126	58	66	179	24	4
	Urban soil	16.20	0	18.40	1.40	1.40	2.60
Yellow/orange	Street dust	12	8	2	0	1	8
	Urban soil	7	0	5.20	0.40	0	1.20
Red/Pink	Street dust	24	12	10	6	0	26
	Urban soil	19.80	0	10.60	1.80	0.20	3.60
Blue/Green	Street dust	18	13	5	15	1	7
	Urban soil	15.60	0.40	1.20	0.60	0.60	1.80
Black/Grey	Street dust	89	5	20	18	5	42
	Urban soil	43.20	0.20	10.40	6	1.60	7.20
L≤250	Street dust	18	1	0	7	0	0
	Urban soil	0.40	0	0	0.20	0	0
250<L≤500	Street dust	26	1	9	19	0	7
	Urban soil	6.60	0	5	0.60	0	1.80
500<L≤1000	Street dust	65	27	19	60	1	42
	Urban soil	40	0.60	7.60	2.80	2	7.40
1000<L≤5000	Street dust	164	66	75	132	30	38
	Urban soil	57.40	0	33.40	6.60	1.80	7.20

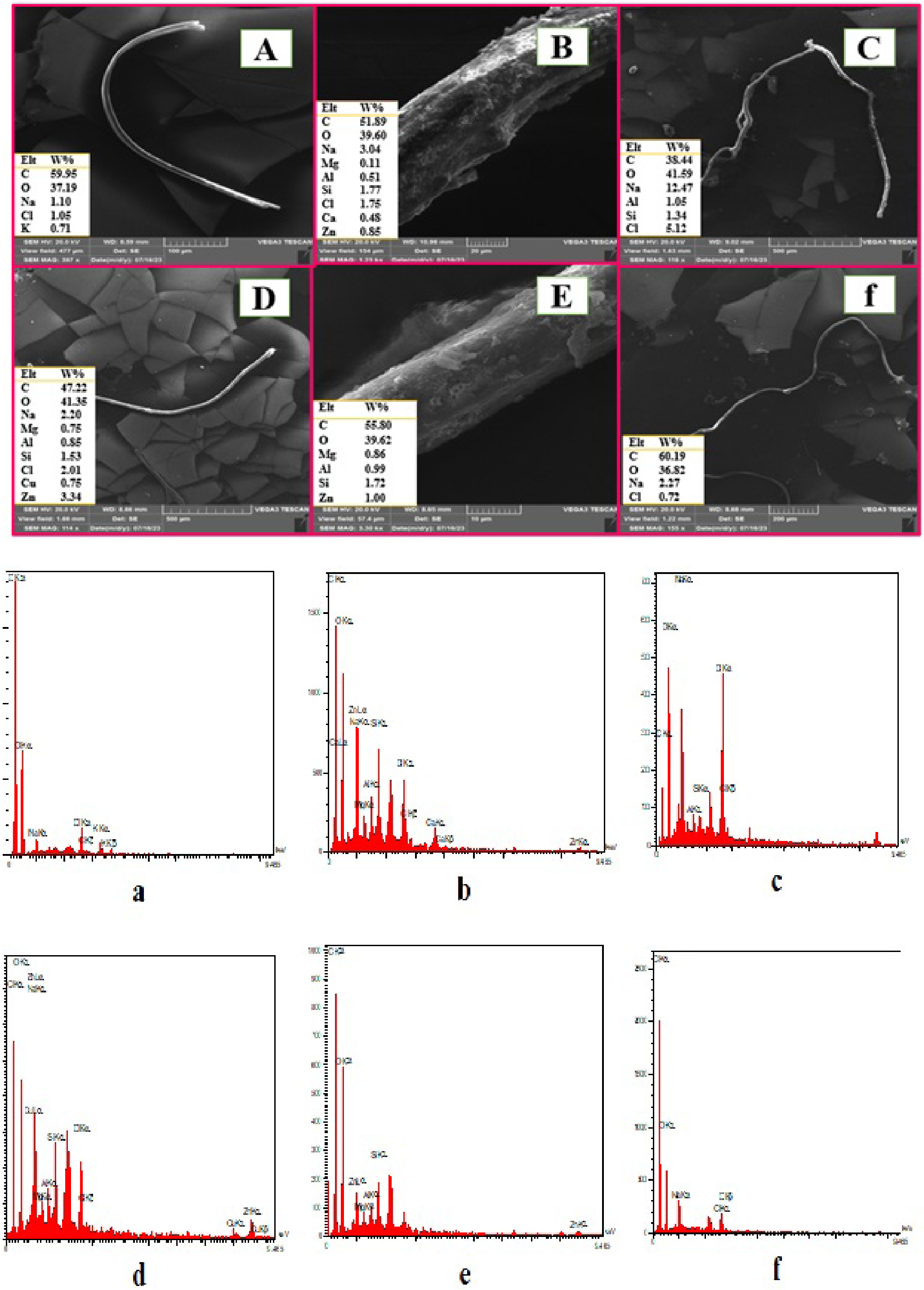

Figure 4. Images (A, B, C, D, E, F) and chart (a, b, c, d, e, f) obtained from SEM-EDX for microplastic samples of road dust and urban soil of Shushtar city

Shushtar city is 9, classified as an extremely high level, which can accelerate the weathering and erosion of plastic equipment. Second, the lack of adherence to proper waste management practices in these areas results in widespread littering of plastic waste by visitors and thus exacerbating environmental microplastics pollution concerns.

In high traffic areas, increased microplastics concentration is probably due to the presence of food stores, high traffic density, and the lack of urban waste management. The same results were obtained in the road dust and storm water region of Melbourne and Australia (43). "Additionally, in green space areas, inadequate urban waste management and littering contribute to an increase in microplastics. The lack of industries related to plastic production and processing in industrial zones can be the reason for the lower microplastics concentration in Shushtar industrial areas with respect to other land uses. A similar result was observed in the Metropolitan region,

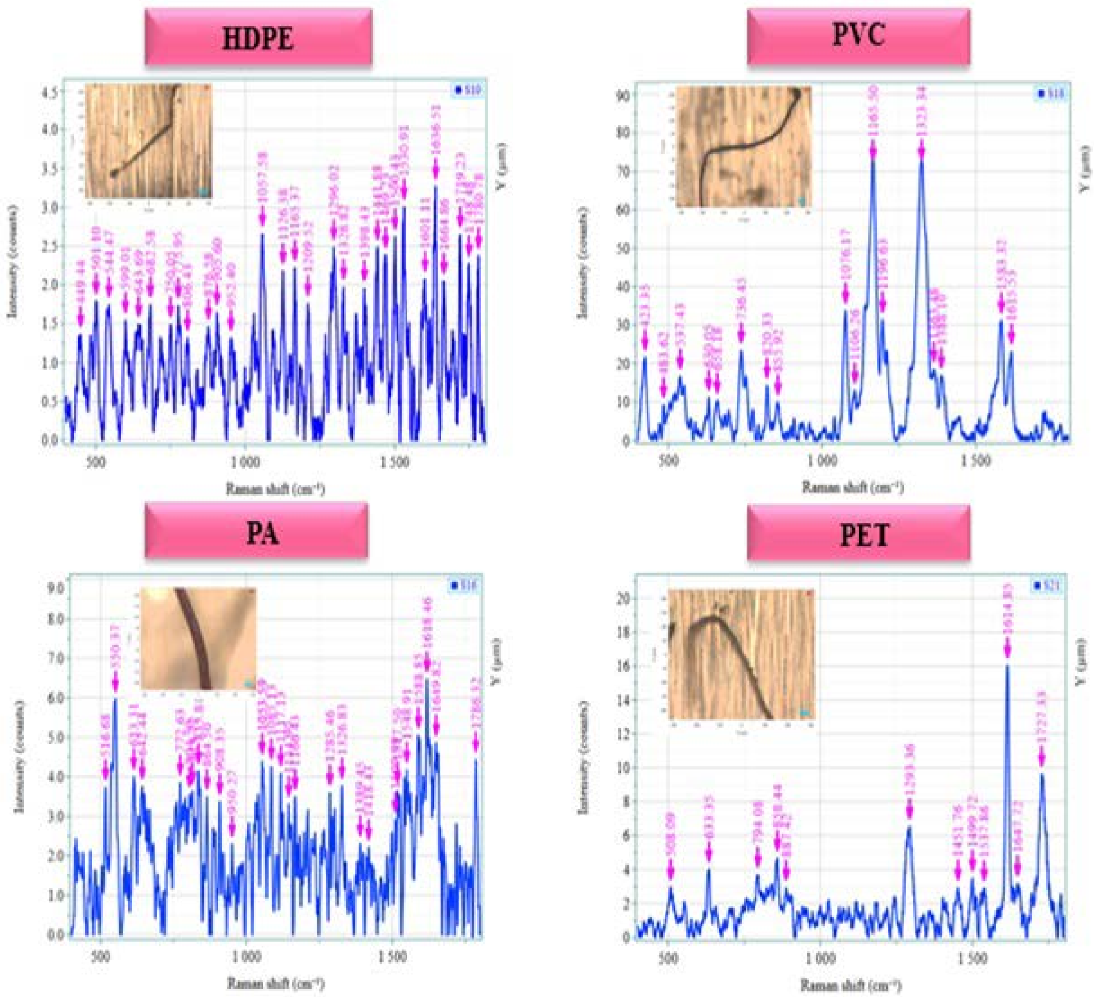

Figure 5. Micro Raman spectra of some selected microplastics in road dust and urban soil.

Thailand, and Kiel Fjord (44,45)

Despite these observations, however, a nonparametric Kruskal-Wallis test revealed a non-significant difference ($P > 0.05$) between different land uses and microplastics shapes, colors, and sizes among sampling stations in both urban soils and street dusts.

Based on the results shown in Figure 2, the highest concentration of microplastics in the road dust occurred in the recreational areas and municipal services areas, and the highest concentration of microplastics in the urban soil was observed in the high-traffic areas. The obtained results are consistent with the findings of Rabin et al. (46). The prevailing wind direction in Shushtar city is from the southwest to the northeast (Figure 2a), so it can be concluded that the distribution of microplastics in road dust likely aligns with wind patterns due to their small size and susceptibility to wind transport (2,42,47) as indicated in Figure 2a. This influence, however, seems less pronounced for microplastics in urban soil samples (Figure 2 b), potentially due to their larger size and the stronger influence of soil properties like soil texture, organic matter, and moisture content, soil compaction, as well as vegetation cover on their mobility (48,49). The distribution of microplastics in the soil is unrelated to the prevailing wind direction.

Figure 3 showed that, regarding the color, in street dust, white-transparent particles were the most abundant microplastics (about 57%), and in urban soil, black-gray particles showed the highest abundance (42%). However, the yellow-orange color group showed the lowest percentage (less than 10%) in both street dust and urban soil samples. The predominant size in street dust and urban soil was 1000-5000 µm, accounting for 63% and 58% of all the particles, respectively. Nearly 3% of particles were in the < 250 µm size category. A similar result was observed in surface road dust in Japan (50). Generally, the breakdown of larger plastic particles due to physical abrasion and photochemical processes can probably lead to these small-sized microplastics (51).

The high-resolution images of microplastic particles using SEM-EDS show that the surfaces of some microplastic particles are smooth and probably indicate the primary sources for these plastic particles (Figure 4) (52). The roughness of the surfaces of some particles can result from physical erosion of larger plastics and photochemical degradation, and weathering by sunlight and other environmental factors (53). These rough surfaces can increase the specific surface of these particles, and increase the surface absorption capacity to other contaminants in the environment. The obtained results are consistent with the findings of Nematollahi et al (40).

The EDS analysis specified that C and O were the major microplastic elements of the road dust and urban soil. The EDS analysis showed that carbon (38.44%–60.19%) and oxygen (36.82%–41.59%) composed the main chemical components of microplastics (54). Low peaks of Ca, S, Mg, Cl, Si, K, Fe, Na, Ti, Zn, and Al were also observed in some samples in road dust and urban soil, which may indicate the presence of additives, chemical compounds used for the samples preparation, or adsorption from external environments (16,55).

Based on the results demonstrated in Figure 5, the high-density polyethylene (HDPE), polyethylene terephthalate (PET), and polyamide (PA) were the most abundant polymer types of microplastics in road dust. The polymer types of microplastics in road dust and urban soil can give information about their origin (56). The origin of PET (or polyester) is plastic bottles, artificial fibers, and personal care products (57). PS is used in cosmetics, packaging material, daily decoration, and insulation material (58). These polymers can be introduced into the urban environment through littering, weathering, and mechanical erosion of larger plastic particles (51,59). However, due to the limited analyzed particles by Raman spectroscopy in this study, these cannot be solely comprehensive interpretation regarding the sources of microplastics.

According to this table, the predominant morphology of microplastics observed in road dust and soil samples from this study was fiber, while in other studies, it was reported as fiber and fragment (40). The primary identified polymer types in road dust and soil samples in Shushtar city were similar to other studies. Similar to other research, the main microplastics colors in road dust and soil samples in this study were white-transparent and black-gray, respectively. The differences in the identified microplastics characteristics in different studies can be related to different sources of microplastics, environmental factors, chemical compositions of plastics, as well as methodological differences (60). The comparison of microplastics characteristics in soil and street dust of Shushtar city with previously published research is shown in Table 3.

Conclusion

This study investigated the concentration and distribution of microplastics in road dust and urban soils across various land uses in Shushtar City, southwest of Iran. Our results confirm the presence of microplastic contamination in both road dust and urban soil throughout the city. While no statistically significant difference was observed in microplastic characteristics between land uses ($P > 0.05$), the identified microplastics likely originated from various sources, including plastic bottles, synthetic fibers, cosmetics, packaging materials, building materials, and insulation. Land-use variations, inadequate waste management practices, and atmospheric deposition are likely the key factors contributing to microplastic accumulation in Shushtar City.

This study provides a valuable baseline assessment of microplastic pollution in Shushtar City. The data can be used for future comparative analyses to track changes in microplastic levels within the urban environment. Further research is recommended to explore the specific influence of factors like land use, waste management practices,

Table 3. The comparison of microplastics characteristics in soil and street dust of Shushtar city with previously published research

Region	Sample type	Abundant (Particles/kg-1)	Color	Shapes	Size µm	Polymers	Reference
Shushtar (Iran)	Road dust	5410	White-transparent	Fiber	1000-5000	PET, PA	This study
Shushtar (Iran)	Urban soil	1447	Black-gray	Fiber	1000-5000	PET, PUA	This study
Shiraz (Iran)	Urban soil	116.50,8-660	Transparent/ Translucent	Fragment, Fiber	< 100	PE (HDPE, LDPE),	(61)
Shiraz (Iran)	Industrial soil	41.16,7-74	Transparent/ Translucent	Fragment, Fiber	< 100	Nylon, PS	(61)
Shiraz (Iran)	Agriculture soil	36.66,7-189	Transparent/ Translucent	Sheet, Fiber	100-250	PE(HDPE)	(61)
Metropolis (Iran)	Industrial soil	390,80-1220	White-transparent	Fiber	NI*	PET, NY	(40)
Ahvaz (Iran)	Urban soil	619,100-3135	White-transparent	Fiber	50-250	PET, NY	(40)
China	Suburban soil	2.2×10^4 to 6.9×10^5	NI*	Fragment	< 1000	PE, PP, PS, PA, PVC	(62)
Sydney, (Australia)	Industrial soils	300-67500	NI*	NI*	NI*	PVC, PE	(63)
Shouguang (China)	Agricultural soil	1444,310-5698	Transparent/ translucent	Fiber	< 0.5 mm	PE, PP	(64)
Swiss	Floodplain soil	593	NI*	NI*	125–500 µm	PE, PP	(65)

*Not identified.

wind patterns, and rainfall on microplastic accumulation in different areas. Additionally, investigating potential ecological and human health risks associated with microplastic exposure in Shushtar City would be valuable. Our suggestions for improving the identification and extraction of microplastics include collecting and editing standard identification methods for the extraction and identification of microplastics, tracking microplastics in agricultural soil, complete identification of microplastics, and microplastic polymer detection using Fourier transform infrared spectroscopy (FTIR).

The limitations of this study include not measuring particles smaller than 100 microns due to the lack of a high-magnification microscope.

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Authors' contributions

Conceptualization: Parisa Asban, Reza Dehbandi, Nematollah Jaafarzadeh Haghighifard.
Data curation: Parisa Asban and Reza Dehbandi.
Formal analysis: Reza Dehbandi, Saeed Ghanbari, Nematollah Jaafarzadeh Haghighifard.
Funding acquisition: Mohammad Javad Mohammadi, Nematollah Jaafarzadeh Haghighifard.
Investigation: Mohammad Javad Mohammadi, Nematollah Jaafarzadeh Haghighifard.
Methodology: Reza Dehbandi, Mohammad Javad Mohammadi, Saeed Ghanbari, Afshin Takdastan.
Project administration: Mohammad Javad Mohammadi, Nematollah Jaafarzadeh Haghighifard.
Resources: Parisa Asban, Reza Dehbandi, Nematollah Jaafarzadeh Haghighifard.
Software: Saeed Ghanbari.
Supervision: Mohammad Javad Mohammadi, Nematollah Jaafarzadeh Haghighifard.
Validation: Parisa Asban, Reza Dehbandi, Afshin Takdastan, Nematollah Jaafarzadeh Haghighifard.
Visualization: Parisa Asban, Reza Dehbandi.
Writing-original draft: Parisa Asban, Reza Dehbandi, Nematollah Jaafarzadeh Haghighifard.
Writing-review & editing: Parisa Asban, Reza Dehbandi, Mohammad Javad Mohammadi, Saeed Ghanbari, Afshin Takdastan, Nematollah Jaafarzadeh Haghighifard.

Competing interests

The authors declare that they have no competing interests.

Ethical issues

The Ethics Committee of Ahvaz Jundishapur University of Medical Sciences approved the study protocol. This study was originally approved by the Ahvaz Jundishapur University of Medical Sciences with code IR.AJUMS.REC.1402.013.

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