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MICROPLASTIC TEXTILE FIBERS IN URBAN SOILS OF SERBIA

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Abstract
Microfibers, as a considerable component of microplastic pollution in the environment have received notable attention during past years. Fast fashion and extensive use of synthetic and semi-synthetic outfits, aging, and discharge of used textile items are dominant sources of microfiber generation and ending up in urban soils. Herein, we examined microfibers' presence in the urban soils of Sremska Mitrovica and Bor. A flotation method based on density separation using saturated NaCl solution was utilized to assess microplastics concentration in soils. The abundance of microfibers was 200 and 600 items per kg of soil, respectively. Fiber structure was confirmed by ATR-FTIR analysis. Items isolated from soil from Sremska Mitrovica contained the natural fiber of cotton, while microfibers detected in soil from Bor referred to semi-synthetic polymer, viscose, i.e. rayon. Despite similar chemical structures based on cellulose, differences in IR spectra allowed the distinguishing of these fiber types. This paper provides insight into the current state of environmental pollution by microplastic fibers and suggests potential origin. More in-depth research on fiber content in soils, measures of prevention, and subsequent remediation should be carried out to face the challenge of microfibers presence in the ecosystem, their entering the food chain, and their impact on biota.

***Keywords**: microfibers, cotton, viscose, isolation, structure*

1. INTRODUCTION

Natural and regenerated textile fibers, a commonly used material for the manufacture of textiles, apparel, furniture, and other commonly used items, play a fundamental role in human societies. The estimated amount of plastic material produced for textile fibers in 2016 reached 65 million tons globally, while the plastic waste generation rate is approaching 400 Mt per year [1, 2]. Production, use, and end-of-life disposal of apparel, industrial, agricultural, and home textiles, and other fibrous materials cause the shedding and releasing of microfibers, a type of microplastics (MPs) found to be ubiquitous in air, terrestrial, and water environments [3]. One of the most common fiber types found in the environment is the natural fiber of cotton and viscose, a semi-synthetic fiber, both extensively used in textile production. Microplastics, defined as solid particles of polymer matrices < 5mm in size, represent ubiquitous pollutants that have become a global environmental challenge [4]. Terrestrial soil is considered a sink for microplastics (MPs). While farmland and agricultural soils have gained considerable attention regarding microplastic pollution, investigations of urban soils have been neglected to a certain extent resulting in a current dearth of knowledge. Due to the increased migration from rural to urban areas, followed by rapid urbanization, anthropogenic activities tend to concentrate in urban sites (express stations, textile mills, urban road dust, atmospheric deposition), representing a crucial source of microplastics pollution [5]. It is known that MPs in soil showed an impact on soil physicochemical properties (pH value, water holding capacity, porosity, aggregation, bulk density, electrical conductivity), and consequently, the function of the soil ecosystem, causing adverse effects on soil biota (bacteria, fungus, pathogens, and plants) [1]. Several methods for microplastic extraction from soil have been proposed, of which the flotation method based on density separation is commonly used and found to be the most appropriate [5].

Herein, we examined the presence and content of microfibers in urban soils in Serbia, using the density separation method, followed by the characterization of isolated particles, indicating the potential pollution sources.

The aims of this study were: 1) assessment of microfiber abundance in urban soils from two cities in Serbia, 2), determination of fibers' chemical structure, i.e. polymer type 3) identification of potential sources of microfiber pollution.

2. EXPERIMENTAL

2.1 Study site description and sample collection

Samples collection was carried out in June of 2021, in Sremska Mitrovica (SM), situated at the east longitude of 19° 36′ 33″ and the north latitude of 44° 58′ 20″, at an altitude of 82 m and Bor (BO), located in the Bor District, 222 km south of Belgrade (44°04′25″ N, 22°05′26″ E), eastern Serbia, at 381 m of altitude (Figure 1).

Figure 1 - Sampling site map

Up to 20 cm in depth of the top-soil layer was sampled for the analysis. About 1 kg of the composite sample formed from at least 5 subsamples, was taken from each sampling site. All sample manipulations and analyses were performed omitting the contamination from the potential contact with plastic materials.

2.2 Isolation, quantification and characterization of microplastics

Microplastic particles were isolated from soil using the flotation method [5]. After air-drying for two weeks, soil samples were sieved. Fraction below 2mm was additionally dried at 60˚C to a constant weight in the heating oven and used for further analysis. 5 g of soil was measured and covered with 60 ml of saturated NaCl solution (1.2 g cm^{-3}), subjected to the ultrasound treatment for 15 min (energy input of 60 J ml^{-1}), and left overnight. About 30 ml of top layers of supernatant containing MPs and SOM were extracted by a glass dropper and filtered through a 20 µm porous stainless steel filter. Filter holding microplastic and organic matter particles was left in 30% H_2O_2 solution in an ultrasonic bath for 10 min and rinsed thoroughly afterward with prefiltered distilled water. The suspension left over was heated to 60˚C and kept for 24h to digest SOM and filtered through a steel filter (20 µm). MPs observation and counting were carried out using a polarizing microscope (Carl Zeiss Jena Pol-U). Analysis was carried out in three replicates. Isolated particle characterization was done by ATR-FTIR spectroscopy using a Thermo Scientific Nicolet iS50 spectrophotometer.

3. RESULTS AND DISCUSSION

3.1 Microfibers abundance in soils

Soils from Bor contained 600 items per kg on average. The mean concentration of 200 fibers in kg was found in soil from Sremska Mitrovica. Our finding is consistent with MPs content reported in soils from Ahvaz (Iran), Nanjing (China), and roadside dust from Victoria (Australia) [4, 5, 6] (Table 1). However, these data consider not only microfibers but microplastic particles in general, including fragments, films, pellets, etc. Particularly, soil from Nanjing contained 39.1% of fibers. Authors identified cosmetics, textile, and plastic manufacturing as the dominant sources of MPs [5]. Microfibers detected in samples from the urban area behind the Lihe River in China contributed 30.88% to the total microplastics content [7]. On the other side, microfibers were the most abundant MPs in urban soils from Ahvaz (70%).

Table 1 – Microplastics abundance reported in urban soils.

Location	Sample type	MPs abundance (items per kg)	Dominant polymer type	Reference
Victoria, Australia	Roadside dust	201 - 529	PE, PP	[6]
Abadan, Khorramshahr, Iran	Urban soil	3470	PET, PP	[2]
Lihe River watershed, China	Urban soil	1293	PP, PAN, PE, Rayon	[7]
Ahvaz metropolis, Iran	Urban soil	100 - 3135	PE, PTFE, Naylon	[4]
Nanjing, China	Urban soil	461 ± 222	PETG, PP	[5]

In general, there is a lack of literature data on microfibers content in soils from (sub)urban areas. For instance, farmland soil from Bangladesh showed MPs at a concentration of 2.13×10^4 particles kg^{-1} [1]. Due to the application of municipal biosolids and sewage sludge containing high levels of microfibers, agricultural and farm soils have been identified as more significant sinks for microplastic fibers containing almost 90% of the total MPs detected [8].

3.2 Microfibers chemical composition

Fibers chemical structure was characterized by ATR-FTIR (Figure 2). All isolated particles from soil from Bor were regenerated cellulose fibers and viscose. The only detected polymer in Sremska Mitrovica was the natural fiber of cotton.

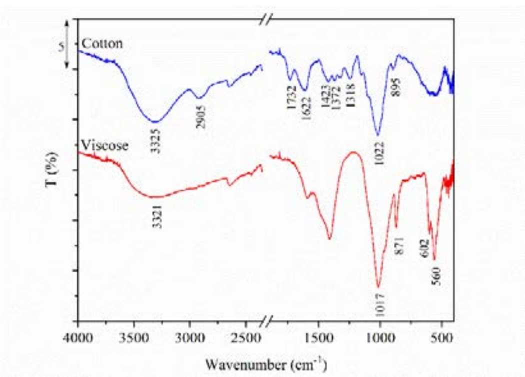

Figure 2 - ATR-FTIR spectra of isolated microplastic fibers of cotton and viscose/rayon

Chemically, viscose and cotton both represent cellulose-based fibers, with differences regarding fiber structure. Cotton is made up of natural fibers, twisted and not uniformly shaped, due to the higher degree of polymerization and crystallinity. Viscose is a man-made fabric, constituted from chemically treated regenerated cellulose. Crystallinity and a higher degree of polymerization in cotton refer to closely parallelly packed cellulose molecules held together by hydrogen bonds, resulting in higher fiber strength. Since both materials are predominantly made from cellulose, the spectra of either group of fibers appear similar (Figure 2). However, particular differences allow the distinguishing of two fiber types. The first one is -OH stretching band profile, found featureless and broad in the spectra of man-made fibers. In natural fiber spectra, it exhibits a distinct peak near 3330 cm^{-1}. Additionally, there is a band close to 1725 cm^{-1}, usually not identified in semi-synthetic fiber, but appears in cotton spectra, being associated with pectine [9]. Natural fiber spectra contained an absorption peak at 1423 cm^{-1} belonging to O-C-H of CH_2 bending (Figure 2), that corresponds with previous reports.

3.3 Potential sources of microfibers in soils

Microfibers end up in the environment through different pathways. In general, wastewater released by domestic laundering and textile industries is considered a direct and prevailing source of microfibers [1]. Additionally, fibers shedding from clothes and discarded textiles aging, interior items, agricultural activities, and atmospheric and ambient deposition significantly contribute to microfiber pollution, as releasing from disposable face masks used during the COVID-19 pandemic. Fiber fragmentation from larger items may result from physical, chemical, and photodegradation and abrasion.

4. CONCLUSION

Microplastic fibers, omnipresent in the environment, represent a matter of global concern. This research assessed microplastic textile fiber content in urban soils from two cities in Serbia, for the first time. Microfibers abundance in soil from Sremska Mitrovica was 200 items per kg, referred to as natural fiber, cotton, as confirmed by ATR-FTIR analysis. Soil from Bor contained 600 microfibers in kg, and all of the isolated fibers were characterized as semi-synthetic material – viscose, also known as rayon. Clothes and discharged textiles shedding could be the dominant source of microfibers' presence in urban soils. Significant effort is needed to reduce microfibers generation and emission. The implementation of regulations on microplastic pollution, which is currently lacking, and adequate control are necessary to prevent and minimize microfibers' release into the ecosystems.

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