The Pollution of Atmospheric Microplastics and Their Potential Risks to Humans

Wang shuo1,2,3*, Duan weiyu1,2, Lv huanming1,2,3, Sun rui1,2 and Zhu xu4

1 Liao Ning Inspection, Examination & Certification Centre, Shenyang 110032, China
2 Liao Ning Province Product Quality Supervision and Inspection Inspection Institute, Shenyang 110144, China
3 National Quality Supervision & Testing Center of Petroleum Products (Shen Yang), Shenyang 110144, China
4 Liaoning huaiyi Testing and Certification Center Co.,Ltd., Shenyang 110000, China

*Corresponding author’s email: wang_shuo@zju.edu.cn; sekiwangeward@163.com

Abstract. As an emerging environmental pollutant, microplastics have widely existed in the global environment. Not like water and soils, the cognition of airborne microplastics is limited. Studies have shown that fiber is the main form of airborne microplastics. For humans, due to the small size of microplastics, microplastics in the atmosphere are easily brought into the human respiratory system through breathing, posing potential risks to human health. This article reviews the characteristics of microplastics in the atmosphere, the transmission routes, and the potential hazards to humans. The characteristics and sources of atmospheric microplastics are investigated, and the airborne transmission path and deposition rules of atmospheric microplastics are summarized. Future research should focus on small-size atmospheric microplastics, which are smaller in size and more biologically toxic. The abundance of atmospheric microplastics need to be expressed in a global unified standard manner to increase feasibility in comparison of research works. Future research should explore the effects of plastics on the composition, structure and functions of terrestrial biota.

1. Introduction

The widespread use of plastics has created many conveniences for modern life as well as global environmental pollution. Due to the high durability of plastics, pollution will continue for many years. Large plastics will slowly degrade or decompose into small particles in the environment after weathering and ultraviolet radiation. Environmental microplastics have attracted increasing attention after Thomicroplasticson proposed the concept of microplastics (microplastics) in 2004 [1], microplastics are plastic particles less than 5 mm, which were considered as emerging pollutants [2]. microplastics have been detected in different types of environmental compartments worldwide, such as soils [3], water [4], sediments [5] and atmosphere [6]. With respect to chemical composition, polyethylene terephthalate (PET), polypropylene (PP), polyvinyl chloride (PVC), polyethylene (PE), polystyrene (PS), and polyamide (PA) were polymer types frequently detected in water [7,8]. Not like water and soils, the cognition of airborne microplastics is relatively limited. Studies on airborne microplastics have gained increasing concerns in the past five years. Microplastics are small in size, light in weight, enter the human body through respiration and threat to human health [6]. Uncredible, there are microplastics in air as an indisputable fact. microplastics migrated with air currents and
entered the atmosphere from the surface by wind, while transferred from the atmosphere to the ground or water as rain or snow. Atmospheric microplastics are considered to be an important contributor to microplastics in the aquatic environment and soil, because atmospheric microplastics enter these environments through dry or wet sedimentation [9]. Plastic rain is a natural phenomenon discovered in recent years. There are a large number of small plastic particles in rain, which was called as “plastic rain”. In 2015, microplastics were observed in atmospheric sediments by Dris, which was reported the first time [10]. Afterwards, researchers have successively reported on the distribution characteristics of microplastics in the air and road dust in many countries [11-13]. Moreover, human beings would be exposed to microplastics in the air through inhalation and dust, which will cause potential adverse effects on human health [14]. Atmospheric microplastics ingested by the human body can cause inflammation and secondary genotoxicity [15]. Furthermore, atmospheric microplastics may contain various harmful chemicals, such as unreacted monomers, plastic additives, and other harmful pollutants absorbed from the environment [15]. These harmful chemicals may increase the toxicity of atmospheric microplastics to humans. The purposes of this review are to 1) summarize the characteristics of airborne microplastics; 2) discuss the sources, distribution and migration pathways of airborne microplastics; 3) assess the potential hazards of airborne microplastics to human beings; and 4) give suggestions for future works to prevention of microplastics pollution in the atmosphere.

2. Microplastic pollution in the atmosphere

How far have microplastics travelled in earth? There is evidence concern that microplastics have reached the most remote regions of the planet. Bergami [16] presents the first evidence of polystyrene fragments inside the common Antarctic collembolan Cryptopygus, which prove microplastics are entering the antarctic terrestrial food webs and represent a new potential stressor to ecosystems. This evidence also indicated that microplastics could migrated through the air route. Not like water and soils, the cognition of airborne microplastics is limited. In the past five years, research on atmospheric microplastics has attracted more and more attention. Atmospheric microplastics are considered to be an important contributor to microplastics in the aquatic environment and soils, because atmospheric microplastics enter these environments through dry or wet precipitation [9]. For the first time, microplastics were observed in atmospheric sediments, with an average of 118 particles/m³/day, a study conducted in Paris [10]. Afterwards, researchers have successively reported on the distribution characteristics of microplastics in the air and road dust in cities in France, Iran, China, Japan, Vietnam and Nepal [11-13]. The potential exposure of microplastics in human’s household dust fibres during a meal were compare with amounts of microplastics present in edible mussels. The fiber ingested by the human body through ingestion of dust in annual dietary pellets per person on Scottish soil is 13,731 to 68,415 pellets/year, which is much higher than the consumption of mussels [17]. The shape of atmospheric microplastics is mainly fibers, with a few fragments and granules, which were summarized in Figure 1 [18].

3. Characteristics of atmospheric microplastics

Microplastics in the suspended atmospheric particulates were detected and the shape, type, size and abundance of microplastics were reported successively. The shapes of atmospheric microplastics include fibers, fragments, granules, films, and foams, among which are mainly fibers (mainly from textiles, Figure 1). Fragments mainly come from degradation products of plastic, and films mainly come from plastic bags or agricultural films [19,20]. Microplastics in the atmosphere are mainly composed of polymers, and cellulose is the main component of most atmospheric microplastics [18,21,22]. The most common polymer types include polyethylene terephthalate (PET), polyethylene (PE), Polypropylene (PP) and polyester (PES), most of which are PET [23,24]. Liu [18] investigated the source and distribution of microplastics in Shanghai using an active suspended particulate sampler. Microfibers comprised 67% of all microplastics, followed by fragments and granules comprising 30% and 3%, respectively. Microplastics abundances from filtered air ranged from 0 to 4.18 n/m³ with blue (37%) and black (33%), which were consisted of polyethylene terephthalate (PET), polyethylene (PE),
polyester (PES), polyacrylonitrile (PAN), poly(N-methyl acrylamide) (PAA), rayon (RY), ethylene vinyl acetate (EVA), epoxy resin (EP), and alkyd resin (ALK). PET was the main type for fibers from Shanghai (50%) \[18\]. In addition, PET, PE, and PES comprised nearly half (49%) of the microplastics observed in Shanghai, followed by PAN (12%) and PAA (9%). The size range of atmospheric microplastics reported in research has a large ranging from 16 microns to 5 mm, but the size range of microplastics with a large number is relatively narrow \[11\]. At present, there are few research reports on small-size atmospheric microplastics. Since atmospheric microplastics can be inhaled into the human body through respiratory tract, research on atmospheric microplastics should pay more attention to small-sized microplastics that are smaller in size and more biologically toxic. \[24,25\]

Figure 1. Typically observed airborne microplastics. a-c: fibers; d-e: fragments; f: a granules \[18\].

Particles/g, Particles/(m².d), Particles/m² (particles/m³), and Particles are four types of atmospheric microplastics abundance units in current research reports, respectively, in which particles/(m².d) was a frequently used unit \[11-13,26-28\]. Fiber concentrations were observed in outdoor TSP samples of industrial (0.76 fibers/m³) and urban (0.63 fibers/m³) in Asaluyeh (Iran), with the highest white or transparent fiber content \[27\]. The fiber in indoor suspended particles in Paris (France) is 0.4-59.4 fiber/m³, which is significantly higher than the fiber in outdoor (0.3-1.5 fiber/m³), and the particle size of most fibers is in the range of 50-250 mm \[29\]. The abundance of atmospheric microplastics need to be expressed in a more standardized manner, and a global unified standard is recommended. The lack of standardization of abundance will cause difficulties in the analysis and comparison of research work.

4. Potential risks to human health

Human intake, intake route and removal method of atmospheric microplastics were investigated. The microplastics in the atmosphere inhaled into human body mainly through the human respiratory system, and are removed through sneezing, mucociliary movement in the respiratory system, phagocytosis of macrophages and lymphocytes \[30\]. The location where microplastics can reach the human respiratory system is affected by the particle size and density of the microplastics, as well as the aerodynamics of the microplastics particles. Atmospheric microplastics with smaller density and particle size can reach the human lungs \[31\]. The process of disposal and removal of microplastics in the body is complicated, not only related to the type, particle size and concentration of microplastics, but also related to the natural physiological conditions of humans, such as the strength of the respiratory tract and the transport capacity of lymphocytes \[32\]. The amount of microplastics inhaled by the human body will affect human health. Ingestion of dust is an important way of human exposure to harmful pollutants, especially for children. Infants inhale microplastics more than adults. The mass concentrations of microplastics in dust and the exposure risk was studied \[24\]. PET microplastics were detected at 212-9020 mg/kg and PC microplastics were detected with median concentrations of 2.0 mg/kg. Indoor dust is a non-negligible source of human exposure to microplastics, accounting for 17,300 ng/kg-bw of children's average daily intake of PET \[30\].

The street dust and suspended dust in the city and county of Asaluye, Iran were studied \[28\]. Among the <5mm street dust retrieved from 15 locations, there are an average of 900 microplastics and
250MRs per 15g sample. Microplastics show various colors and sizes (<100 to >1000 μm). The air dust collected at two locations every day for eight days shows that the ubiquitous range of fibrous MP is 2 μm to 100 μm, and the abundance per m is about 1 m. According to the median concentration of street dust, for construction workers and young children, the acute exposure caused by ingestion is estimated to be about 5MPd and 15MPd, 2MRD and 7MRd, respectively. The number of inhalable particulate matter is more difficult to define, but the potential toxicity of MP and MR ingested by this route was evaluated by measuring the particulate matter isolated from street dust in the presence of artificial lung fluid. The existence, characteristics and potential health risks of microplastic dust ingestion was investigated [11]. A binocular microscope was used to determine the plastic loading of 88 to 605 types of microplastics per 30 grams of dry dust in 10 street dust samples, with black and yellow particulate microplastics predominant, ranging in size from 250 to 500 μm. Considering that exposure in outdoor activities and workplaces with high plastic content is acute exposure, children and adults consume an average of 3223 and 1063 plastic particles each year. Therefore, street dust is an important source of potential microplastic pollution in the urban environment, so control measures need to be taken. Toxic effects and mechanisms of atmospheric microplastics were investigated. Compared with microplastics in other ecosystems, microplastics in the air can be directly and continuously inhaled to the human body, posing a threat to health [14]. Microplastics inhaled in human lungs may undergo clearance mechanisms, including mechanical methods (sneezing), mucociliary escalators, macrophage phagocytosis, and lymphatic transport. Most of the microplastics were removed by the clearance. However, some microplastics may avoid the clearance mechanisms and reach the human lungs [33]. Many studies have revealed the connection between inhaled synthetic fibers and respiratory diseases. Two-thirds of sheep workers frequent have respiratory symptoms, such as throat inflammation and shortness of breath, coughing and chest pain, which was difficult to cure [34]. Chronic inflammation and irritation may lead to pulmonary fibrosis and sometimes even cause cancer [35]. The mechanisms of inhaled particle injury include oxidative stress, which may be caused by production of radical oxygen species, or ROS, induce cell injury and the release of inflammatory mediators, dust overload, which may be caused by high surface particles induce high chemotactic gradients that prevent macrophage migration, cytotoxicity, which maybe caused by free intracellular particles may damage cellular structures, and translocation, which may be caused by injury of secondary sites and vascular occlusion by particles or increased coagulability [14]. Cancer may result from chronic inflammation or from gene mutation. When exposed to microplastics, the level and activity of antioxidant-related enzymes will increase to protect organs from adverse effects. It has been reported that plastic fibers can remain in the synthetic extracellular lung fluid for 180 days without changes in surface area [36]. Microplastics induce oxidative stress and destruction by generating ROS in some species [37]. MP can cause inflammation due to the release of intracellular messengers, proteases and reactive oxygen species (ROS) [38]. Therefore, microplastics may accumulate and persist in human lungs for a long time, which may cause continuous oxidative damage caused by ROS.

5. Conclusion
In recent years, some studies have shown that microplastics are widespread in the atmosphere. Fibers are the main source of airborne microplastics. Additionally, the degradation and fragmentation of plastic products also increase the abundance of airborne microplastics. Wind can transport microplastics through the atmosphere over a long distance, and thus microplastics are present worldwide even in polar regions. Therefore, airborne microplastics represent a source of contamination in water and soils. Therefore, street dust is an important source of potential microplastic pollution in the urban environment, so control measures need to be taken. Future research should focus on small-size atmospheric microplastics, which are smaller in size and more biologically toxic. The abundance of atmospheric microplastics need to be expressed in a global unified standard manner to increase feasibility in comparison of research works. Future research should explore the effects of plastics on the composition, structure and functions of terrestrial biota.
Conflicts of Interest & Acknowledgments
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