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Review

The Peril of Plastics: Atmospheric Microplastics in Outdoor, Indoor, and Remote Environments

Shikha Jyoti Borah [1], Abhijeet Kumar Gupta [1], Vinod Kumar [1,*], Priyanka Jhajharia [2], Praduman Prasad Singh [3], Pramod Kumar [3], Ravinder Kumar [4], Kashyap Kumar Dubey [5] and Akanksha Gupta [6,*]

1 Sustainable Energy & Environmental Nanotechnology Group, Special Centre for Nano Science, Jawaharlal Nehru University, Delhi 110067, India; shikha40_cns@jnu.ac.in (S.J.B.); abhijeetvas@gmail.com (A.K.G.)
2 Department of Chemistry, Kirori Mal College, University of Delhi, Delhi 110007, India; priyankajhajharia@kmc.du.ac.in
3 Department of Chemistry, Sri Aurobindo College, University of Delhi, Delhi 110007, India; ppsingh-elect@aurobindo.du.ac.in (P.P.S.); nita_pramod@yahoo.com (P.K.)
4 Department of Chemistry, Gurukula Kangri (Deemed to be University), Haridwar 249404, India; ravinder.kumar@gkv.ac.in
5 School of Biotechnology, Jawaharlal Nehru University, Delhi 110067, India; kashyapdubey@jnu.ac.in
6 Department of Science and Technology, Technology Bhavan, Delhi 110016, India
* Correspondence: kumarv@mail.jnu.ac.in or vinod7674@gmail.com (V.K.); akankshachem05@gmail.com or akanksha.g@gov.in (A.G.)

Abstract: The increasing commercial, industrial, and medical applications of plastics cannot be halted during the coming years. Microplastics are a new class of plastic pollutants which have emerged as escalating environmental threats. The persistence, effects, and removal of MPs present in soil, water, and numerous organisms have become an important research field. However, atmospheric microplastics (AMPs), which are subcategorized into deposited and suspended, remain largely unexplored. This review presents the recent developments and challenges involved in fully understanding suspended and deposited AMPs. The evaluation of indoor suspended MP fibers needs to be critically investigated to understand their implications for human health. Furthermore, the transportation of AMPs to isolated locations, such as cryospheric regions, requires immediate attention. The major challenges associated with AMPs, which have hindered advancement in this field, are inconsistency in the available data, limited knowledge, and the lack of standardized methodologies for the sampling and characterization techniques of AMPs.

Keywords: plastic waste; atmospheric microplastic; cryospheric; deposition; suspension

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1. Introduction

The Earth has essentially become the home of plastics. Plastics are synthetic polymers which, once formed, cannot be reversed back to their monomers and, when disposed of in the environment, do not naturally decompose into non-toxic products. As a result of this durability and resistance, large landfills and the debris of plastic have intricately released its existence in all forms of the environment. This increasing plastic pollution is an outcome of the Anthropocene Epoch [1]. A large amount of accumulated plastic debris can undergo weathering due to physical, chemical, and biological strains to produce smaller fragments of plastic called microplastics (MPs) and nanoplastics (NPs). The classification of plastics depends on their size. MPs are plastic particles which have a size range of 5 mm–1 µm [2], and they can be further subcategorized into primary and secondary MPs. Primary MPs are obtained from direct sources which are intentionally produced, such as microbeads in personal care products. Contrastingly, secondary MPs are the result of the unintended generation of MPs from the degradation and fragmentation of bulk plastic [3]. Nanoplastics, on the other hand, have sizes smaller than 1 µm [4]. Modified definitions for

MPs have emerged in the last few years. For instance, MPs can also be identified as solid polymers which may contain additives or other substances. Additionally, these particles are composed of at least 1% particles by weight, which have a particle size in the range 100 nm $\leq \times \leq$ 5 mm. More specifically, for MP fibers, their dimensions include a length range of 300 nm to 15 mm, with a length-to-diameter ratio greater than 3 [5,6].

Micro- and nanoplastics are capable of leaking into various ecosystems, creating ripples of detrimental consequences at different trophic levels. In addition to this, plastic production utilizes the addition of certain chemical compounds, known as chemical additives (CAs), which are used to enhance various plastic properties. These toxic chemical substances can leach out of polymers under the influence of various factors like UV exposure, storage conditions, diffusion, etc. [7].

Contamination by MPs, along with other contaminants in water, soil, and air, has emerged as a global concern, and it has grabbed the attention of the scientific and academic communities, policymakers, and the media. Numerous scientific investigations are being carried out to study the repercussions and toxic effects of MPs and CAs in soil, water, lower-level organisms, plants, terrestrial and aquatic higher organisms, and humans. These kinds of studies are crucial for exploring their source–pathway–sink relationships. MPs can enter various ecosystems and cause detrimental effects in both biotic and abiotic forms. Studies have been carried out to understand the impact of MPs on lower organisms like microalgae [8], coral reefs [9], and zooplankton [10]. Apart from this, investigations have revealed that honeybees [11], freshwater and marine organisms [12,13], slugs, soil [14], plants [15], moss [16], and even the human body [17] can become contaminated by MPs due to increasing ubiquitous plastic consumption. Moreover, soil and water bodies can also host MPs to form MP sinks, leading to their leakage into the food chain [18].

An upsurge of interest has been observed in the last decade due to the alarming increase in MP leakage. WWTPs, plastic microbeads, synthetic textile production, and many other MP sources have now been put under the scrutiny of researchers [19]. The regulation of MP flow into soil, water, and organisms has turned into a global concern. Globally, only a handful of successful investigations have been reported on suspended AMPs; however, deposited AMPs have gained a considerable number of breakthroughs. Even though research dating back nearly a decade was able to trace the presence of MPs in the air, current studies largely revolve around the deposition of MPs from the atmosphere (atmospheric deposition) on various environmental surfaces, such as land and water [20,21].

This literature study is a modest attempt to shed light on and focus on MP-derived atmospheric pollution and its transportation to remote areas. Recent developments in deposited and suspended AMPs have been highlighted. A major emphasis has been put on the risk posed by indoor aerial MP contamination and the transportation of AMPs to isolated areas. Furthermore, meteorological factors associated with the transportation of AMPs have also been briefly discussed. To the best of our knowledge, this literature study is the first of its kind to assemble the aforementioned claims. This study will provide valuable insights into the less explored areas of AMPs in the environment, thereby helping the scientific and academic communities strengthen their knowledge.

1.1. Composition

The quantification of MPs is a difficult process due to complex sample preparation, limited detection limits, and expensive methodologies [22]. A large variety of MPs, such as PUR (polyurethane), PC (polycarbonate), PP (polypropylene), RY (rayon), PES (polyester), PS (polystyrene), PET (polyethylene terephthalate), PAN (polyacrylonitrile), PA (polyamide), PVC (polyvinyl chloride), PVF (polyvinyl fluoride), and many others, have been detected in the last two decades [23,24]. Figure 1 shows the various shapes of MPs that have been found through images obtained from scanning electron microscopy (SEM) of MPs detected in varying polymer compositions [25]. Although it has been successfully demonstrated that MPs can be present in the atmosphere, complete knowledge has not yet been achieved. The particulate matter in the air has been found to be filled with small MP particles, which

are commonly referred to as atmospheric microplastics (AMPs) [26]. A recurring trend has been most commonly observed for high concentrations of MP fibers (MPFs) in the atmosphere as compared to other types of MPs, though fragments, films, beads, and other shapes may also be present. This creates a large probability of MPFs being inhaled by many higher organisms, resulting in respiratory problems.

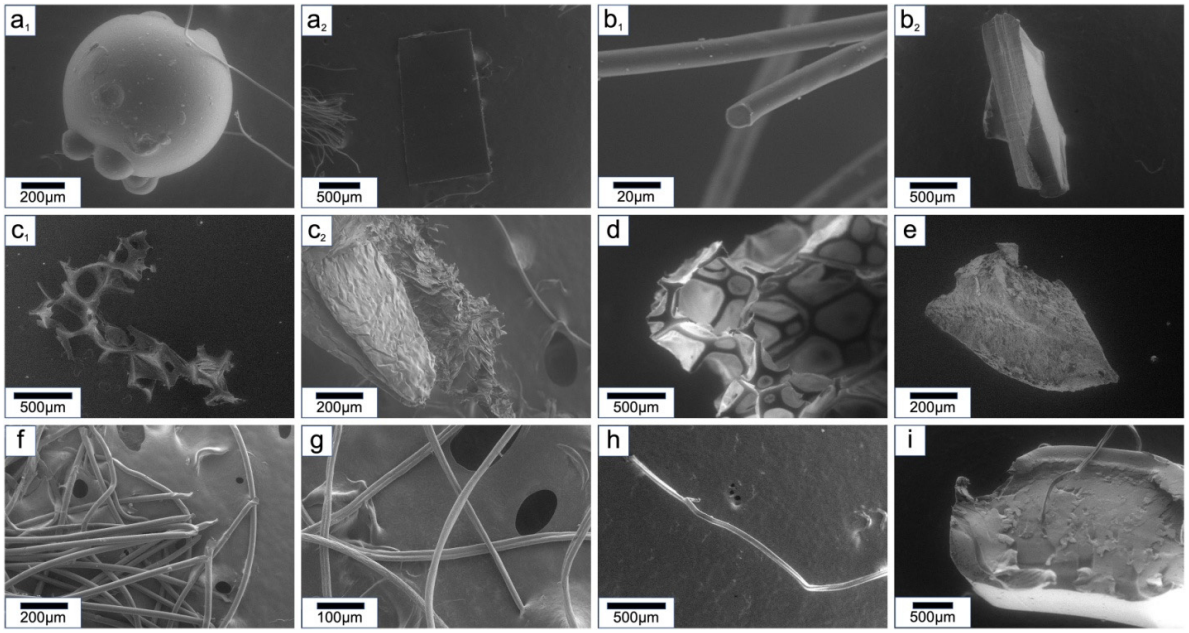

Figure 1. SEM images of various MPs depicting varying sizes and shapes. (**a$_1$**) PE bead; (**a$_2$**) PE film; (**b$_1$**) PET fiber; (**b$_2$**) PET fragment; (**c$_1$**) PS fragment; (**c$_2$**) PS foam; (**d**) PUR foam; (**e**) PC fragment; (**f**) PP fiber; (**g**) PAN fiber; (**h**) PA fiber; and (**i**) PVC. Reproduced from ref. [25]. Copyright © 2022 The Authors. Published by Elsevier B.V.

1.2. Inhaling Airborne Microplastics

Given the socioeconomic and geographic conditions of plastic production, consumption, and disposal, as well as the processes by which it undergoes weathering, it is reasonable to assume that AMPs are released into and accumulate in our local atmosphere. AMPs may remain suspended or be deposited on a variety of surfaces. Suspended AMPs may prove to be lethal due to their unknown effects on humans, while deposited AMPs can further accumulate on surfaces in bulk, inducing detrimental effects. The emission of MPs into the atmosphere is depicted in Figure 2, and these pollutants are also capable of being deposited in a number of habitats, with humans being particularly susceptible to suspended AMPs. Only a handful of studies have been reported on the evaluation of the total suspended MPs in the air, while a large part of the globe is bereft of any such studies.

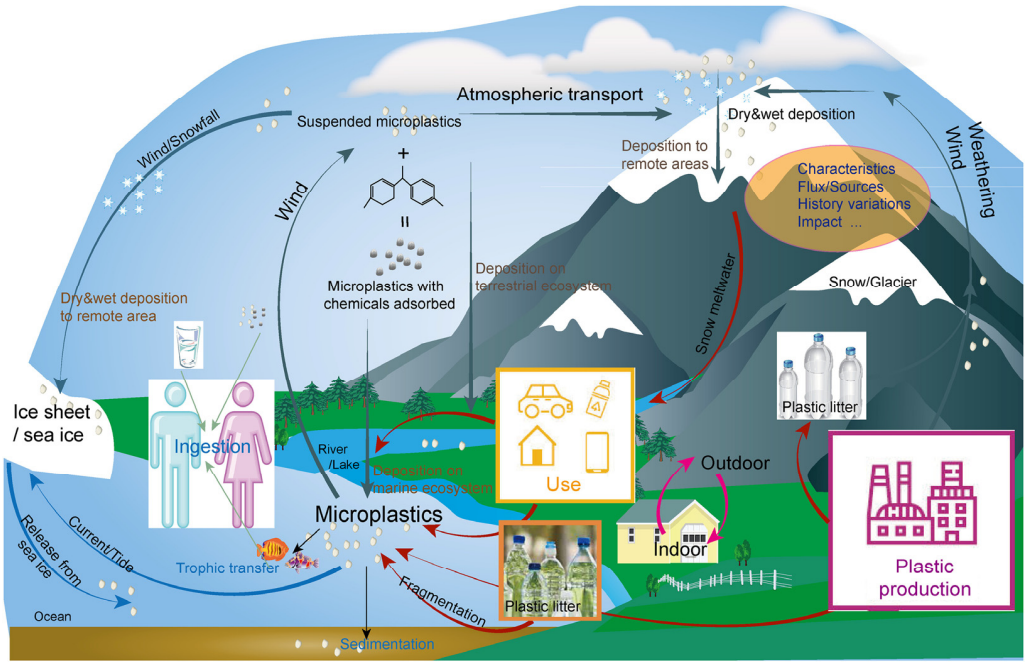

Figure 2. A schematic illustration of the source–trajectory–sink interrelationship formed due to the suspension and deposition of AMPs. Reproduced from ref. [27]. Copyrights © 2020 The Authors. Published by Elsevier B.V.

2. Progressive Atmospheric Deposition

One of the first studies on MP contamination in the atmosphere can be traced back to an urban case study in Greater Paris by Dris et al. in 2015. They reportedly confirmed the presence of MPs in the total atmospheric fallout, freshwater, and sewage. Their study concluded that MP fibers (MPFs) in a range of 29–280 MP per m^2/day were predominantly found in a large section of the atmospheric fallout [28]. In another study, Dris et al. also reported that 29% of the atmospheric fallout (2–355 MP per m^2/day) comprised MPFs, which can be attributed to a wide range of possible sources like the degradation of bulk plastic debris, waste incineration, synthetic polymers from the petrochemical and textile industries, etc. [29]. They emphasized the importance of the evaluation of AMPs, as they could be transported by the wind into other aquatic and terrestrial environments. Another follow-up study on the impact of AMPs was carried out by Dris et al. to understand and compare the contamination of indoor and outdoor air. Samples were collected from three indoor sites (two apartments and an office) and one outdoor site. The concentration ranges from 1 to 60 fibers/m^3 and 0.3 to 1.5 fibers/m^3 for indoor and outdoor sites, respectively. This shows that indoor AMPs require in-depth analysis. They estimated a high range of indoor atmospheric deposition (1586–11,130 fibers/m^3), 67% of which was naturally derived cellulose and other such materials, while 33% contained synthetic polymers derived from petrochemicals. They concluded that these AMPs could further be inhaled along with dust particles, and children may be at a higher risk of AMP ingestion [30]. These attempts by Dris et al. clearly show that as their work progressed from 2015 to 2017, a range of atmospheric deposition rates increased to higher levels. Subsequently, numerous investigations have surfaced in an effort to understand the deeply interlocked relationship between suspended and deposited AMPs.

Table 1 is a compilation of recent studies that indicate the widespread atmospheric deposition of MPs across various geographical locations. Furthermore, many studies have indicated that, due to the lack of a standard protocol for the quantification and qualification of MPs, they determined the deposition flux, which was followed by the characterization of the detected MPs based on morphological studies and their chemical composition.

However, it should be noted that this is only a fraction of the reported studies and cannot be used for a comparative analysis.

Table 1. A list of studies which have reported the atmospheric deposition of MPs.

MP	Size	Shape	Techniques	Deposition	Location	Ref.
			Asia			
PET, PP	347.9 ± 189.2 µm	Fibers and fragments	Deposition flux	1959.6 ± 205 MPs/m^2/day	Patna, Bihar, India	[31]
PET	50~500 µm	Fragments and fibers	Deposition flux followed by visual inspection and FTIR	353.83 MP/m^2/day	Lanzhou, China	[32]
MP	50–100 µm	Fragments	Nile Red method and µ-FTIR	114 to 689 MP/m^2/day	Southeast Asia (Malaysia)	[33]
Rayon, PET, PE	3–50 µm	Fibers	Fluorescence microscopy and µ-FTIR	892–75,421 MP/m^2/day	Quzhou County, China	[34]
PES, PS, PE and Polybutadiene	500–1000 µm	Foam, fragments, and fibers	Deposition using rain gauge and FTIR	3 to 40 MP/m^2/day	Jakarta, Indonesia	[35]
MP	<100 µm	Amorphous fragments	-	10^5 MP/m^2/day	Dining/drinking venues, China	[36]
PP, PE, PVC	300–5000 µm	Fibers, films, and fragments	Deposition flux	71 to 917 MP/m^2/day	South of Vietnam	[37]
PA, PET and PVF	<1000 µm	Fibers	-	3261.22 ± 2847.99 MP/m^2/day	Shanghai, China	[38]
PET, Rayon	-	Fibers	Deposition flux	84.00 ± 6.95 items/m^2/d (wet season) and 47.88 ± 8.35 items/m^2/d (dry season)	Guangzhou, Southern China	[39]
			Europe			
MP	-	Fibers in higher amounts	-	89 ± 61 MP/m^2/day	Northern Germany	[40]
Rayon		Fibers	Visual examination under stereomicroscope and FTIR	11.28 to 79.2 MP/m^2/day	Southwest England	[41]
PP, PET, PE, PS, PVC	≤30 µm	Fibers and fragments	µRaman spectroscopy	178 (±79) MP/m^2/day	Central Pyrenees	[42]
MPs	<2.5 mm	Fibers and fragments	Microscopy	61.7–107.7 MPs/day	Pristina, Republic of Kosovo	[43]

PE: polyethylene; PP: polypropylene; rayon; PES: polyester; PS: polystyrene; PET: polyethylene terephthalate; polyacrylonitrile; PA: polyamide; PVC: polyvinyl chloride; PVF: polyvinyl fluoride.

Cai et al. determined the presence of three MPs (PP, PS, and PE) in the atmospheric fallout in Dongguan City (China). A variety of shapes were reported, including fragments, films, fibers, and foam, amongst which fibers were predominantly found through scanning electron microscopy (SEM) [44]. In another study, Klein et al. studied the concentration of AMPs in the region of Hamburg in Germany. They investigated a total of six sites, which included three rural areas (an open field site, a beech/oak site, and a Douglas fir forest canopy) and three urban areas situated further into the city with varying populations and levels of industrialization. Their results concluded that MPs are ubiquitously spread at all six sites, with an estimated median abundance ranging from 136.5 to 512 MPs per m^2/day. However, a surprising observation was sparked in this study, which concluded that rural MP contamination showed higher concentrations in the Douglas fir forest canopy, which may be attributed to the direct or indirect input of MPs flowing in from the neighboring highways and agricultural localities. Furthermore, they identified the existence of PE/ethylvinyl acetate copolymers in high concentrations of 48.8% and 22%, respectively [45]. This indicates that a significant amount of MP accumulation at the topmost layer (canopy) may be continuously developing as a result of atmospheric fallout. Hence, studies should be extended from the troposphere to higher atmospheric layers to critically investigate the composition and flow of AMPs.

3. Microplastic Exchange between Indoor and Outdoor Atmospheres

The ingestion of MPs through atmospherically suspended dust particles has recently been questioned, as it may lead to direct respiratory contamination in various animals and humans. In this context, Liu et al. determined the mass concentrations of polycarbonate (PC) and polyethylene terephthalate (PET) in a total of 39 samples, which included both outdoor and indoor air from major cities in China. Large concentrations of PET were predominantly found in all the samples, while PC MPs were detected in only 70% of the samples. The indoor concentrations of PET (1550–120,000 m/kg) were higher than the outdoor concentrations of PET (212–9020 mg/kg), while the indoor (4.6 mg/kg) and outdoor (2 mg/kg) concentrations of PC were comparatively much lower. MPFs were the major shape of the MPs. This, again, indicates that exposure to indoor PET MPs cannot be ignored, and it accounts for a geomean daily uptake of 17,300 ng/kg body weight of PET MPs in young children [46]. However, it should be noted that MPFs are not consistently found to be the largest contributor to AMPs. For instance, Zhu et al. studied AMPs spread across northern and southeast cities in China. They reported that nearly 88.2% of the AMPs found were mainly in the shape of fragments, with a size smaller than 100 µm. High contributions from PE, PS, and PES were determined, but they could not decipher a distinct, consistent interrelationship between AMPs and socioeconomic indices [47].

In a similar study in South Korea, it was estimated that the concentration of large and heavy MPs was 1.5 times higher in indoor air, which included high concentrations of PE and PP MPs within a size range of 20–100 µm (Figure 3). In addition to this, their study also concluded that a substantial amount of thin and long MPs, along with synthetic fibers, were found in indoor air [48]. In a UK-based study, Jenner et al. studied the presence of suspended MPs in 20 households spanning through the City of Hull and the Humber region. An average amount of 1414 MP/m^2 day ± 1022 (mean ± SD) was observed, which consisted of 90% MPFs. Their results also indicated that PET content was present in nearly all the samples, while PA and PP were also common. This indicates that humans may be at a higher risk of indoor exposure to MPs as compared to outdoors, and hence the implications of indoor MPs must be studied at a realistic level [49]. In another one of their studies, Jenner et al. discussed the quantification of outdoor AMPs in the Humber region. They observed a mean MP concentration of 3055 ± 5072 MP m^2/day, which included fragments and films of PET (31%) and nylon (28%) mainly [50]. However, a general correlation between such studies determining the exchange between outdoor and indoor environments has not been definitively reported in most studies.

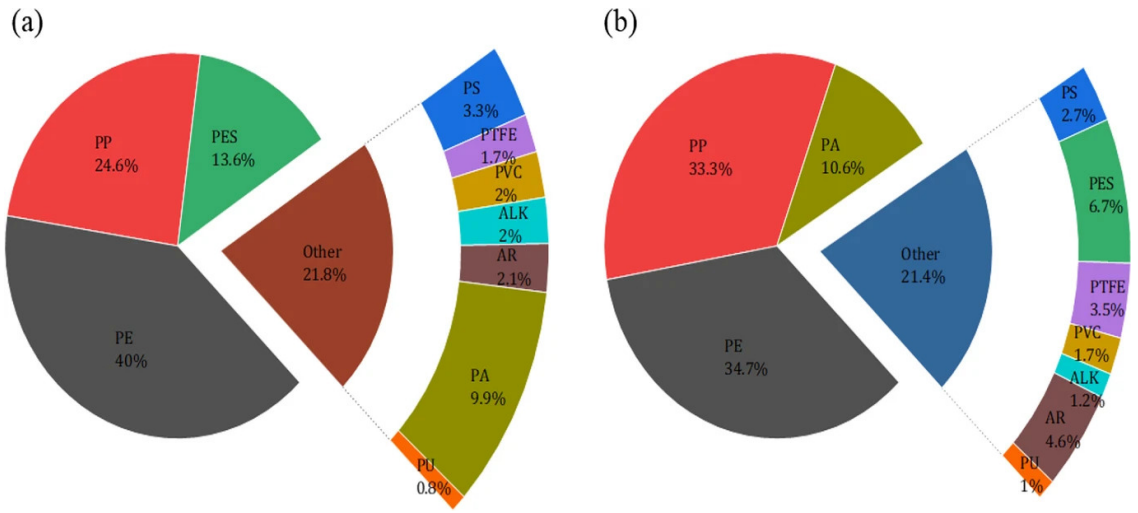

Figure 3. The composition of various MPs obtained from different (**a**) indoor and (**b**) outdoor samples. Reproduced from ref. [48]. Copyright © 2022, The Author(s), under exclusive license to Springer Nature Switzerland AG.

A recent study revealed high microplastic fiber (MPF) contamination in indoor split air conditioner (AC) filters, with densities ranging from 1.47 to 21.4 × 102 items/cm^2 and 27.7–35.0% of fibers being MPFs. Polyester (45.3%), rayon (27.8%), and cellophane (20.1%) were prevalent. Dormitories showed significant MPF accumulation after 35–42 days. Simulated AC filters lined with PET MPFs released MPFs into indoor air, with the estimated daily intake reaching up to 44.0 items/kg-BW/day by day 70. AC filters act as both sinks and sources of MPFs, necessitating an evaluation of their health risks [51]. A further study assessed indoor microplastics (MPs) in urban environments: buses (17.3 ± 2.4 MPs/m^3), subways (5.8 ± 1.9 MPs/m^3), houses (4.8 ± 1.6 MPs/m^3), and workplaces (4.2 ± 1.6 MPs/m^3). Polyamide (PA), polyester (PES), and polypropylene (PP) were common, mainly from personal care products and textiles, posing potential inhalation risks due to their small sizes [52]. Another study in Sri Lanka revealed higher concentrations of airborne microplastics (AMPs) indoors (0.13–0.93 particles/m^3) compared to outdoors (0.00–0.23 particles/m^3). The dominant size range was 100–300 µm, with polyethylene terephthalate being the most common type. Textile fibers were identified as a major source. Further research is needed to assess trends and health risks [53].

The presence of suspended MPFs in the air has also been confirmed by other studies carried out in various other places, such as New Jersey, USA [54], Ahvaz metropolis, Iran [55], and Greater Bandung City, Indonesia [56]. In a recent review, Kacprzak and Tijing discussed the sources, characteristics, behavior, mitigation, and fate of MPs present in indoor air [57]. However, studies on the persistence, quantification, and implications of suspended MPs are scarcely distributed throughout the globe. Even more difficult is studying, understanding, and analyzing available data through a comparison of such data. Inconsistency in collected data and detection methods owing to a lack of standardized methods for sampling and quantification are the major causes behind the slow progress of research in this field. Thus, it is very important that research and further investigations be carried out to confirm the risks of inhaling MPFs contaminating indoor air, which can produce toxic consequences for animals and humans.

4. Current Microplastic Sinks in Remote Areas

Urban and industrial locations are major areas where a high AMP content is present; however, it has been hypothesized that remote areas may also be equivalently contaminated over the next few years. Terrestrial MPs have been moderately explored via atmospheric fallout and disposition studies, whereas suspended and deposited MPs in isolated regions have not received enough attention comparatively. Only a handful of reports have been carried out in mountainous areas [58,59], arctic regions [60,61], and glaciers [62,63]. Despite the lack of human civilization and activity in these areas, investigations have emerged with shocking conclusions.

Investigations carried out over the East Indian Ocean and South China Sea concluded that the AMP abundances for the Pearl River Estuary, East Indian Ocean, and South China Sea were 4.2 ± 2.5, 0.4 ± 0.6, and 0.8 ± 1.3 items/100 m^3, respectively. This indicates that AMP transport can occur over long ranges, and they can play a major role in causing oceanic MP contamination, eventually paving their way into aquatic ecosystems and seafood [64]. Such a study further provoked the need for the detection of AMPs in the marine atmosphere. A group of researchers collected aerosol samples in a 2.5-year research project during the Tara Pacific expedition. As shown in Figure 4, Raman microspectroscopy was able to characterize airborne microplastics, indicating the presence of PS, PE, PP, and polysilicone compounds. Furthermore, a comparative analysis of Raman spectral data obtained for aerosol and seawater MPs suggests that the emission of AMPs could be the result of the wind-related transportation of MPs from seawater [65].

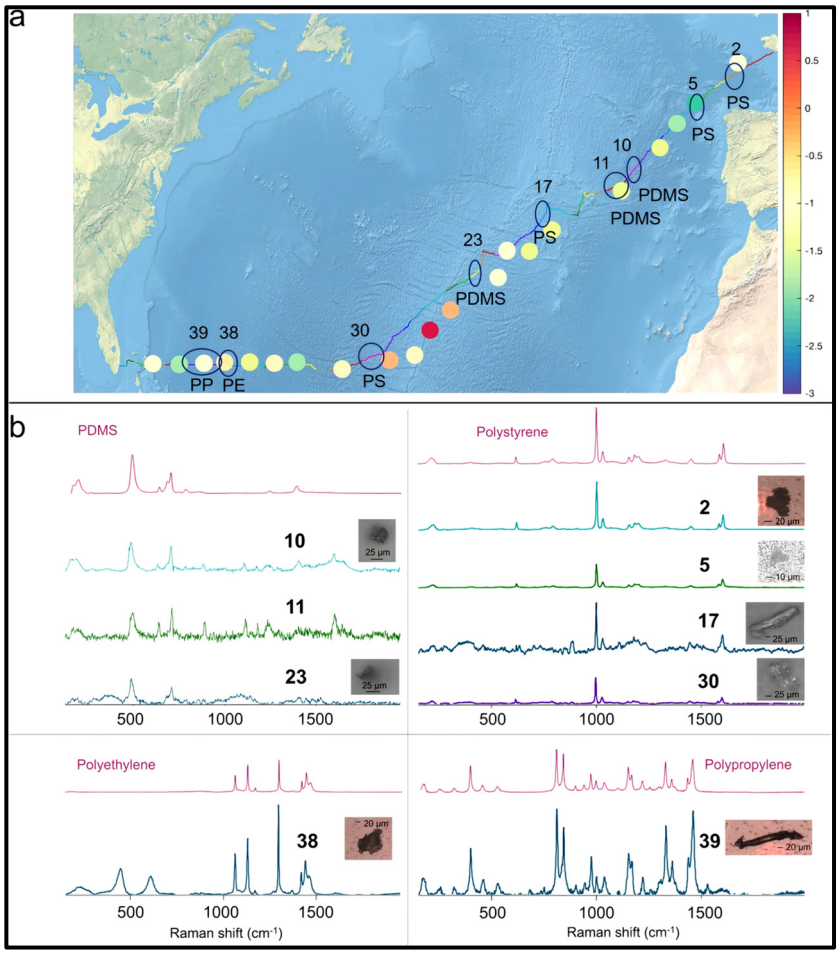

Figure 4. (**a**) Multiple MPs detected during the Tara Pacific Expedition along the Atlantic transect. (**b**) Raman spectra for the detected AMPs, along with their light microscope images. The standards for detected MP types have been correspondingly presented in magenta. PS: polystyrene; PE: polyethylene; PDMS: polymethylsiloxane; PP: polyproylene. Reproduced from ref. [65]. Copyright © 2020, The Author(s).

Table 2 is a list of MPs detected in various remote areas. This indicates that MPs may be consistently transported to isolated areas due to various meteorological and geographical factors. The prominent presence of fibers and fragments depicts that these shapes dominate MP compositions. This is also observed in the studies reported in Table 1. Investigations indicate that water from alpine rivers also shows a high average abundance of MPFs. Additionally, studies indicate that recreational hiking and running trails in remote areas can contribute to the atmospheric deposition of MPs. Tourism attracted by the Himalayan region acts as a source of MPs in rivers, such as Ganga, Indus, Brahmaputra, Alaknanda, and Kosi [66]. Besides tourism, newly established communities near isolated water sources, such as remote lakes and rivers, can directly contribute towards the development of MP sinks. In their recent extensive literature study, Citterich et al. reviewed the existing knowledge concerning the presence of MPs at the poles of the Earth, including the Antarctica and Artic regions. The transportation of AMPs to isolated areas such as the Arctic regions can depend on biovectors, like seabirds, migratory birds, and aquatic animals, which may defecate digested plastic micropollutants. Atmospheric deposition can also be the cause of MPs detected on the surface of marine rivers and glaciers [67,68]. Similarly, snow and ice in cryospheric regions need to be critically assessed with standard procedures for the sampling, detection, and identification of MPs [63].

Table 2. A summarized list of various types of MP compositions found in isolated areas around the world.

MP	Size	Shape	Techniques for Identifying Shape	Deposition	Location	Ref.
PE, PET, PES, HDPE, LDPE	50–1910 µm	Fibers and fragments	µ-FTIR	0.39 ± 0.39 to 4.91 ± 2.48 MPs/L	Aosta Valley, Western Italian Alps	[58]
PP	-	Transparent fibers	Microscopy and Raman spectroscopy	0.48 ± 0.28 MPs/L	Qilian Mountain, China	[69]
MPs	50–300 µm	Fibers	Fourier-transform infrared spectroscopy (FTIR) and Raman spectroscopy	Water: 305.79 ± 289.66 MPs/m^3	Hindu Kush Mountain, Pakistan	[70]
				Sediment: 588.29 ± 253.95 MPs/kg		
PET, PU, PS, and polyamide	-	Fibers	Laser Direct Infrared Imaging (LDIR), SEM	17.4 MPs/m^2/day	Hiking trail in Southeast Australia	[71]
PP and PET	100.2–142.1 µm	Fibers and fragments	Stereomicroscopy, FTIR	Upper lake: 1.75 ± 0.62 MPs/m^3	Sediments in Lake Balma, Cottian Alps	[72]
	101.1–138.6 µm			Lower lake: 1.33 ± 0.67 MPs/m^3		
MPs	-	Fibers, films, and fragments	FTIR-ATR spectroscopy	2.0 ± 1.7 MPs/L	Water samples from Sagarmatha National Park, Nepal	[73]
MPs	48–200 µm	Fibers and films	Raman microscope	Snow: 9.55 ± 0.9 MPs/L	Tibetan Plateau	[74]
MPs	-	Non-fibrous material	Raman spectroscopy	Dry deposition: 4 to 140 MPs/m^2/dayWet deposition: 0.006–0.050 MPs/mL	Flathead lake, USA	[75]
MPs	-	Fibers, films, and fragments	ATR-FTIR	131 ± 24 MPs/L	Andean glacier	[76]
	<45 µm	Fibers and fragments	Stereomicroscope	21.3 MPs/L	High mountain lakes of Sierra Nevada, Spain	[77]
PES, nylon, PA, PP	250–750 µm	Cellulosic compounds, polyester, and acrylic microfibers	Stereomicroscope, µ-FTIR	167 ± 104 and 188 ± 164 MPs/L	High mountain snow, El Teide, Spain	[78]

5. Meteorological Factors

In recent years, the roles of meteorological factors such as wind speed, air humidity, temperature, and many more have surfaced as important factors which can influence the persistence and transport of suspended AMPs. Due to their small size and low density, wind speed and direction act as crucial factors which influence the transport of AMPs, and ample studies have suggested that MPs can travel over long distances. This uncontrollable and inevitable ease of transportation via wind has been hypothesized to be a major source of suspended and deposited AMPs in remote and sparsely populated areas such as glaciers and snow lands.

In Gdynia, Poland, it was determined that AMPs could travel distances as long as 100 km before being deposited, while in the French Pyrenees mountains, these micropollutants can travel up to 95 km [79,80]. In addition to wind speed, wind direction has been studied as an important factor [81]. However, a significant influence of wind directions has not been determined in most studies, which may be due to the distance between sampling sites. This was also reported by a group of researchers in Ontario, Canada, who determined the presence of polyamide and PET in anthropogenic particles, which are plastic types highly used in the textile industry and as thermoplastics. They further determined that wind speed was significantly associated with the detected anthropogenic particles, suggesting that a higher wind speed leads towards a larger airshed source area, which eventually results in an increase in the distance travelled by the suspended AMPs. Although no correlation could be found between wind direction and the transport of anthropogenic particles, a noteworthy change in wind direction with changing seasons could imply a change in the source region of these particles [82]. However, due to inconsistency in the methods adopted for the sampling, pre-treatment, and detection of these micropollutants, a distinct trend in the interrelationship between the source, sink, and trajectory, which can be globally

observed, has not yet been established. The same factors which may be positively correlated with AMPs in a particular study may exhibit a negative or no correlation in another study. Thus, the development of a standardized method for the experimental and analytical methods incorporated in studying AMPs is critical for achieving research progress.

The deposition and scavenging of suspended AMPs have also been influenced by wet precipitation. Dris et al. determined an increased abundance and detection of AMPs after rainfall [28,29]. In other studies, dry deposition provided no significant impact, whereas wet deposition was observed to play a larger role in the collection of suspended AMPs [79]. Rainfall has been speculated to affect deposition greatly, but no clear significant effect could be determined with respect to rain capacity at most sampling sites. On the other hand, longer periods of snowfall were associated with low MP abundances [80]. Most of the studies have been successful in establishing a correlation between precipitation and AMPs; however, the influence mechanisms of wet and dry precipitation have not been fully understood due to the shortcomings arising from limited existing knowledge.

Besides wind speed and precipitation, air humidity is another important factor which can affect dry deposition as well as the suspension of AMPs. It has been hypothesized that the increase in AMP size brought on by hygroscopic development as a result of rising humidity will eventually cause an increase in the AMP deposition rate [79,83]. Contrastingly, low temperatures can trigger the nucleation and condensation of particulate matter, thereby reducing the abundance of AMPs. Thus, the abundance of suspended and deposited AMPs is definitively dependent on meteorological conditions like temperature, wind speed and direction, precipitation, and air humidity. But it should be noted that the effect of these factors is practically observed as a combined effect of two or more related factors.

6. Challenges and Visions

The ubiquity of MPs in soil, water, air, and life forms has become an inevitable facet of plastic-derived pollution. Countermeasures adopted to understand, eliminate, and regulate the flow of MPs are constantly being explored and adopted globally. However, scientific progress in this field is slow, while the continuous exploitation of plastic-based products in commercial, industrial, and medical sectors surges every minute. Some of the challenges which have hindered developments in understanding AMPs have been briefly addressed, along with some suggestions for future research:

(a) Scarce studies on terrestrial AMPs present in various indoor and outdoor sites across the globe overshadow the true reality of suspended AMPs. Moreover, a generalized conclusion cannot be drawn regarding the flow of MPs between indoor and outdoor environments. This hinders the development of a rigid source–pathway–sink trajectory.

(b) The transportation of AMPs and their role as vectors are vastly unexplored. Incomplete source–pathway–sink relationships of AMPs hinder developments, and a wide array of future research can be dedicated to understanding these interrelationships, which can help in regulating the influx or efflux of AMPs.

(c) It is quite challenging to understand the spread of suspended AMP deposition in remote areas with negligible local transport of plastic pollutants, such as glaciers, arctic areas, and other such environments. More future investigations into this approach could provide insights into the relationship of MP pollution with population, industrialization, AMPs transportation, and other parameters.

The requirement for standardized techniques for the characterization and identification of AMPs has been well established in the last few years. However, they still remain undeveloped. The development of standard procedures for the sampling, identification, and quantification of AMPs will help in reproducing and comparing results, consequently providing better risk assessments.

7. Conclusions

The Anthropocene Epoch witnessed a revolution of man-made developments on Earth, which gave rise to plastic that has extensive applications in the commercial, industrial, and medical sectors. Today, plastic-generated waste accounts for a large section of the environmental pollution which has hampered various ecosystems. However, accumulated plastic debris can generate smaller fragments of MPs, which pose an even greater risk to all ecosystems. In response to this global threat, the scientific and academic communities, policymakers, and the media have been striving to spread awareness and develop countermeasures for a plastic-free environment. MPs present in the air and their subsequent deposition in both populated and isolated areas can occur through long/short-range transportation. The persistence of fibrous AMPs in indoor air can directly affect human health. Furthermore, the interaction between suspended AMPs and airborne viruses, such as the Corona virus, should be explored in depth to mitigate the probability of even more severe respiratory consequences. Unexplored areas, such as the source–pathway–sink trajectories of AMPs, should be thoroughly studied to develop a better understanding. Additionally, various remote regions, including glaciers, lakes, mountains, and arctic regions, may prove to be important locations for studying atmospheric deposition and the trajectories of MP influx or efflux.

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References

1. Bank, M.S.; Hansson, S.V. The Plastic Cycle: A Novel and Holistic Paradigm for the Anthropocene. *Environ. Sci. Technol.* **2019**, *53*, 7177–7179. [CrossRef] [PubMed]
2. Hartmann, N.B.; Hüffer, T.; Thompson, R.C.; Hassellöv, M.; Verschoor, A.; Daugaard, A.E.; Rist, S.; Karlsson, T.; Brennholt, N.; Cole, M.; et al. Are We Speaking the Same Language? Recommendations for a Definition and Categorization Framework for Plastic Debris. *Environ. Sci. Technol.* **2019**, *53*, 1039–1047. [CrossRef] [PubMed]
3. Sources, fate and effects of microplastics in the marine environment: Part two of a global assessment. In *Reports and Studies-IMO/FAO/Unesco-IOC/WMO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) eng no. 93*; International Maritime Organization: London, UK, 2016; 220p.
4. Alimi, O.S.; Budarz, J.F.; Hernandez, L.M.; Tufenkji, N. Microplastics and nanoplastics in aquatic environments: Aggregation, deposition, and enhanced contaminant transport. *Environ. Sci. Technol.* **2018**, *52*, 1704–1724. [CrossRef] [PubMed]
5. *ISO-ISO/DIS 4484-2*; Textiles and Textile Products—Microplastics from Textile Sources—Part 2: Qualitative and Quantitative Evaluation of Microplastics. ISO: Geneva, Switzerland, 2022. Available online: https://www.iso.org/standard/80011.html (accessed on 2 June 2024).
6. *ISO 5157_2023(en)*; Textiles—Environmental Aspects—Vocabulary. ISO: Geneva, Switzerland, 2023.
7. Hahladakis, J.N.; Velis, C.A.; Weber, R.; Iacovidou, E.; Purnell, P. An overview of chemical additives present in plastics: Migration, release, fate and environmental impact during their use, disposal and recycling. *J. Hazard. Mater.* **2018**, *344*, 179–199. [CrossRef] [PubMed]
8. Lagarde, F.; Olivier, O.; Zanella, M.; Daniel, P.; Hiard, S.; Caruso, A. Microplastic interactions with freshwater microalgae: Hetero-aggregation and changes in plastic density appear strongly dependent on polymer type. *Environ. Pollut.* **2016**, *215*, 331–339. [CrossRef] [PubMed]
9. Arreola-Alarcón, I.M.; Reyes-Bonilla, H.; Sakthi, J.S.; Rodríguez-González, F.; Jonathan, M.P. Seasonal tendencies of microplastics around coral reefs in selected Marine Protected National Parks of Gulf of California, Mexico. *Mar. Pollut. Bull.* **2022**, *175*, 113333. [CrossRef] [PubMed]
10. Botterell, Z.L.R.; Bergmann, M.; Hildebrandt, N.; Krumpen, T.; Steinke, M.; Thompson, R.C.; Lindeque, P.K. Microplastic ingestion in zooplankton from the Fram Strait in the Arctic. *Sci. Total Environ.* **2022**, *831*, 154886. [CrossRef] [PubMed]

11. Wang, K.; Zhu, L.; Rao, L.; Zhao, L.; Wang, Y.; Wu, X.; Zheng, H.; Liao, X. Nano-and micro-polystyrene plastics disturb gut microbiota and intestinal immune system in honeybee. *Sci. Total Environ.* **2022**, *842*, 156819. [CrossRef] [PubMed]
12. Bobori, D.C.; Dimitriadi, A.; Feidantsis, K.; Samiotaki, A.; Fafouti, D.; Sampsonidis, I.; Kalogiannis, S.; Kastrinaki, G.; Lambropoulou, D.A.; Kyzas, G.Z. Toxic effects of polyethylene-microplastics on freshwater fish species: Implications for human health. *Public Health Toxicol.* **2022**, *2*, A108. [CrossRef]
13. Dey, T. Microplastic pollutant detection by Surface Enhanced Raman Spectroscopy (SERS): A mini-review. *Nanotechnol. Environ. Eng.* **2022**, *8*, 41–48. [CrossRef]
14. Moniuszko, H.; Malonga, W.A.; Koczoń, P.; Thijs, S.; Popek, R.; Przybysz, A. Accumulation of Plastics and Trace Elements in the Mangrove Forests of Bima City Bay, Indonesia. *Plants* **2023**, *12*, 462. [CrossRef] [PubMed]
15. Mészáros, E.; Bodor, A.; Kovács, E.; Papp, S.; Kovács, K.; Perei, K.; Feigl, G. Impacts of plastics on plant development: Recent advances and future research directions. *Plants* **2023**, *12*, 3282. [CrossRef] [PubMed]
16. Capozzi, F.; Sorrentino, M.C.; Cascone, E.; Iuliano, M.; De Tommaso, G.; Granata, A.; Giordano, S.; Spagnuolo, V. Biomonitoring of Airborne Microplastic Deposition in Semi-Natural and Rural Sites Using the Moss Hypnum cupressiforme. *Plants* **2023**, *12*, 977. [CrossRef] [PubMed]
17. Ibrahim, Y.S.; Anuar, S.T.; Azmi, A.A.; Khalik, W.M.A.W.M.; Lehata, S.; Hamzah, S.R.; Ismail, D.; Ma, Z.F.; Dzulkarnaen, A.; Zakaria, Z. Detection of microplastics in human colectomy specimens. *JGH Open* **2021**, *5*, 116–121. [CrossRef] [PubMed]
18. Horton, A.A.; Walton, A.; Spurgeon, D.J.; Lahive, E.; Svendsen, C. Microplastics in freshwater and terrestrial environments: Evaluating the current understanding to identify the knowledge gaps and future research priorities. *Sci. Total Environ.* **2017**, *586*, 127–141. [CrossRef] [PubMed]
19. Tadsuwan, K.; Babel, S. Unraveling microplastics removal in wastewater treatment plant: A comparative study of two wastewater treatment plants in Thailand. *Chemosphere* **2022**, *307*, 135733. [CrossRef] [PubMed]
20. Wright, S.L.; Ulke, J.; Font, A.; Chan, K.L.A.; Kelly, F.J. Atmospheric microplastic deposition in an urban environment and an evaluation of transport. *Environ. Int.* **2020**, *136*, 105411. [CrossRef]
21. Liu, K.; Wu, T.; Wang, X.; Song, Z.; Zong, C.; Wei, N.; Li, D. Consistent Transport of Terrestrial Microplastics to the Ocean through Atmosphere. *Environ. Sci. Technol.* **2019**, *53*, 10612–10619. [CrossRef] [PubMed]
22. Borthakur, A.; Leonard, J.; Koutnik, V.S.; Ravi, S.; Mohanty, S.K. Inhalation risks of wind-blown dust from biosolid-applied agricultural lands: Are they enriched with microplastics and PFAS? *Curr. Opin. Environ. Sci. Health* **2022**, *25*, 100309. [CrossRef]
23. Miri, S.; Saini, R.; Davoodi, S.M.; Pulicharla, R.; Brar, S.K.; Magdouli, S. Biodegradation of microplastics: Better late than never. *Chemosphere* **2022**, *286*, 131670. [CrossRef]
24. Veerasingam, S.; Ranjani, M.; Venkatachalapathy, R.; Bagaev, A.; Mukhanov, V.; Litvinyuk, D.; Verzhevskaia, L.; Guganathan, L.; Vethamony, P. Microplastics in different environmental compartments in India: Analytical methods, distribution, associated contaminants and research needs. *TrAC Trends Anal. Chem.* **2020**, *133*, 116071. [CrossRef]
25. Shi, B.; Patel, M.; Yu, D.; Yan, J.; Li, Z.; Petriw, D.; Pruyn, T.; Smyth, K.; Passeport, E.; Miller, R.J.D.; et al. Automatic quantification and classification of microplastics in scanning electron micrographs via deep learning. *Sci. Total Environ.* **2022**, *825*, 153903. [CrossRef] [PubMed]
26. Shao, L.; Li, Y.; Jones, T.; Santosh, M.; Liu, P.; Zhang, M.; Xu, L.; Li, W.; Lu, J.; Yang, C.-X. Airborne microplastics: A review of current perspectives and environmental implications. *J. Clean. Prod.* **2022**, *347*, 131048. [CrossRef]
27. Zhang, Y.; Kang, S.; Allen, S.; Allen, D.; Gao, T.; Sillanpää, M. Atmospheric microplastics: A review on current status and perspectives. *Earth-Sci. Rev.* **2020**, *203*, 103118. [CrossRef]
28. Dris, R.; Gasperi, J.; Rocher, V.; Saad, M.; Renault, N.; Tassin, B. Microplastic contamination in an urban area: A case study in Greater Paris. *Environ. Chem.* **2015**, *12*, 592–599. [CrossRef]
29. Dris, R.; Gasperi, J.; Saad, M.; Mirande, C.; Tassin, B. Synthetic fibers in atmospheric fallout: A source of microplastics in the environment? *Mar. Pollut. Bull.* **2016**, *104*, 290–293. [CrossRef] [PubMed]
30. Dris, R.; Gasperi, J.; Mirande, C.; Mandin, C.; Guerrouache, M.; Langlois, V.; Tassin, B. A first overview of textile fibers, including microplastics, in indoor and outdoor environments. *Environ. Pollut.* **2017**, *221*, 453–458. [CrossRef] [PubMed]
31. Parashar, N.; Hait, S. Plastic rain—Atmospheric microplastics deposition in urban and peri-urban areas of Patna City, Bihar, India: Distribution, characteristics, transport, and source analysis. *J. Hazard. Mater.* **2023**, *458*, 131883. [CrossRef] [PubMed]
32. Liu, Z.; Bai, Y.; Ma, T.; Liu, X.; Wei, H.; Meng, H.; Fu, Y.; Ma, Z.; Zhang, L.; Zhao, J. Distribution and possible sources of atmospheric microplastic deposition in a valley basin city (Lanzhou, China). *Ecotoxicol. Environ. Saf.* **2022**, *233*, 113353. [CrossRef]
33. Hee, Y.Y.; Hanif, N.M.; Weston, K.; Latif, M.T.; Suratman, S.; Rusli, M.U.; Mayes, A.G. Atmospheric microplastic transport and deposition to urban and pristine tropical locations in Southeast Asia. *Sci. Total Environ.* **2023**, *902*, 166153. [CrossRef]
34. Li, J.; Zhang, J.; Ren, S.; Huang, D.; Liu, F.; Li, Z.; Zhang, H.; Zhao, M.; Cao, Y.; Mofolo, S.; et al. Atmospheric deposition of microplastics in a rural region of North China Plain. *Sci. Total Environ.* **2023**, *877*, 162947. [CrossRef] [PubMed]
35. Purwiyanto, A.I.S.; Prartono, T.; Riani, E.; Naulita, Y.; Cordova, M.R.; Koropitan, A.F. The deposition of atmospheric microplastics in Jakarta-Indonesia: The coastal urban area. *Mar. Pollut. Bull.* **2022**, *174*, 113195. [CrossRef] [PubMed]
36. Fang, M.; Liao, Z.; Ji, X.; Zhu, X.; Wang, Z.; Lu, C.; Shi, C.; Chen, Z.; Ge, L.; Zhang, M.; et al. Microplastic ingestion from atmospheric deposition during dining/drinking activities. *J. Hazard. Mater.* **2022**, *432*, 128674. [CrossRef] [PubMed]
37. Truong, T.-N.-S.; Strady, E.; Kieu-Le, T.-C.; Tran, Q.-V.; Le, T.-M.-T.; Thuong, Q.-T. Microplastic in atmospheric fallouts of a developing Southeast Asian megacity under tropical climate. *Chemosphere* **2021**, *272*, 129874. [CrossRef] [PubMed]

38. Jia, Q.; Duan, Y.; Han, X.; Sun, X.; Munyaneza, J.; Ma, J.; Xiu, G. Atmospheric deposition of microplastics in the megalopolis (Shanghai) during rainy season: Characteristics, influence factors, and source. *Sci. Total Environ.* **2022**, *847*, 157609. [CrossRef] [PubMed]
39. Yuan, Z.; Pei, C.; Li, H.; Lin, L.; Liu, S.; Hou, R.; Liao, R.; Xu, X. Atmospheric microplastics at a southern China metropolis: Occurrence, deposition flux, exposure risk and washout effect of rainfall. *Sci. Total Environ.* **2023**, *869*, 161839. [CrossRef] [PubMed]
40. Klein, M.; Bechtel, B.; Brecht, T.; Fischer, E.K. Spatial distribution of atmospheric microplastics in bulk-deposition of urban and rural environments—A one-year follow-up study in northern Germany. *Sci. Total Environ.* **2023**, *901*, 165923. [CrossRef]
41. Kyriakoudes, G.; Turner, A. Suspended and deposited microplastics in the coastal atmosphere of southwest England. *Chemosphere* **2023**, *343*, 140258. [CrossRef]
42. Allen, D.; Allen, S.; Le Roux, G.; Simonneau, A.; Galop, D.; Phoenix, V.R. Temporal Archive of Atmospheric Microplastic Deposition Presented in Ombrotrophic Peat. *Environ. Sci. Technol. Lett.* **2021**, *8*, 954–960. [CrossRef]
43. Cakaj, A.; Lisiak-Zielińska, M.; Drzewiecka, K.; Budka, A.; Borowiak, K.; Drapikowska, M.; Cakaj, A.; Qorri, E.; Szkudlarz, P. Potential Impact of Urban Land Use on Microplastic Atmospheric Deposition: A Case Study in Pristina City, Kosovo. *Sustainability* **2023**, *15*, 16464. [CrossRef]
44. Cai, L.; Wang, J.; Peng, J.; Tan, Z.; Zhan, Z.; Tan, X.; Chen, Q. Characteristic of microplastics in the atmospheric fallout from Dongguan city, China: Preliminary research and first evidence. *Environ. Sci. Pollut. Res.* **2017**, *24*, 24928–24935. [CrossRef] [PubMed]
45. Klein, M.; Fischer, E.K. Microplastic abundance in atmospheric deposition within the Metropolitan area of Hamburg, Germany. *Sci. Total Environ.* **2019**, *685*, 96–103. [CrossRef] [PubMed]
46. Liu, C.; Li, J.; Zhang, Y.; Wang, L.; Deng, J.; Gao, Y.; Yu, L.; Zhang, J.; Sun, H. Widespread distribution of PET and PC microplastics in dust in urban China and their estimated human exposure. *Environ. Int.* **2019**, *128*, 116–124. [CrossRef] [PubMed]
47. Zhu, X.; Huang, W.; Fang, M.; Liao, Z.; Wang, Y.; Xu, L.; Mu, Q.; Shi, C.; Lu, C.; Deng, H.; et al. Airborne Microplastic Concentrations in Five Megacities of Northern and Southeast China. *Environ. Sci. Technol.* **2021**, *55*, 12871–12881. [CrossRef] [PubMed]
48. Choi, H.; Lee, I.; Kim, H.; Park, J.; Cho, S.; Oh, S.; Lee, M.; Kim, H. Comparison of Microplastic Characteristics in the Indoor and Outdoor Air of Urban Areas of South Korea. *Water Air Soil Pollut.* **2022**, *233*, 169. [CrossRef]
49. Jenner, L.C.; Sadofsky, L.R.; Danopoulos, E.; Rotchell, J.M. Household indoor microplastics within the Humber region (United Kingdom): Quantification and chemical characterisation of particles present. *Atmos. Environ.* **2021**, *259*, 118512. [CrossRef]
50. Jenner, L.C.; Sadofsky, L.R.; Danopoulos, E.; Chapman, E.; White, D.; Jenkins, R.L.; Rotchell, J.M. Outdoor Atmospheric Microplastics within the Humber Region (United Kingdom): Quantification and Chemical Characterisation of Deposited Particles Present. *Atmosphere* **2022**, *13*, 265. [CrossRef]
51. Chen, Y.; Li, X.; Zhang, X.; Zhang, Y.; Gao, W.; Wang, R.; He, D. Air conditioner filters become sinks and sources of indoor microplastics fibers. *Environ. Pollut.* **2022**, *292*, 118465. [CrossRef] [PubMed]
52. Torres-Agullo, A.; Karanasiou, A.; Moreno, T.; Lacorte, S. Airborne microplastic particle concentrations and characterization in indoor urban microenvironments. *Environ. Pollut.* **2022**, *308*, 119707. [CrossRef]
53. Perera, K.; Ziajahromi, S.; Nash, S.B.; Manage, P.M.; Leusch, F.D.L. Airborne Microplastics in Indoor and Outdoor Environments of a Developing Country in South Asia: Abundance, Distribution, Morphology, and Possible Sources. *Environ. Sci. Technol.* **2022**, *56*, 16676–16685. [CrossRef]
54. Yao, Y.; Glamoclija, M.; Murphy, A.; Gao, Y. Characterization of microplastics in indoor and ambient air in northern New Jersey. *Environ. Res.* **2022**, *207*, 112142. [CrossRef]
55. Nematollahi, M.J.; Keshavarzi, B.; Mohit, F.; Moore, F.; Busquets, R. Microplastic occurrence in urban and industrial soils of Ahvaz metropolis: A city with a sustained record of air pollution. *Sci. Total Environ.* **2022**, *819*, 152051. [CrossRef] [PubMed]
56. Syafina, P.R.; Yudison, A.P.; Sembiring, E.; Irsyad, M.; Tomo, H.S. Identification of fibrous suspended atmospheric microplastics in Bandung Metropolitan Area, Indonesia. *Chemosphere* **2022**, *308*, 136194. [CrossRef]
57. Kacprzak, S.; Tijing, L.D. Microplastics in indoor environment: Sources, mitigation and fate. *J. Environ. Chem. Eng.* **2022**, *10*, 107359. [CrossRef]
58. Parolini, M.; Antonioli, D.; Borgogno, F.; Gibellino, M.C.; Fresta, J.; Albonico, C.; De Felice, B.; Canuto, S.; Concedi, D.; Romani, A. Microplastic contamination in snow from Western Italian alps. *Int. J. Environ. Res. Public Health* **2021**, *18*, 768. [CrossRef] [PubMed]
59. Yang, L.; Kang, S.; Wang, Z.; Luo, X.; Guo, J.; Gao, T.; Chen, P.; Yang, C.; Zhang, Y. Microplastic characteristic in the soil across the Tibetan Plateau. *Sci. Total Environ.* **2022**, *828*, 154518. [CrossRef]
60. Primpke, S.; Booth, A.M.; Gerdts, G.; Gomiero, A.; Kögel, T.; Lusher, A.L.; Strand, J.; Scholz-Böttcher, B.M.; Galgani, F.; Provencher, J.F. Monitoring of microplastic pollution in the Arctic: Recent developments in polymer identification, quality assurance and control (QA/QC), and data reporting. *Arct. Sci.* **2022**, *9*, 176–197. [CrossRef]
61. Hamilton, B.M.; Bourdages, M.P.T.; Geoffroy, C.; Vermaire, J.C.; Mallory, M.L.; Rochman, C.M.; Provencher, J.F. Microplastics around an Arctic seabird colony: Particle community composition varies across environmental matrices. *Sci. Total Environ.* **2021**, *773*, 145536. [CrossRef] [PubMed]

62. Dong, H.; Wang, L.; Wang, X.; Xu, L.; Chen, M.; Gong, P.; Wang, C. Microplastics in a remote Lake Basin of the tibetan plateau: Impacts of atmospheric transport and glacial melting. *Environ. Sci. Technol.* **2021**, *55*, 12951–12960. [CrossRef]
63. Zhang, Y.; Gao, T.; Kang, S.; Shi, H.; Mai, L.; Allen, D.; Allen, S. Current status and future perspectives of microplastic pollution in typical cryospheric regions. *Earth-Sci. Rev.* **2022**, *226*, 103924. [CrossRef]
64. Wang, X.; Li, C.; Liu, K.; Zhu, L.; Song, Z.; Li, D. Atmospheric microplastic over the South China Sea and East Indian Ocean: Abundance, distribution and source. *J. Hazard. Mater.* **2020**, *389*, 121846. [CrossRef] [PubMed]
65. Trainic, M.; Flores, J.M.; Pinkas, I.; Pedrotti, M.L.; Lombard, F.; Bourdin, G.; Gorsky, G.; Boss, E.; Rudich, Y.; Vardi, A.; et al. Airborne microplastic particles detected in the remote marine atmosphere. *Commun. Earth Environ.* **2020**, *1*, 64. [CrossRef]
66. Talukdar, A.; Bhattacharya, S.; Bandyopadhyay, A.; Dey, A. Microplastic pollution in the Himalayas: Occurrence, distribution, accumulation and environmental impacts. *Sci. Total Environ.* **2023**, *874*, 162495. [CrossRef] [PubMed]
67. Citterich, F.; Giudice, A.L.; Azzaro, M. A plastic world: A review of microplastic pollution in the freshwaters of the Earth's poles. *Sci. Total Environ.* **2023**, *869*, 161847. [CrossRef] [PubMed]
68. Evangeliou, N.; Grythe, H.; Klimont, Z.; Heyes, C.; Eckhardt, S.; Lopez-Aparicio, S.; Stohl, A. Atmospheric transport is a major pathway of microplastics to remote regions. *Nat. Commun.* **2020**, *11*, 3381. [CrossRef] [PubMed]
69. Liu, Q.; Xiong, X.; Wang, K.; Wang, H.; Ling, Y.; Li, Q.; Xu, F.; Wu, C. Homogenization of microplastics in alpine rivers: Analysis of microplastic abundance and characteristics in rivers of Qilian Mountain, China. *J. Environ. Manag.* **2023**, *340*, 118011. [CrossRef] [PubMed]
70. Bilal, M.; Qadir, A.; Yaqub, A.; Hassan, H.U.; Irfan, M.; Aslam, M. Microplastics in water, sediments, and fish at Alpine River, originating from the Hindu Kush Mountain, Pakistan: Implications for conservation. *Environ. Sci. Pollut. Res.* **2023**, *30*, 727–738. [CrossRef] [PubMed]
71. Forster, N.A.; Wilson, S.C.; Tighe, M.K. Microplastic pollution on hiking and running trails in Australian protected environments. *Sci. Total Environ.* **2023**, *874*, 162473. [CrossRef]
72. Pastorino, P.; Anselmi, S.; Esposito, G.; Bertoli, M.; Pizzul, E.; Barceló, D.; Elia, A.C.; Dondo, A.; Prearo, M.; Renzi, M. Microplastics in biotic and abiotic compartments of high-mountain lakes from Alps. *Ecol. Indic.* **2023**, *150*, 110215. [CrossRef]
73. Han, B.; Yacoub, M.; Li, A.; Nicholson, K.; Gruver, J.; Neumann, K.; Sharma, S. Human Activities Increased Microplastics Contamination in the Himalaya Mountains. *Hydrology* **2024**, *11*, 4. [CrossRef]
74. Wang, Z.; Zhang, Y.; Kang, S.; Yang, L.; Luo, X.; Chen, P.; Guo, J.; Hu, Z.; Yang, C.; Yang, Z.; et al. Long-range transport of atmospheric microplastics deposited onto glacier in southeast Tibetan Plateau. *Environ. Pollut.* **2022**, *306*, 119415. [CrossRef] [PubMed]
75. Xiong, X.; Tappenbeck, T.H.; Wu, C.; Elser, J.J. Microplastics in Flathead Lake, a large oligotrophic mountain lake in the USA. *Environ. Pollut.* **2022**, *306*, 119445. [CrossRef] [PubMed]
76. Cabrera, M.; Moulatlet, G.M.; Valencia, B.G.; Maisincho, L.; Rodríguez-Barroso, R.; Albendín, G.; Sakali, A.; Lucas-Solis, O.; Conicelli, B.; Capparelli, M.V. Microplastics in a tropical Andean Glacier: A transportation process across the Amazon basin? *Sci. Total Environ.* **2022**, *805*, 150334. [CrossRef] [PubMed]
77. Godoy, V.; Calero, M.; González-Olalla, J.M.; Martín-Lara, M.A.; Olea, N.; Ruiz-Gutierrez, A.; Villar-Argaiz, M. The human connection: First evidence of microplastics in remote high mountain lakes of Sierra Nevada, Spain. *Environ. Pollut.* **2022**, *311*, 119922. [CrossRef] [PubMed]
78. Villanova-Solano, C.; Hernández-Sánchez, C.; Díaz-Peña, F.J.; González-Sálamo, J.; González-Pleiter, M.; Hernández-Borges, J. Microplastics in snow of a high mountain national park: El Teide, Tenerife (Canary Islands, Spain). *Sci. Total Environ.* **2023**, *873*, 162276. [CrossRef]
79. Szewc, K.; Graca, B.; Dołęga, A. Atmospheric deposition of microplastics in the coastal zone: Characteristics and relationship with meteorological factors. *Sci. Total Environ.* **2021**, *761*, 143272. [CrossRef] [PubMed]
80. Allen, S.; Allen, D.; Phoenix, V.R.; Le Roux, G.; Jiménez, P.D.; Simonneau, A.; Binet, S.; Galop, D. Atmospheric transport and deposition of microplastics in a remote mountain catchment. *Nat. Geosci.* **2019**, *12*, 339–344. [CrossRef]
81. Liu, K.; Wang, X.; Fang, T.; Xu, P.; Zhu, L.; Li, D. Source and potential risk assessment of suspended atmospheric microplastics in Shanghai. *Sci. Total Environ.* **2019**, *675*, 462–471. [CrossRef] [PubMed]
82. Welsh, B.; Aherne, J.; Paterson, A.M.; Yao, H.; McConnell, C. Atmospheric deposition of anthropogenic particles and microplastics in south-central Ontario, Canada. *Sci. Total Environ.* **2022**, *835*, 155426. [CrossRef]
83. Roblin, B.; Ryan, M.; Vreugdenhil, A.; Aherne, J. Ambient atmospheric deposition of anthropogenic microfibers and microplastics on the western periphery of Europe (Ireland). *Environ. Sci. Technol.* **2020**, *54*, 11100–11108. [CrossRef]

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