Microplastics as potential source for environmental pollution: An updated review on Indian scenario Post Covid -19

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Abstract

Technological advancement has tremendously accelerated the promotion of microplastics in our environment. In early 2020, the COVID-19 pandemic accelerated the production and use of plastics in the form of facemasks, face shields and PPE kits across the globe has intensified and becomes a new environmental challenge. As scientific knowledge is limited concerning the source, exposure, toxicity, and bioavailability of microplastics in the surroundings, this review has been aimed to provide comprehensive information about microplastics present in the environment with special emphasis on their deposition and related increasing menace in India, during and after the COVID 19 period. We have focussed on the 5 key research needs, involving (1) the occurrence and abundance of microplastics (2) sources, fate, and occurrence of microplastics in different media (water, air and soil), (3) toxicological implications of microplastics on human beings, (4) scenario of microplastics disposal during COVID-19 pandemic and (5) major challenges and future directions to curtail them. We suggest that addressing these knowledge gaps will lay the groundwork to counteract such environmental issues which are important to prevent them from exagerbating. Combating microplastic contamination can be achieved through an intensive and combined effort of all, including the stakeholders, researchers, educators, media and policymakers. We can join the effort to manage plastic in the environment by refusing, reducing, reusing and recycling the plastic products, to prolong every item’s life cycle as far as possible. A start would be a focus on limiting the use of single-use plastic products, especially if alternatives are readily available.

Keywords: Microplastics; Plastic pollution; Plastic microbeads; Bioaccumulation; Biomagnification

1. Introduction

Environmental pollution is a wide-reaching problem, and it is likely to influence the health of human populations considerably. Most of the seabed is made up of plastics resulting from the waste collected on the coasts and in the sea [1]. When plastic gets released into the environment it undergoes degradation, which leads to serious issues. Atmospheric agents, such as waves, abrasion, ultraviolet radiation, and photo-oxidation combined with bacteria can degrade plastic fragments into micro and nano-sized particles, called microplastics and nanoplastics.

Microplastics (MPs) are defined as plastic particles less than 5 mm in size [2]. Microplastics have been detected in environments and media as varied as oceans, rivers, sediments, sewages, soil, and even table salts [3,4]. Microplastics accumulated in the earth’s environment adversely affect wildlife, habitat, aquatic habitat, and human beings[5]. A report by the World Health Organization on "Microplastics in drinking water" encourages extensive research to assess their hazardous effects [6]. There is evidence of the presence of microplastics in the human placenta and that prenatal exposure to microplastics affected the early development of neonates [7].

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Even excessive use of face masks, Personal Protective Equipment kits (PPE kits) made up of plastics during the pandemic times (Covid-19) created a huge amount of wastage of microfibres (as microplastics) that is detrimental to our environment[8]. Research into the extent and consequences of microplastics in the environment is significant in light of growing shreds of evidence confirming the seriousness of this issue. Therefore, there is a great need to address microplastics induced toxicity that is both inevitable and essential. Moreover, the toxicological problem with these microplastics is their non-biodegradable materials, which then get washed down the drain and end up accumulating in water bodies via the natural phenomenon of biomagnification and bio-accumulation [9].

The increasing attention of research on microplastics is attributable to their longevity, which enables long-distance distribution from their source and consequent accumulation in water bodies [10]. In India, the presence of microplastics has also been reported in different lakes of India [11,12]. Microplastics have been accumulated by aquatic animals and can also transfer from one species to another species by the process of biotransformation and bioaccumulation. In a study, microplastics can be accumulated from algae (Scenedesmus sp.) to zooplankton (Daphnia magna) to goldfish (Carassius carassius), with noticeable effects on the feeding behaviour of (C.carassius) exposed to microplastics [13]. This study shows the ‘natural’ trophic transfer of microplastic and its translocation to the hemolymph and tissues of a carp. Globally, these aquatic animals are consumed by human beings as a source of proteins and concentrated in the food chain through a process called biomagnification, subsequently contaminating the fish and wildlife species that human beings can be consumed by which microplastics can enter into the cell through the cell membrane disrupting the cell organelles.

Microplastics can also act as a vector for many contaminants such as BPA, PCB, and heavy metals, which is detrimental to both terrestrial and aquatic habitats. The sorption rate of these pollutants on plastic debris can vary among polymers: shape, crystallinity, surface functional groups and ageing of particles affect the sorption capacity of pollutants [14,15]. For example, polyethylene pellets have a higher affinity for polychlorinated biphenyls (PCB) than propylene. The higher affinity of polyethylene is the result of the larger volume of the inertial cavities, which allows the diffusion of compounds into the polymer [16]. Espinosa et al. investigated the in vitro effects of microplastics polyvinylchloride (PVC) and polyethylene (PE) on glilhead seabream (Sparus aurata) and European sea bass (Dicentrarchus labrax), resulting continued exposure of fish to PVC or PE microplastics could impair fish immune parameters in the fish leucocytes [17]. Yang et al. investigated poly styrene microplastics in mice systems based on toxicity-based modelling to quantify organ-bioaccumulation and biomarker responses for mice and establish a TBTK/TD framework for mechanistically assessing potential from mice size-specific MPs exposure that would offer a tool-kit for health risk assessment perspective [18]. Reviewing the literature, it becomes evident that the present state of information on microplastic exposure and its various toxicological effects shows lacunae in scientific knowledge of microplastic-induced toxicity in animals and human beings.

2. Types and Sources of Microplastics

Microplastics are divided into two types: primary and secondary microplastics. Primary microplastic is synthetic microbeads developed for domestic and industrial purposes. These microbeads are used as raw materials in the plastic industry for the production of cosmetics, detergents, and other hygiene and personal care products. These primary microplastic particles that get released into rivers from water treatment plants will subsequently enter into the sea on a global scale and are mostly unknown, thus critical for evaluating the acute and chronic effects of microplastics [19].

About 93% of the microbeads used in personal care products and cosmetics contain microplastics such as polyethylene (PE), polypropylene (PP), polymethyl methacrylate (PMMA), polyethylene terephthalate (PET), and nylon [20]. These microbeads can eventually transport to wastewater treatment plants that enter the oxidation ponds and sewage sludge. These microplastic particles may pass through filtration systems and sink into the water bodies and affect aquatic habitats [14,21].

Secondary microplastics are plastic particles derived from macro-plastics fragmentation through photo-degradation, mechanical abrasions, and physical and biochemical reactions. It includes fishing nets, industrial resin pellets, domestic items, and other discarded plastic debris [22,23,24]. Other sources of microplastics include effluent treatment plants, landfills, irrigation, industrial wastewater, and domestic usage [25,26,27]. According to Geyer et al. yearly plastic production has tremendously increased in international markets from 2 million tons to 381 million tons in 2015, 42% of which were used as single-use packaging [28]. It was estimated that the excessive use of plastic could increase its waste to 155-265 million tons per year by 2060 [29].

Most of the research on microplastics has been focussed on marine waterbodies, less than 4% of microplastic related studies have been reportedly associated with freshwater [30]. This shows the scarcity of research and information but
also reveals the abundance of microplastics in freshwater and its dispersion in freshwater is extremely heterogeneous [31]. Microplastics can accumulate over time in the sediments of different water bodies [32]. Microplastics are considered an emerging global problem but only (22.9%) of countries have engaged in microplastic research. This creates a lacuna of information on microplastics abundance and distribution on a global scale.

3. Physical Characteristics of Microplastics: Shape, Size and Colour

Microplastics in the environment appear in a wide range of shapes and sizes in the form of spheres, beads, pellets, foam, fibres, fragments, films, and flakes. The shape of microplastic particles depends on their actual form and the degradation and erosion processes of these plastic particle surfaces with time in the environment. These shapes of microplastics are used to infer their origin and pathway because certain shapes may be more prolifically shed from particular products. Besides, the texture of particles indicates that mechanical abrasion and chemical weathering might play a key role in the degradation of microplastics in the environment [33]. For example, Microfibres used to make synthetic clothes could get fragmented from the exposure of larger plastic items to UV light [34]. Particle size and shape are the important aspects that can help to determine the interaction of pollutants with biota and its environmental providence [35]. The influence of shape and size on atmospheric transport is currently unknown and it requires further research. Specific shapes or sizes of microplastics may have a higher potential to cause physical harm to organisms, with smaller angular particles passing membrane barriers more easily than particles presenting regular surfaces or longer edges. Exposure to microplastics induced significant size-dependent effects, such as reduced growth rate, reduced life span and increase in reproduction time. These findings suggested that microbead toxicity was size-dependent and the smaller the size of the microbeads more it is toxic to the organisms. Antioxidant-related enzymes and mitogen-activated protein kinase (MAPK) signalling pathways were activated in response to microplastics exposure in a size-dependent manner, thus indicating serious kinds of shocks to organisms at the cellular level.

The colour of microplastic particles helps to categorize the potential sources of plastic fragments and potential pollutants during sample preparation. In previous studies, microplastics have been reported in different colours, including red, orange, yellow, brown, tan, off-white, white, grey, blue, green, and so on [33,36]. In a study, Xiong et al. investigated the effect of size, colour, and shape of microplastic particles on goldfish (Carassius auratus). The result suggested that microplastic particles with food-like colours could be ingested more than microplastics with other colours by goldfish [37]. Recently, Pegado et al. studied the ingestion of microplastics (MPs) by Longnose stingrays in the Western Atlantic Ocean and found fibres were the most frequent item (82%), blue was the most frequent colour (47%), and Polyethylene Terephthalate (PET) was the most frequent polymer recorded (35%), as identified by 2D imaging - Fourier Transform Infrared (FTIR) [38]. These diverse types of microplastics in the environment, which differ in shape, colour, and size, have different likelihoods of ingestion by aquatic animals indicating the growing problem of microplastics pollution.

4. Distribution of Microplastics in Different Medium of the Environment

4.1. Microplastics in Water

Water is a key source for our living on earth. It is the foremost part of the biosphere. We know that 75% of our whole earth is filled with water, and it is our responsibility to save our water bodies and aquatic lives from the risk of global warming. In the last few years, different studies have reported an increase in the number of killings of marine animals (birds, turtles, mammals) due to plastic ingestion and strangling by abandoned (ghost) fishing nets. Fossi et al. reported the presence of organochlorine compounds in fin whales suggesting that MPs might have potential effects on them [39]. Nevertheless, the mechanism of microplastic metabolism and its effect on aquatic organisms need to be explored.

The distribution of microplastic particles was also reported in freshwater bodies. The possible sources of the accumulation of microplastics in the freshwater ecosystem are wastewater plants [40], which can potentially transfer the polluted microplastics from seawater to the river and descent into lakes. In a study, Luo et al. suggested that the microplastic pollution of small freshwater bodies is more serious than estuarine and coastal waterbodies [41]. Meanwhile, the properties of microplastics can be quite heterogeneous. The order in globally detected polymers is polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinylchloride (PVC), polyethylene terephthalate (PET), which probably reflects the global plastic demand and a higher tendency for PVC and PET to settle as a result of their higher densities [42].

Microplastic accumulated in water bodies can also act as a vector for contaminants such as polycyclic aromatic hydrocarbons (PAH), heavy metals, and antibiotics [43]. Wang et al. investigated the effects of exposure of polyethylene
microplastics to air, water and soil on their adsorption behaviours for copper and tetracycline [44]. Ašmonaitė et al. compared the polystyrene (PS) and polyethylene (PE) to act as vectors for hydrophobic organic chemicals (HOCs) in fish Three-spined stickleback (*Gasterosteus aculeatus*) after ingestion and found polystyrene (PS) and polyethylene (PE) microplastics mediated higher chemical transfer and accumulation of model HOCs [45]. Present studies show that microplastics can serve as a vector for other contaminants. However, more research is needed to achieve an indistinct understanding of the underlying factors influencing the sorption capacity and bioaccumulation behaviours. Progressive research coupled with management could determine the future production, consumption, and leakage of microplastics into the environment.

### 4.2. Microplastics in Air

Airborne microplastic pollution represents the newly emerging threat which creates a great emergency to deal with it. These microplastics can originate from different sources, such as synthetic materials washed off clothes during laundry cycles, such as polyester and polypropylene, abrasions to vehicle tires on the road that cause tiny tire shreds to fly off, erosion of everyday plastic or synthetic objects, like the soles of shoes and cooking utensils, runoff from plastic components used to develop and mark roads, coatings used on marine equipment and infrastructure, such as container ships, the plastic microbeads used in personal care products, such as plastic microdermabrasion beads in face wash. According to National Oceanic and Atmospheric Administration NOAA study, microplastics get generated as a by-product of sewage treatment, which sinks into the ocean where microplastics then evaporate into the atmosphere in huge volumes [46]. Cai et al. investigated the characteristic of microplastics in the atmospheric fallout from Dongguan city, China and found dust particles emission and deposition between the atmosphere, land surface, and aquatic environment were associated with the transportation of microplastics [47]. Dris et al. found a concentration of microfibres (synthetic plastic) ranging from 190 to 670 fibres/mg in domestic dust [48]. Catarino et al. estimated microfibre exposure from dust fallout of 13,731–68,415 airborne particles/year/capita in a household [49]. Gaston et al. investigated airborne microplastics inside and outside of buildings in coastal California by filtering known volumes of air through glass fibre filters, suggesting polyvinyl chloride dominates indoor air, followed by polyethylene (PE) and polyethylene terephthalate PET [50]. The ubiquity of airborne microplastic points to significant new potential sources of plastic inputs to terrestrial and marine ecosystems and raises concerns about inhalation exposure of microplastic particles to human beings both indoors and outdoors.

### 4.3. Microplastics in Soil

Agricultural soils are particularly prone to exposure to microplastic, as several pathways for plastic addition and incorporation exist in agroecosystems. Intensive farming and less organic matter in the soil can lead to declining soil health and structure. On the other hand, contamination of microplastics in the soil can create more stress on the agroecosystem [51]. Plastic mulching is extensively used in agricultural fields to increase yields, fruit quality and water-use efficiency. However, potentially promote soil degradation and soil water repellency. [52,53]. Many countries have been facing the problem of microplastics in agronomies such as, Europe, China, Bangladesh, Australia, Mexico, India, and Switzerland (54,55,56,57). Recent research has identified the risk of biomagnification of microplastics from terrestrial agriculture to the human food chain [58,59]. Thus, microplastics are considered an imminent hazard to food safety and sustainable agriculture.

Microplastics have specific morphology and properties rendering to their polymer types (e.g., flexibility, roughness, resistance, and durability) [60]. For example, polyurethane, a polymer used to produce flexible foams, has the potential for soil biology as millions of tons of this plastic are produced annually, potentially increasing its concentration in the soil [61]. Other microplastic shapes, such as foams or fragments, can be incorporated into the soil due to littering, street runoff, or wind deposition [62]. Lazano et al. have reported that microplastic particles can affect plant traits and soil physical and biological properties depending on their polymer types and shapes [63]. Microplastics can also interrupt the natural carbon cycle by influencing soil microbial processes, plant growth, or litter decomposition [64]. Therefore, more research is needed to understand the ubiquitous effects of microplastics on the functioning agricultural and terrestrial ecosystems.

### 5. Toxicological Implications of Microplastics on Human-beings

Microplastics have been observed in many food substances like salt, branded milk, fish and other seafood, and tea from teabags [65]. One of the most prevalent microplastic entry points into the human body system is the ingestion of microplastics contaminated food [66]. Seafood is a nutrition-rich source for human beings. Microplastics potentially get transferred from seafood to human beings by biomagnification, which poses a greater risk to human health. Danopoulos et al. reported microplastic contamination in seafood (*Mollusks, crustaceans, fish and Echinodermata*) for
Human consumption and estimated the annual human microplastic uptake to be close to 55,000 microplastic particles [67].

In a study, Prata et al. reported that exposure to microplastic particles through ingestion, inhalation and dermal contact cause particle toxicity. The failure of the immune system to remove these particles can lead to chronic inflammation and an increased risk of neoplasia [68]. Ranjan et al. reported that three coffees in disposable paper cups are enough to make us ingest about 75 thousand microplastic particles. The commonly used paper cups have a thin layer of plastic which, in contact with the hot liquid, researchers observed about 25,000 micron-sized microplastic particles [69]. The daily use of plastic feeding bottles and plastic water bottles is the potential release of microplastics (MPs), which threaten the health of infants and children. Recent studies suggested that exposure to microplastics is detrimental to early child development. It can cause male infertility, making them a potential hazard to reproductive success [70,71].

### Figure 1
Bioaccumulation, Biotransformation and Biomagnification of Microplastics

6. Microplastic distribution in India

India has a long coastline of 7,517 km, contributing to ecological wealth, biodiversity and economy. In India, thousands of tons of garbage composed of plastics, glass, metals, and fibres can reach the oceans, and plastic litter contribute a large portion (~60%) every year. In India, the distribution of microplastics has been reported by many researchers. In 2016, microplastics found in the sediments of Vembanad Lake, a Ramsar site in India [72]. Similarly, Veerasingam et al. examined the distribution, abundance, weathering and chemical characteristics of microplastics on the beaches of Goa and their transportation to the coast during the southwest monsoon [73]. Gopinatha et al. has been quantified microplastic in Red Hills Lake of Chennai city, Tamil Nadu and found high-density polyethylene, low-density polyethylene, polypropylene, and polystyrene [74]. Narmadha et al. examined the presence, quantification and identification of microplastics in the ambient air from urban and rural sites of Nagpur and identified the polymers of polyethylene, rayon, rubber fibres, polystyrene, polyaniline, polyolefin, and chlorinated polyvinyl chloride [75]. Similarly, Bharath et al. have examined the quality and quantity of microplastic contaminants in water and soil samples at Veeranam lake in Tamil Nadu, India. They found that collected water and sediment samples deposited with polymer-type of plastic particles were nylon (39%), polyethylene (23%), polystyrene (19%), polypropylene (15%), and polyvinyl chloride (4%) (Bharath et al., 2021). The present state shows a scenario of microplastics is susceptible and microplastics are an emerging problem for waterbodies in India.

In 2021, Selvam et al. evaluated heavy metals (cadmium, manganese, lead, arsenic and copper) adsorption capacities of different microplastic polymers (Polyamide, polyester, polypropylene, polyethylene, polyvinyl chloride and cellulose) in groundwater and surface water from coastal south India [76]. This study indicates that future research strategies to be made to reduce the environmental risks of particulate plastics as a potent vector for transportation of toxic trace elements and the subsequent impact on human health through the OSPRC framework (Origins, Sources, Pathways, Receptors and Consequence). Additionally, microplastics having found in riverine like the Indus, Brahmaputra, Ganga,
the coast of Kanyakumari, and the different regions of the Himalayas [77,78,79,80]. Thus, the present literature has shown evidence of the wide distribution of microplastics in different regions of India.

7. Scenario of Microplastic Disposal During COVID-19 Pandemic

World Health Organization (WHO) declared COVID-19 as a pandemic in 2020. Corona Virus 2019 as COVID-19 is a virus that causes pneumonia in people with the severe acute respiratory syndrome (SARS) (SARS-CoV-2). The virus gets transmitted through direct contact with respiratory droplets of an infected person (generated through coughing and sneezing) and touching surfaces contaminated with the virus. COVID-19 virus causes an inflammatory response in an infected person that induces severe damage to alveolar cells, culminating in substantial fluid accumulation [34]. As a result, numerous steps have been implemented around the world to prevent the virus from spreading further.

The most effective preventive approach is lockdown (staying at home), travel limitation, and isolation. However, countries are concerned that the global economy will weaken and a catastrophe would erupt. As a result, the people and governments of various countries were forced to lift the lockdown and pursue other possibilities. They use disposable face masks and implement social distancing, sanitation, proper personal hygiene (hand washing), and avoiding social gatherings [81].

Before COVID-19, disposable face masks were used by healthcare professionals and researchers, who are skilled to use and disposing of them to prevent occupational hazards. But, with the global spread of the COVID-19 wearing face masks has become the new normal for every human being. COVID-19 acts as a catalyst for already existing issues with microplastics. The surge in the production and usage of face masks across the globe has intensified a new environmental challenge, plastic particle waste in the environment. Developed countries have been extensively using face masks since the emergence of COVID-19 worldwide, and developing countries are using them in mass. Due to improper disposal, these face masks eventually pass through the waterways from where they can reach the freshwater and marine environment, adding to plastics in the aquatic medium [82,83].

For instance, plastic packaging materials, drinking bottles, and fast-food containers are leading sources of microplastic pollution globally. Similarly, disposable face masks (single use) that get to the environment (disposal in landfill, dumpsites, freshwater, oceans or littering at public spaces) could be an emerging new source of microplastic fibres, as they can get fragmented into small particles under environmental conditions. The other implication of these extensively disposed face masks in the environment is the possibility of acting as a medium for disease outbreaks, as plastic debris is known to proliferate microbes such as invasive pathogens [84,85].

COVID-19 acts as a catalyst for already existing issues with microplastics. In a study, Abbasi et al. reported that the extensive use of face masks during the COVID-19 pandemic causes microplastic pollution and potential health concerns in the Arabian Peninsula, contributing to up to 32-235 thousand tons of microplastics [86]. In 2021, Ardusso et al. reported COVID-19 pandemic repercussions on plastic and antiviral polymeric textile causes pollution on beaches and coasts of South America [87]. Akhbarizadeh et al. also assessed the presence of PPE wastes and their microplastics along the coastline of Bushehr port, the Persian Gulf [88].

De-la-Torre et al. reported the occurrence and distribution of COVID-19-associated PPE along the coast of the overpopulated city of Lima, Peru and suggested that the inappropriate disposal, landfilling, and incineration of PPE plastic wastes will reach the marine environment is exacerbating pollution in the aquatic ecosystems.[89].

In another, Gallo Neto et al. reported the presence of an adult-size PFF-2 protective mask within the stomach of the Magellanic penguin (Spheniscus magellanicus) on Juquehy Beach, Brazil [90]. Therefore, the awareness of Covid-19 prevention is intense across the globe and will indeed be admirable if the consciousness on the protection of our environment through reduction and elimination (where possible) but, the proper management of disposable face masks should be carried along. Otherwise, microplastic pollution may be the next world pandemic.

India is the second-most populated country after China and the second worst-hit nation by the coronavirus disease 2019 (COVID-19) after the United States of America (As of November 9, 2020). Due to the improper biomedical waste management system and lack of resources, India faces severe consequences during COVID-19. Untreated and improperly managed biomedical waste material is a potential source of microplastic pollution. According to the Central Pollution Control Board’s annual report [91], India creates roughly 9.4 million tonnes of plastic garbage per year, of which 5.6 million tonnes are recycled and 3.8 million tonnes are left uncollected/littered (9400 tonnes of waste/day) in the land [92]. Developing countries such as India are already dealing with waste management concerns [93], and the garbage generated by the COVID-19 pandemic phase has exacerbated the situation. With hospitals, quarantine wards,
health care or medical institutions, and other departments in India producing roughly 517 tonnes of biomedical waste per day [94] hospitals are predicted to generate nearly six times more biomedical waste during the COVID-19 pandemic.

![Figure 2 Average monthly generated COVID-19 biomedical waste (BMW) in India](image)

Figure 2 Average monthly generated COVID-19 biomedical waste (BMW) in India

(Source: Central Pollution Control Board Report (CPCB), 2020-2021)

India has become the second-largest producer of PPE Kits. Before the Coronavirus pandemic, India used to import the majority of PPE kits from outside but the viral outbreak coupled with demand for PPE kits pushed the country to manufacture indigenously. With the ramped-up production of PPE kits, India has become a producer of PPE kits and become the second largest producer of PPE Kits globally, with a daily production of more than 5 lakh PPE kits [95].

Nevertheless, it also increases the burden of plastics on the environment. Every day 25 lakhs PPEs are required to fight against COVID-19 [96]. For instance, the demand for plastics is increasing by 40% in packaging and 17% in other applications, including medical uses. For example, masks, sanitizer bottles, personal protective equipment, food packaging, and water bottles. Life came to be concealed in a plastic shell. Safety concerns related to shopping in supermarkets during COVID-19 led to a preference of consumers and providers for fresh food packaged in plastic containers (to avoid food contamination and to extend shelf-life) and the use of disposable food packaging and plastic bags to carry groceries. Also, the consumables used for the coronavirus testing kits that are made up of plastics, give rise to plastic waste generation. Researchers have considered single-use plastic as a hidden pandemic. The pandemic halted and, in some cases, reversed much of the microplastic remediation progress [97].

The issue of plastic pollution and microplastic generation continues to compound as the COVID-19 pandemic drives global demand for disposable, safe solutions. E-commerce sales have a projected growth rate of more than 20% in 2020 because economic shutdowns and home quarantine orders have created additional plastic waste with packaging. In a report, Plastic packaging shipped with the 7 billion packages delivered in 2019 generated 465 million pounds of waste. As a result, 22.4 million pounds of that plastic packaging ended up in waterways and marine ecosystems [98,99].

8. Major Challenges and Future Directions

The goal to minimize the impact of plastic debris leakage into the environment has become a global challenge. Industries play an important role in environmental contamination. It releases chemicals and additives into the environment. Industries can also indirectly generate secondary microplastics and can use primary microplastics for their manufacturing processes is decisive. Additionally, seafood constitutes one of the important sources of protein worldwide, [100]. Trophic transfer of microplastics that are swallowed by seafood (Bivalves, molluscs, crustaceans, fishes) is a potential pathway for microplastics to enter a living ecosystem. Further research on microplastic bioaccumulation, biotransformation and biomagnification can bridge the gaps in scientific knowledge and help to understand the underlying mechanisms and molecular targets of microplastic toxicity which will certainly contribute to the global efforts to combat microplastics induced toxicity. There is also scarce research which can demonstrate human health risks and considerate exposure, dose-dependent relationship, mechanism of toxicity, and interaction with other pollutants. Also, there are limited possibilities of risk assessment of microplastics inducing toxicity. There is also a lack of information about microplastic accumulation in the organs or tissues.
Additionally, stakeholders and policymakers have to reform the policies, plans, and guidelines as a significant and practical way of solving problems of escalating plastic waste management to control the environmental transmission of the COVID-19 Pandemic [101]. If plastic emissions into the environment continue at current rates, there may be widespread risks associated with microplastics to aquatic ecosystems within a century [102], with potentially concurrent increases in human exposure.

In response to concerns about the impact of plastic and microplastic pollution, public engagement and political commitment have increased. More than 60 countries are already taxing or banning single-use plastics, primarily plastic bags [103]. Nevertheless, we should also take microplastics as a serious issue of man-made environmental change. Plastic pollution is a visible example of how humans and the environment interact and unveils our relationship with the environment. What kind of environment do we want, and how do we want to live? We need to explore the intersections between global risks, power relations, and societal relations with the environment if we want to bring sustainable transformation.

9. Conclusion

Microplastics have adversely affected the environment by contaminating air, soil and water. Our existing knowledge is limited regarding the source, exposure, toxicity, and bioavailability, of microplastics in the environment. Therefore, more investigation is needed to understand its potential source and pathway of bioaccumulation and elimination. Experimental research and observations can consciously measure the variations and responses of microplastics in the environment. Combating microplastic contamination will be achieved through an intensive and combined effort of all, including stakeholders, researchers, educators, media and policymakers. We can join the effort to manage plastic in the environment by refusing, reducing, reusing and recycling plastic, in that order, to prolong every item’s life cycle as far as possible. A start would be a focus on limiting the use of single-use plastic products with a short lifetime, especially if alternatives are readily available.

Compliance with ethical standards

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