Plastic Pollution

Subjects: Environmental Sciences

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Plastic is a word that initially meant “material that can be easily shaped, formed, molded by providing heat and pressure”. It only recently became a name for a category of materials called synthetic polymers. The polymer means “of many parts” and is a long chain of repeating smaller or larger molecules (monomers) bonded in subunits. Generally, natural polymers and synthetic polymers are used for making plastics. Synthetic polymers differ from natural polymers (such as silk, cellulose, muscle fiber, rubber, hair, and DNA). They are manufactured using raw materials such as oil, coal, and natural gas. There are two other types of plastics that do not fall into the above category of materials (natural or synthetic) and are known as biodegradable plastics and bioplastic materials. Biodegradable plastic is made from petroleum- or biomass-based resources. Bioplastic products are manufactured using biomass-based materials only. Both plastic materials are substitutes for synthetic plastic.

Keywords: microplastic ; nanoplastic ; single-use plastic ; online food delivery service

1. Micro and Nano-Plastic Particles

Plastic debris can be of different sizes, shapes, colors, and densities, and all plastic debris play a vital role in its degradation and bioavailability. Micro- (MPs) and nano-plastic particles (NPs) have emerged as a global problem due to a worldwide rise in the plastic pollution rate, adversely affecting the overall environment and biota on the Earth. MPs and NPs are solid and insoluble plastic particles [1][2]. Plastic particles are classified based on their particle size: (1) 5 mm–1 mm as large MPs, (2) 1 mm–1 μm as tiny MPs, and (3) <1 μm as NPs. MPs have different sizes and shapes (fiber, microbead, film foam pellet, fragment, and filament) [3][4].

In addition, MPs can be divided into two types based on their sources of origin: (1) primary and (2) secondary particles [5]. While the primary MPs are manufactured intentionally by industries for commercial purposes, secondary MPs occur due to weathering and degradation of large plastic residues in open field conditions due to several climate actions such as solar exposure, waves, mechanical shear, thermal oxidation, and others [6]. Studies have reported that the continuous degradation of primary and secondary plastic particles could cause significant variations and alterations in their physical properties, such as their shape and color, morphology of the surface, crystallinity, size, and density. These variations and changes might impact their chemical and physical properties and other life forms in nature [7][8]. MPs have been found in several areas in nature, from soil, water, air, marine organisms, salt, beer, and others. Recently, some studies have reported their presence in plastic bottles used for drinking water [9][10]. Wright and Kelly [11] said that MPs, upon exposure to open fields, can accumulate and be transported into different body parts of living bodies, such as human and animal tissues. After entering living bodies, the MPs can alter the immune system or cause several clinical disorders and complications. Additionally, the breaking up of MPs into different smaller sizes, shapes, and components—or the development of nanotechnologies, which involves the engineering of nano- or micron-sized polymeric materials—can lead to the formation of even more challenges in the future.

Studies have reported that a large amount of attention was only being given to MP pollution in the environment; however, several researchers have recently begun to consider the fragmentation of plastic particles down to a tiny scale, below 1 μm; these are known as NPs [12]. NPs are generated during the fragmentation and weathering of MP debris. They can also originate from engineered materials manufactured in industries. Exposure of MP plastic debris to solar radiation catalyzes the rate of the photo-oxidation process and makes them more brittle. However, the abrasion process and wave action can further degrade the larger plastic fragmentations into micro-size and nano-size particles [13][14]. Gigault et al. [15] noted that converting MPs into NPs largely depends on the buoyancy and sedimentation of the plastic waste. The attributes linked to NP formation showed that they have colloidal behavior in nature. This colloidal behavior is attributed to and regulates contaminants, chemical partitioning, and sorption mechanisms to control their environmental fate and toxicological chemistry. NPs have large surface-to-volume ratios compared to MPs, making them more prone to adsorption, diffusion across air, soil, and water plumes, and being taken up by microorganisms, wildlife, and plants. Thus, they can pose a significant threat to human health by entering their bodies via the human food supply chain [16][17].

Ng et al. [18] reported that MP and NP particles are tiny. Therefore, it is possible that many organisms can ingest them quickly. However, our understanding of their ecological impact on the terrestrial environment is limited, and we must develop a greater understanding of any potentially harmful or adverse impacts of MPs and NPs on our agroecosystems and surrounding environments.

2. Plastic Use and Waste Generation in Our Ecosystem

The conception of plastic, its subsequent and continued growth, and mass production have resulted in the current throw-away culture (use and dispose of as waste). However, when plastic was initially introduced, it was thought that its imperviousness to moisture and its extreme versatility made it a dream material for many industries. These attributes made plastic an advantageous material. At the same time, it also negatively impacts the Earth's ecosystem. Currently, plastic products dominate packaging, construction, transportation, electrical and electronic equipment, agriculture, household items, sports goods, and medical supplies and equipment [19][20]. Sbarberi et al. [21] reported that for these reasons, the demand for plastic follows a positive trend worldwide; its usage is increasing, and its global production reached 391 Mt in 2021. However, in 2017, its global production was 348 Mt compared to 1.5 Mt in 1950 [20][22]. The recent data on global plastic production provided by Statista [23] reported that in 2023, the global plastic market was valued at USD 712 billion. The global plastic production market is projected to grow in the coming years to reach a value of more than USD 1050 billion by 2033.

The plastic's properties (chemical and physical) make it a material that is challenging to dispose of or degrade in the natural environment. Some plastic types may take thousands—even tens of thousands—of years to degrade in landfills under natural conditions. Degraded plastic pollution is an even bigger environmental issue, as plastic particles break into microscopic particles and pollute our ecosystems (see **Figure 1**). Plastic pollution can also significantly alter habitats and natural processes. It can reduce the ecosystem's ability to adapt to climate change, affecting millions of people's livelihoods and food production capabilities.

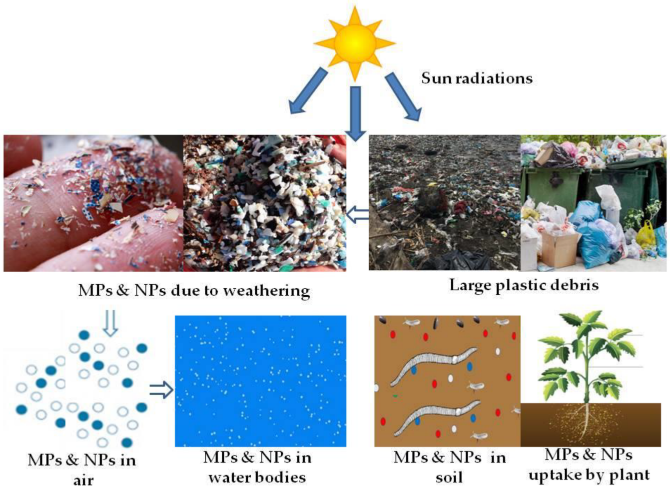

Figure 1. How plastic waste enters the ecosystem.

Plastic use will continue to increase at a faster rate and could lead to a 50% increase in plastic debris leakage into our ecosystem by 2040 (30 Mt per year). The current trends of population growth and higher incomes could lead to a 70% increase in annual plastic use and waste generation in 2040 compared to 2020. The above prediction is based on the current scenarios, such as production rate, low recycling rate, and lack of plastic degradation, which have created sizeable problems, and plastic pollution is accumulating significantly at alarming rates in our ecosystems [24]. The current sheer magnitude of our society's use and consumption of plastic products results in a significant carbon footprint associated with plastic manufacturing, a lot of garbage being produced, ongoing pollution, and harm to ecosystems and species. Several research studies have predicted that accumulated plastic leakage and waste in our ecosystem could increase in the coming years, exacerbating climate change and health impacts on living bodies. Greenhouse gas emissions (GHG) from the plastic lifecycle are projected to more than double to 4.3 Gt CO_2e. However, its adverse impacts on other lifecycle or environmental parameters, such as ozone formation and degradation, acidification, and human toxicity, will double in the coming years [24]. The United Nations [25] estimated that by 2050, greenhouse gas emissions from the manufacturing, use, and disposal of plastics will contribute 15% of the total allowable emissions, which will help keep global warming at the 1.5 °C (34.7 °F) set by the Paris Climate Agreement. Furthermore, plastic pollution is anticipated to threaten over 800 marine and coastal species via entanglement, ingestion, and other dangers.

Now, the world must act to find sustainable substitutes to tackle plastic pollution, protect our ecosystem, and fight climate change. Plastics have significantly impacted our daily lives, including technology, medicine and treatments, and domestic appliances, and their wastes are generated during both production processes in the industry and after the product reaches its end. There are many possibilities where waste may be generated during any of these steps, and the waste generated during this stage is called pre-consumer or production waste. Plastic waste is also generated when the consumer uses a plastic-containing product. This waste is called post-consumer or end-of-life waste. Pre-consumer waste is generally easier to recycle than post-consumer waste as it is less contaminated and mixed with other materials.

3. Single-Use Plastic Pollution through Online Food Delivery (OFD) and a Strategy to Reduce Its Usage

OFD apps have put food a click away and are preferred as they save the hassle associated with cooking. The OFD industry has opened up new opportunities for restaurant owners and consumers by having food delivered to their homes without meeting physically (see **Figure 2** [26]). On the other hand, its popularity can increase the risk of enormous plastic waste generation because each order often comes with at least 3–4 disposable plastic containers. These plastic consumption habits result in 500 billion single-use plastic (SUP) cups ending up in landfills annually [27]. According to Vasarhelyi [28], one million SUP plastic bottles or cups are bought every minute, and up to five trillion plastic bags are used globally annually.

Figure 2. Online food delivery value chain (from placing an order to the final disposal).

In addition, the COVID-19 pandemic promoted an unprecedented change in consumption habits that involved using SUP products. The COVID-19 pandemic boosted worldwide demand for OFD [29][30]. Beyrouthy [31] reported that grocery and meal delivery segments of the OFD industry earned revenues that were more than double those of pre-pandemic levels. Hu et al. [32] reported that in Japan, the OFD industry increased by 25% from 2016 to 2020, and it is set to increase by a further 17% from 2021 to 2025. South Korea's OFD industry sales have grown by an average of 85% over the past four years, achieving USD 14.3 billion in sales in 2020 [33]. Bush [34] stated that in 2019, Canadians spent CAD 4.7 billion on online food orders, and is estimated will be worth over CAD 98 billion by 2027. Lin et al. [35] reported that during the COVID-19 pandemic, the OFD industry in China experienced 20% annual growth, leading to revenue growth from USD 3.2 billion in 2015 to USD 51.5 billion in 2020. Nowadays, China has the world's most prominent takeaway food market, and its scale is more than a quarter of China's catering industry [36]. However the OFD industries in Bangkok [37], Pakistan [38], Brazil [39], India [40], Indonesia [41], New Zealand [42], South Africa [43], Saudi Arabia, the United Arab Emirates, Bahrain, Kuwait, Qatar [44], Bangladesh [45], Vietnam [46], Turkey, Spain [47], and Russia [48] saw significant popularity during the COVID-19 period. Additionally, these figures indicate a substantial potential for future growth in the OFD industry. However, this fast-growing trend does not show that although the sector is improving, its effects on society, agriculture, and climate are not very optimistic. This behavior will significantly increase the burden on waste disposal, generating significant waste that litters cities, chokes rivers, causes soil pollution, and threatens wildlife [42].

The OFD industry has witnessed massive growth in the last few years, and ordering a meal is a convenient option but its impacts on our ecosystem are unsuitable. Janairo [49] and Sha [50] reported that OFD services are a significant burden against the United Nation's developed sustainable goals that address good health, climate action, decent work, and economic growth. This study further stated that high volumes of OFD consumption exacerbate plastic waste and increase the contamination of natural environments such as oceans, freshwater systems, and terrestrial areas. A study [51] on the environmental impacts of takeout food containers revealed that SUP products are the worst packaging material for takeout food, with many adverse effects on the environment. Plastic containers made from polypropylene and polystyrene foam accounted for approximately 75% of the total food delivery packaging waste by weight [52]. Additionally, each OFD order generated an equivalent of 111.80 g of CO_2 emission on average. Most (86%) of the CO_2 equivalent of the express food delivery came from the SUP food packages [53]. However, the UN environment program report [54] mentioned that approximately 36% of all SUPs produced are used for packaging food and beverages. The GHG emissions associated with making, using, and disposing of conventional fossil fuel-based plastics are forecast to grow by 19% of the global carbon budget by 2040.

Their significant usage and disposal have become a global concern, and the over-utilization has pushed governments to implement a mix of policy measures or ban single-use plastic products. However, after being used, the items are disposed of in waste dumping sites and landfills, where they may end up in rivers, oceans, soil, and the atmosphere [55][56][57][58][59].

SUPs have created many environmental issues, and there are also various upstream consequences of a consumption-oriented society that will not be removed even if plastic waste is significantly decreased [60][61][62]. The Competitive Enterprise Institute [63] reported that studies have shown that the vast majority of plastic waste is due to poor global disposal practices. Therefore, to some extent, disposable plastic can be removed from the environment through proper recovery and recycling. Putting plastic trash in its correct context is the first step toward better scientific communication about its environmental impact. Furthermore, to assist the public in making linkages between product consumption, energy use, and upstream environmental implications, scientific communication needs to go beyond the “Reduce, Reuse, and Recycle” mantra [64].

Martin [65] stated that both governments and consumer bodies should put pressure on manufacturing industries to adopt sustainable manufacturing practices to reduce emission levels as fossil fuels are depleted and global warming increases. Customers can also do their part by refusing SUP packaging and opting for reusable alternatives whenever possible. Kochańska et al. [66] stated that bioplastics could be the best alternative material for packing takeaway food. Bioplastics can be produced using food waste, a significant stimulus for transformations in producing petroleum-derived plastics [67].

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