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Meththika Vithanage and Majeti Narasimha Vara Prasad

Microplastics in the Ecosphere

Air, Water, Soil, and Food

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Edited by

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Preface

Microplastics (MPs) are emerging global contaminants, and the scientific community is becoming increasingly interested in this topic. This book discusses recent developments in multidisciplinary research on MPs, including their distribution in the soil, hydrosphere, and aerosphere, as well as their sources, fates, distribution, toxicity, and management. Particularly during the SARS-CoV-2 pandemic, there has been tremendous production and consumption of single-use MPs. But although most MPs are produced on land, they are eventually deposited in the marine environment. This book reviews the state of single-use plastics and MPs in the atmosphere, the ocean, soil systems, and the food chain and food web along with treatment technologies and management.

The sampling, processing, and analytical procedures employed to date to identify MPs are complex. Leaching MPs from landfills and industrial wastewater, vector transport of pollutants, and MPs found on beaches and in marine settings are all evaluated in the hydrosphere. Additionally, MPs in sewage sludge, soils fertilized with sludge, and soils irrigated with wastewater are explored, as well as any potential consequences for plants and human health. Important management strategies are also covered, including suggestions for useful information for policymakers, non-experts, environmental researchers, ecologists, and toxicologists. The interplay of MPs at the macro and molecular levels with the human, animal, and environmental domains is highlighted (Figure 1). As MPs enter or accumulate in the food chain or participate in the food web, their fate in the ecosystem is crucial. It is well-recognized that MPs have a significant capacity for adsorbing a wide range of pollutants, particularly organic toxins. Therefore, it is anticipated that all of the findings will contribute to the establishment of necessary environmental laws and policies as well as pinpoint knowledge gaps regarding MP pollution and contamination.

MPs in the environment originate from a variety of sources and are distributed worldwide. Sources include abrasion of synthetic textiles during laundry, tire abrasion while driving, city dust, spills, road markings, weathering and abrasion by vehicles, marine coatings, etc., in addition to domestic items such as personal care products and industrial uses such as plastic pellets in manufacturing, transport, and recycling. MPs also come from marine accidents such as the X-Press Pearl maritime disaster in 2021, which released thousands of tons of plastic nurdles and other polymers into the marine environment, contaminating coral reefs, seagrass beds, and the food chain. The pathways of global MP cycling include the road runoff pathway, wastewater pathway, wind pathway, and ocean pathway. The fate of MPs in the environment is particularly important because they are transferred to and accumulate in the food chain and become part of the food web.

Management of plastics and MPs is critical for many reasons:

1) Every year, several million tons of primary and secondary MPs leak into the oceans.
2) Discarded plastics could wrap around the earth four times in a single year.
3) Disposable plastic items represent 50% of marine litter.
4) About 95% of disposable plastic packing is wasted.
5) Plastics can survive in the environment for up to 500 years.
6) Recycling plastics takes 88% less energy than making new plastic. We can save a huge amount of gasoline by recycling plastics.

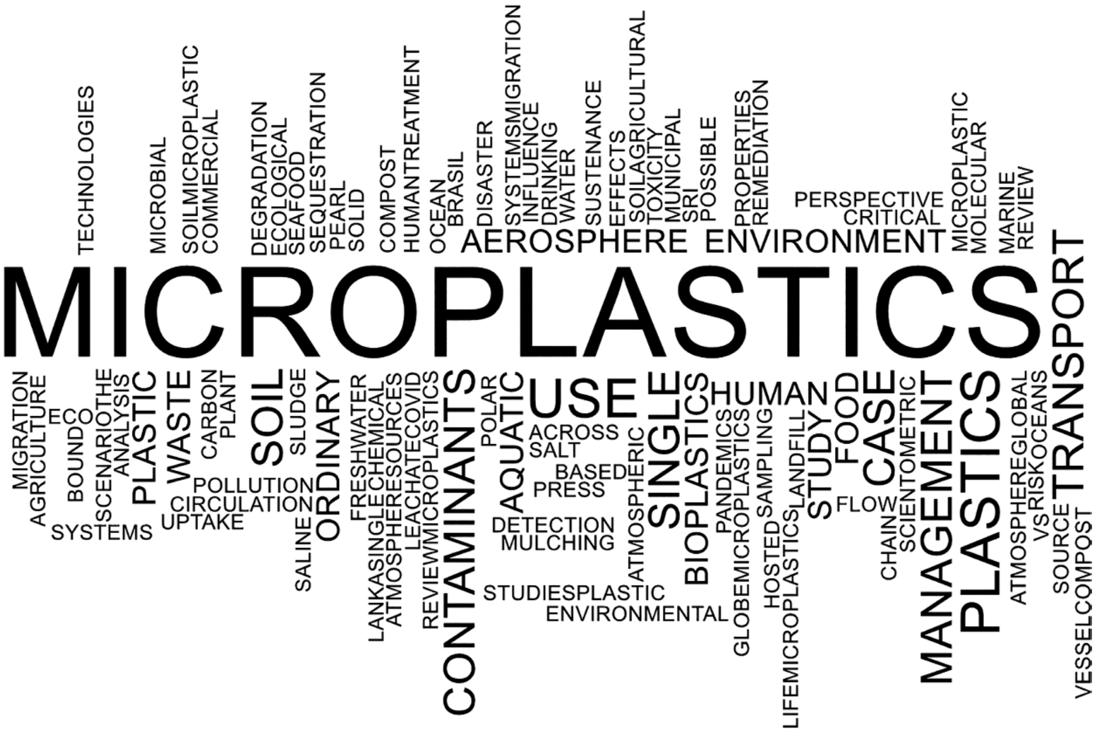

Figure 1 The word cloud map generated from the titles and keywords of the chapters in this book.

"Mission Starfish 2030: Restore Our Ocean and Waters" is a document prepared by an independent commission of the European Union for Healthy Oceans, Seas, and Coastal and Inland Waters. Its overall goal is to restore the earth's oceans and waters by 2030. More concretely, inspired by the shape of a starfish, the Mission highlights four interdependent challenges – unsustainable footprint; climate change; lack of understanding, connection, and investment; and inadequate governance – by proposing five overarching objectives for 2030:

a) Filling the knowledge and emotional gap
b) Regenerating marine and water ecosystems
c) Zero pollution
d) Decarbonizing our waters, ocean, and sea waters
e) Revamping governance

This book is relevant for helping to achieve the Mission Starfish goals via plastic abatement.

Section I

Single Use Plastics

1

Scientometric Analysis of Microplastics across the Globe

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1.1 Introduction

Plastics consist of monomers, additives, dyes, and other ingredients, most of which are toxic. They are combinations of unreacted monomers and hazardous chemicals that can cause adverse health effects if they enter the human body. *Microplastics* are plastics smaller than 5 mm (Arthur et al. 2009; Thompson et al. 2004) formed from the breakdown of plastics over time due to natural or anthropogenic causes. Even if microplastics are not visible, they can affect the quality of the air, water, and soil.

Most microplastics are created by the breakdown of larger items such as clothing, car tires, and mismanaged urban plastic waste. It is known that microplastics accumulate in the soil and roadside dust in cities (Jan Kole et al. 2017). Low-density polymeric materials can easily be suspended by wind, water, and vehicle traffic and transported long distances by air circulation, leading to the presence of microplastics in different areas of the environment.

Another source of microplastic is the textile industry (Bhat et al. 2021). Synthetic fibers are necessary materials originating from the textile industry and are used in every field. Polyester, especially polyethylene terephthalate, is the most widely used synthetic fiber in the textile industry due to its hydrophobic property, elasticity, and high thermal insulation. Other fibers used in the textile industry are nylon, acrylic, and polypropylene.

Plastics are considered environmentally permanent; however, once released into the environment, they become susceptible to disintegration by exposure to external forces like chemical decomposition, photo-oxidation, biological decomposition, and mechanical forces that disrupt their structural integrity. Plastics that are broken down naturally or anthropogenically by external factors are not destroyed but are broken down into smaller pieces each time.

Although the basis of plastics is petroleum, which is organic, its structure suits the purpose of plastic. Each different type of plastic means another chemical bond and the use of another chemical. There are more than 5000 different types of plastic on the market, so the number of chemicals used to produce plastic is quite large (Zimmermann et al. 2019). Each plastic's unique structure causes the plastics to be not evaluated as a whole, and recycling becomes difficult. It has been observed that microorganisms can degrade most organic-based polymers in a hot and humid environment. However, providing a suitable environment is not easy in practice, and more research is needed to confirm the validity of this approach (Pekhtasheva et al. 2012).

Microplastics in the Ecosphere: Air, Water, Soil, and Food, First Edition. Edited by Meththika Vithanage and Majeti Narasimha Vara Prasad.

Microplastics can be harmful to humans, animals, and the environment due to their small dimensions (Bhat et al., 2022a, 2022b). They have been found in humans: for example, cellulosic and plastic microfibers were observed in human lung tissue (Pauly et al. 1998). Research has also found that a person can breathe between 26 and 130 airborne microplastics in an indoor environment (Prata 2018). Plastic fibers have been found to remain in lung fluid for 180 days (Law et al. 1990). Therefore, inhaling microplastics will cause problems due to their accumulation in the human body (Bhat et al., 2022a, 2022b).

Microplastics and nanoplastics are new topics, and their definitions are still limited. Microplastics are defined based on their size as polymeric particles ˂5 mm (Arthur et al. 2009; Thompson et al. 2004). Very little biological information is known about polymeric particles ˂5 mm and are more likely to be ingested than larger items. However, the decision about size limits is not based on actual evidence but rather on pragmatism. Using the prefix *micro*, the size definition of microplastics should be within the micro range: between 1 and 1000 µm. If we use a size definition below ˂5 mm, these polymeric particles should be described as millimeter-, micro-, and nano-sized polymeric plastics, because the ˂5 mm definition includes the millimeter, micrometer, and nanometer size range. From a nomenclature point of view, it would be intuitive to categorize plastics based on conventional size units. In general, plastics with sizes in the nanometer scale (1–1000 nm) should be nanoplastics. Following this reasoning and using the SI prefixes for length, microplastics would have sizes of 1–1000 µm, followed by milli-plastics (1–10 mm), centi-plastics (1–10 cm), and deci-plastics (1–10 dm). However, this conflicts with the current terminology. For example, nanoplastics and microplastics are typically considered 1–100 nm and 1–5000 µm in size, respectively. Accordingly, new size categories, fully consistent with the SI nomenclature, would have little chance of being adopted by the scientific community. As a pragmatic compromise, we propose the following categories: (i) nanoplastics, 1 to <1000 nm (to conform to existing definitions of nanomaterials, a subdivision in nanoplastics [1 to <100 nm] can be made); (ii) microplastics, 1 to <1000 µm; (iii) mesoplastics, 1 to <10 mm; and (iv) macroplastics, 1 cm and larger.

Apart from the size definition, researchers also define microplastics as polymeric particles produced from the breakdown of bigger plastic particles, while nanoplastics are formed from microplastics; however, microplastics and nanoplastics are also categorized into primary and secondary polymeric particles. So, the definitions of microplastics and nanoplastics should include both primary and secondary polymeric particles. We define microplastics and nanoplastics as polymeric particles that are either deliberately designed for commercial use or produced from the breakdown of larger plastic particles. It is clear that microplastics (˂5 mm) include a broad range of sizes, and it is impossible to see all these particles with the naked eye, especially when taking a sample in the micro or nano range. Microplastics can also be defined as polymeric particles, half of which can be seen by the naked eye.

The majority of studies on microplastics to date have seen fibers in their samples irrespective of other types of microplastics (Dris et al. 2015, 2016, 2017; Prata et al. 2020; Soltani et al. 2021; Song et al. 2021; Su et al. 2020; Szewc et al. 2021; Truong et al. 2021). The reason is that fibers are straight and long and usually larger than other microplastics like pellet fragments. Researchers have primarily focused on the millimeter size of microplastics, and fibers are abundant under this size range. Other microplastics can also be seen under the micro- or nanometer size range dimensions, including pellets, fragments, granules, films, etc. So during the analysis of microplastics in the future, not only the millimeter size range but also micro-size ranges should also be considered.

Scientific study using bibliometric analysis has recently gained popularity (Can-Güven 2020; Eraslan et al. 2021; Sun et al. 2020; Yu et al. 2020). Statistical and quantitative analysis of research publications displays quantifiable data when examining research trends in the literature for the growth of specific themes. As a result, we can analyze the specific research patterns and characteristics of the research literature in a given field, such as the metrological characteristics of the research literature in that field. This approach is also gaining popularity as a tool for scientific investigation. The data visualization and analysis software RStudio (biblioshiny, the shiny interface for bibliometrix) has transformed traditional bibliometric analysis, making it one of the most popular tools for knowledge mapping (Eraslan et al. 2021). It enhances the visualization of the analytic process and enables quick access to the bibliometric structure of a study subject. This can assist researchers in identifying potential future study hotspots.