Beyond the Naked Eye: Microplastics

Wavhal Nilam[1], Simranpreet Kaur[2] and Nitin Wakchaure[3]

[1]PhD scholar, Dept. of Veterinary Public Health & Epidemiology, Guru Angad Dev Veterinary & Animal Sciences University, Ludhiana.

[2]Associate Professor, Centre for One Health, Guru Angad Dev Veterinary & Animal Sciences University, Ludhiana.

[3]Assistant Professor, Dairy Economics & Business Management, Guru Angad Dev Veterinary & Animal Sciences University, Ludhiana.

[*]Corresponding Author: yoginiwavhal@gmail.com

Introduction

Plastic, a polymeric material known for its moldability under heat and pressure, exhibits traits such as low density, transparency, and toughness, facilitating its use in diverse products. Alexander Parkes is credited with the discovery of Parkesine, achieved by dissolving cellulose in a solvent and allowing it to dry, while in 1907, Leo Hendrik Baekeland pioneered Bakelite, a fully synthetic plastic, by combining phenol and formaldehyde. Polyethylene terephthalate is the first most manufactured plastic widely used in food & beverage packaging. High-density polyethylene used in shampoo bottles, and detergent bottles, is durable & most easily recycled plastic. Low-density polyethylene is cheap to produce & is used in plastic bags, and plastic wraps, but can't be recycled. As per the Plastic & Rubber Products global report, 2022, the market size of plastic products in 2021 was $1229.98 billion while it increased to $1357.49 billion in 2022 & is expected to grow to $1923.6 billion in the year 2026. As per a report released by the Directorate General of Commercial Intelligence & Statistics, India's plastic export is increasing year by year from $ 5.8 to $ 9.8 from 2017-17 to 2021-22.

In 2019, global plastic production was 370 million tonnes, but only 9% of plastic was recycled (Kumar et al, 2021). 85% of marine water pollution is due to plastic pollution & out of that 50% is due to single-use plastic (Yuan et al. 2022). Now, what happens to this plastic in the ocean? Plastic breakdowns due to various climatic conditions into small plastic particles, which are not visible to the naked eye & such plastic particles smaller than 5 mm in diameter (Arthur et al., 2009), are called as microplastics (MP). There are two types of MPs. Primary MPs are intentionally engineered to be small, serving various purposes in cosmetics, toothpaste, and products like glitter and stuffed toys. Secondary MPs are not intentionally produced but are rather the result of the degradation of larger plastic items, such as fragments from plastic bottles, films from plastic bags, and fibers from netting, rope, and synthetic clothing. They can vary in color and form, posing a significant environmental challenge.

The first report of the presence of MP in an aquatic environment was in the Sargasso Sea in 1972, and since then studies on MP are in increasing trend from 2012 onwards. By 2050, it is predicted that there will be likely more plastic in the oceans than fish due to the increase in plastic manufacture. Moreover, the usage of single-use plastics in coastal tourism & fishing activities also significantly contributes to microplastic pollution.

MPs are found everywhere: freshwater, the ocean, the atmosphere, and even living things (Zbyszewski and Corcoran 2011; Klein et al. 2015; Prata 2018; Rezania et al. 2018; Waring et al. 2018; Barletta et al. 2019; Patel et al. 2020). Soil from Hormoz Island (Iran) was used to prepare traditional spices; traces of polyethylene terephthalate, polystyrene, and polypropylene were reported by Amiri et al. 2022 from the same soil. MPs can be transmitted to other organisms through inhalation, contact with skin & mucus membrane of the eye, or through ingestion of contaminated food. Even synthetic clothing is a significant potential source of MP. As per the United States Environment Protection Agency report (2018), out of 17 million tons of fibers produced in the clothing industry, 60% are synthetic. A 6 kg washing load of polyester-cotton blend is estimated to discharge 137,951 fibers, with polyester potentially releasing 496,030 and acrylic perhaps releasing 728,789 (Napper & Thompson, 2016).

The characteristics of polymers, particle size, shape, concentration, exposure period, additives, surface modification, and hydrophobicity decide the fate & harmful effect of MPs (Santana et al. 2017, Guerrera et al. 2021). Among the most poisonous polymers are epoxy resin, acrylonitrile-butadiene-styrene, polyacrylonitrile, polyvinyl chloride, and polystyrene (Yuan et al. 2022). Acute and chronic toxicity from MPs can impact development, reproduction, locomotion, neurotoxicity, immunotoxicity, genotoxicity, and cytotoxicity (Bhagat et al. 2020). They have been discovered in organisms, skin, hair, saliva, and fecal samples, and their effects on health vary depending on their location. They can also pose direct or indirect harm to human health.

The direct health effects due to MPs depend on several variables, including the kind of polymer, the shape, size, and presence of additives employed in the plastic processing process. Plastics contain monomers like vinyl chloride and styrene, which are particularly dangerous because of their possible health impacts. In addition, substances added on purpose during the production of plastic, such as plasticizers like phthalates, can pass through the intestinal barrier and impact fertility, and cause allergies, and hormone imbalance (Rana et al. 2020).

MPs can indirectly impact human health by serving as carriers of biological contaminants and chemical pollutants. Their surfaces provide ideal environments for pathogens like fungi, bacteria, and protozoa to grow and form specific layers, potentially leading to dysbiosis and increased susceptibility to infections. Pathogenic fungi on microplastics can become resistant to environmental factors like temperature and sunlight (Gkoutselis et al. 2021). Additionally, the slimy layers of sediment or biofilm on plastic surfaces facilitate the adhesion, growth, and mutation of pathogens, including antibiotic-resistant bacteria (Pham et al. 2021).

In the process of absorbing, releasing, and moving chemical pollutants such as pesticides, heavy metals, organic pollutants, and pharmaceuticals, MPs may exacerbate the harmful effects of these pollutants by acting as carriers. For instance, the adsorption of heavy metals onto the surface of MPs can be facilitated by biofilm formation, and the size of the particles has an impact on their adsorption capability (Zhang et al. 2022). Microplastics, particularly smaller ones, exhibit greater adsorption of heavy metals due to the increased number of functional groups on their surfaces, leading to chemical association and electrostatic interactions (Kinigopoulou et al. 2022). The diffusion of metal ions into surrounding fluids can also have an impact on aquatic environments.

Additionally, microplastics promote the accumulation of compounds such as tetrabromobisphenol A (endocrine disruptor & immunotoxic agent) in commercial mussel species, causing possible health hazards (Zhang et al. 2022).

Retention time is impacted by several biological factors, including the anatomical site of deposition and structure; biological factors such as size, shape, solubility, and surface chemistry; and the nature of particle interaction with various biological structures, such as the aqueous phase, the air-liquid interface, and free cells (e.g. macrophages, dendritic cells, epithelial cells) (Schürch et al. 1999).

A change from a linear to a circular paradigm is required to address microplastic pollution. This includes tactics like avoiding or limiting the use of single-use plastic, recycling, reusing & looking for alternatives. Several countries have already put policies in place to outlaw single-use plastics and microplastics in specific items. It is also essential to encourage recycling & waste reduction in addition to the development of biodegradable plastics. Nationwide campaigns for behavior modification and public education are also essential for increasing awareness and decreasing plastic pollution. Combating this issue also requires tracking microplastics in the environment and evaluating their effects on ecosystems and human health.

Conclusions

There is less research on India's contribution to the worldwide microplastic pollution problem. While freshwater systems have been examined more in rivers than in lakes or groundwater, the majority of studies on microplastics concentrate on marine ecosystems in comparison to surface water (Vaid et al. 2021). It is necessary to create standardized and trustworthy methodologies for both detection and quantification. The origin, movement, and eventual fate of microplastics in various environmental compartments are poorly understood. Although the exact degree of their toxicity is unknown, however, it is evident that there will be an increase in microplastic contamination as the demand and production of plastic rise. Expanding research efforts and creating appropriate mitigation methods are required to eliminate microplastics from various environmental niches.

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