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Effect of Microplastic on Animalsand Humans

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Abstract:

Microplastics are increasingly gaining attention due to their discovery in living organisms and diversity. Microplastics in the ocean have received the most attention for the massive microplastic garbage patches prevalent in oceans. However, microplastics in terrestrial biomes are overlooked despite their significance. Microplastics on land have three pathways into the food chain: soil ingestion of microplastics from plastic mulching, livestock consumption of microplastics, and microplastic contamination from food packaging, which has a negative and disproportionate impact on food security and health for marginalized communities. This paper investigates the impact of microplastics across these contexts and makes recommendations forsustainable practice.

1: Introduction

Microplastics are tiny pieces of plastic less than 5 millimeters in diameter, ubiquitous, and often come from the degradation of plastics. They are classified into primary and secondary microplastics. Primary microplastics are small plastic particles intentionally manufactured at microscopic sizes for various applications. These particles are found in products such as cosmetics, personal care items, and industrial abrasives. On the other hand, secondary microplastics result from the breakdown of larger plastic debris, such as bottles, bags, and fishing nets, due to environmental factors like UV radiation, weathering, and mechanical forces. Over time, these plastics fragment into smaller pieces, which can accumulate in ecosystems (Węgrzyńska & Flak, 2024).

These microplastics often cause contamination, which is now becoming a significant andwidespread issue across the world because of their harm to preserving our planet's ecosystemsand the health of animals. Furthermore, microplastics have infiltrated almost all ecosystems on Earth, with oceans and water bodies being highly contaminated by secondary microplastics broken off from plastic waste in the seas. Additionally, plastic agricultural products and untreated waste also lead to microplastic contamination, with high levels of microplastic output reaching terrestrial ecosystems (Hale et al., 2020).

Furthermore, in addition to microplastic contamination, another significant danger of microplastics is their resistance to biodegradation. Microplastics are composed of recalcitrant polymers that break into monomers that require further degradation processes. Additionally, microplastics also lack rich functional groups and hydrolyzable bonds that allow microorganisms to degrade the plastic properly (Cai et al., 2023). Furthermore, typical degradation conditions like UV radiation, temperature changes, and physical damage only lead to fragmentation rather than degradation, which only produces more particles to consider (Xiang, Zhang, Wu, & Li, 2023). Their high resistance to degradation leads to more problems with microplastic bioaccumulation, which can create high concentrations of microplastics across several trophic levels in the environment. Moreover, in the agricultural sector, microplastics have been shown to diminish crop quality, yield, and the physical, chemical, and biological properties of soil.

2. Plastic mulch as a contaminator of microplastics

2.1. Overview of plastic mulch

Plastic mulch is a thin layer of polyethylene film that covers the surface of soils. It is widely utilized globally because it benefits plant productivity by maintaining soil moisture, improving soil fertility and health, and reducing weed growth (Heydari, 2022). Mulch can be classified into two subcategories: organic and synthetic/mineral. Organic mulch is made of biodegradable and natural materials like grass and weed clippings. Though this organic mulch decomposes quickly and requires frequent replacement, its decomposition transfers nutrients into the soil, thereby improving the structure and nutrients of the soil. On the other hand, synthetic mulch is made of inorganic materials like plastic and landscape fabric and decomposes much slower than its organic counterparts. Synthetic mulch functions to retain moisture within the soil and also blocks the growth of weeds, but since they decompose slowly, they do not provide any nutrients to the soil (Iannotti, 2024).

2.1.2 History of plastic mulch

The practice of mulching being used in agriculture had existed since around 500 BCE when farmers recorded proof of using organic matter (Mansoor et al., 2022). As the years progressed, the material used for mulching gradually increased in sophistication until plastic mulch was first introduced in 1950 (Mansoor et al., 2022). Plastic mulching was very popular for its low cost and overall effectiveness and was widely used for agricultural purposes all throughout the world.

However, by 1980, the negative environmental impact of plastic mulching became apparent. Despite this, many farmers still opted to use this form due to its significant effectiveness. Thus, plastic mulching remains the most popular form of mulching for farmers to this day (Mansoor et al., 2022). However, the very materials that support crop growth come with environmental consequences.

2.1.3 Mulching Benefits on Yield

Plastic mulching provides a wide variety of benefits to plant growth. Firstly, mulching enhances the overall composition and health of the soil. Plastic mulch creates insulation, which warms the soil. This is backed up by one study that found that in spring, with cool climates, mulching warmed the soil by an average of 8–10°F, with the exact amount being dependent on ambient air temperature, sunlight, soil type, available soil moisture, and mulch color (Orzolek, 2017; Lamont,2017). Furthermore,plastic mulch can control many external problems, such as weed and pest control. Attesting to this, Liu et al. (2023) report that plastic mulching helped in reducing evaporation and wind erosion, inhibiting weed growth, and mulching improved pest control.

Furthermore, other studies also show that plastic mulching improves crop yields for plants, which is caused by the above benefits. One study compared the crop yield of plants with and without plastic mulching in several Chinese fields and found a 13.7% increase in wheat yield across all fields (Luo et al., 2022).

2.1.4 Environmental Drawbacks of Mulching

Despite the above-mentioned benefits of plastic mulch, research indicates that it possesses some drawbacks that might limit its use. For instance, unlike organic mulch, plastic mulch doesn't biodegrade into the soil and must be manually replaced at the end of each growing season. However, this replacement process is both costly and lengthy. It takes about 42 hours of labor per hectare to replace plastic mulching (hours vary by mulching density, type of plastic, and soil type, etc.) and takes even longer to clean the field of smaller plastic fragments that have broken off the main mulching (Madrid et al., 2022). The sheer time required to completely cleanse the field of plastic fragments

discourages many farmers from conducting thorough replacement procedures.

Additionally, prolonged soil exposure to plastic mulch and fragments has been shown to create large amounts of plastic residue in the ground. One field survey in China found that the accumulation of plastic residue in cropland soils has reached 550,800 tonnes due to plastic mulching (Zhang et al., 2020). The microplastic accumulation in soil issue is only exacerbated by the fact that plastic mulching, in general, is a costly practice: both the placement of new mulching and removal of old ones require specialized equipment and labor, which discourages farmers from replacing it annually as is supposed to be done (Grant, 2023). This prolonged residue in the soil may lead to microplastic contamination, which is one major pathway of ingestion in animals.

Furthermore, the unabated accumulation of plastic residue in field sites negatively impacts soil health by increasing the evaporation of water in the soil and impacting microbial activity, which impacts the growth and survival of soil microbial communities (Machado et al., 2019). Lastly, microplastics' ability to act as a carrier for harmful substances like heavy metals impacts both soil health and the safety of human consumption (Bradney et al., 2019). This impact on soil health has a significant toll on soil health and can threaten food security in the long run.

2.2 Microplastic Pathways in Animal Systems

Microplastics have become pervasive in various ecosystems, making their way into animal systems through multiple pathways. On land, the most common pathways for microplastics in animals are through the grazing plants of plastic mulching and consuming contaminated feed. For instance, plastic mulching causes large amounts of microplastic ingestion in the soil. The microplastics in the soil are transported from the soil and into the plants through the xylem, where they reach edible parts of the plant (Urli et al., 2023). Because many farm animals graze these plants, large amounts of microplastics stemming from plastic mulching enter the food chain in this manner.

The other common pathway of microplastics is the consumption of contaminated animal feed. (Wu et al., 2021). For instance, one China study found a large distribution of plastic particles in chicken feed, with approximately 96 particles per kg (Aardema et al., 2024). Moreover, in less developed countries, larger plastic fragments exist in both the grazing grounds and in animal feed (Beriot et al., 2020). The consumption of microplastics further increases the plastic concentration in animals.

Lastly, microplastics can also enter animal systems through airborne contamination, although this pathway is not common. Microplastic particles can be airborne, and prolonged exposure to microplastics outdoors can lead to increased microplastic contamination in animals. The small size of microplastics allows them to penetrate into the respiratory system of animals and evade typical expelling mechanisms from the body (Saha & Saha, 2024). For example, grazing animals near polluted roads may inhale tiny plastic particles from the air. These particles can settle in their lungs, causing irritation or even long-term respiratory issues, much like dust or other pollutants. However, in addition to animals, it has been observed that microplastic ingestion is also common among humans.

2.3 Microplastic in the Human System

Human exposure to microplastics has been estimated to be annually around 74,000 to 121,000 plastic particles, and trends show that this number will only increase if plastic production is not lessened (Kutralam-Muniasamy et al., 2023). These microplastics make their way into human systems through multiple pathways.

2.3.1 Microplastics in human packaging

Besides having microplastics left in the soil and ingesting residues of microplastics in food tissues, another major

contributor to microplastic ingestion is plastic packaging. Since plastic packaging is very convenient and portable, plastic packaging is used in a wide variety of settings, from food to bottles.

When people rip up plastic packaging to eat their foods, approximately 14,000–75,000 microplastics are generated in the food, with the exact amount being dependent on conditions such as stiffness, thickness, and the density of plastic materials (Sobhani et al., 2020). This is very common in packaging such as bottled water. Attesting to this, one study showed that there is global exposure to microplastics from bottled water, with approximately 240,000 tiny pieces of plastic per liter of water, which is 100 times more than seen in previous studies, although 90% of these plastic pieces were nano plastics.

2.3.2 Microplastics in cosmetic items

Human cosmetic items such as body washes, scrubs, or toothpaste also contain notable concentrations of microplastic that can lead to further contamination. Microplastics in the cosmetic industry are known as primary microplastics because they are produced specifically for the product, which, in most cases, is because they are a cheaper option as an exfoliant.
Microplastics are released when the product causes physical abrasion with the surface of the body, for example, with the contact of toothpaste to the teeth or cosmetic products with the skin (Guerranti et al., 2019).

3 Impact of Microplastic on health

Although the impact of microplastics on the health of plants, animals, and humans has been explored by research, these findings are uncertain due to a lack of long-term evidence. However, these findings all point to the danger of microplastics.

For instance, recent advancements in microplastic research have also shown multiple negative effects of microplastics on terrestrial organisms. Around 30 separate studies utilized mice as a sample, exposing them to microplastics. These studies found that microplastics spread into multiple different tissues in the animal body, with microplastics detected in the intestines, liver, kidneys, and more, causing damages such as structural damage, biochemical changes, and offspring development (Zolotova et al., 2022). Similarly, another study exposed chickens to 200 mg of microplastics per kg of feed, finding a significant decrease in daily weight gain, reduced microbiome diversity in the gut, and worsened digestive system performance (Prata, 2023).
Additionally, studies show that microplastics and other particulate plastic matter can absorb smaller toxic chemicals that are dangerous to health. Due to the hydrophobic nature of plastic particulate matter, they are capable of accumulating toxic chemicals through absorption in various environments (Bradney et al., 2019).

The impact of these microplastics on human health can be observed in how they affect the liver, kidneys, and intestines. According to Goodman et al. (2022), when humans ingest microplastics into their systems, these can travel to internal organs such as the kidneys and liver and cause adverse effects on the cellular level. They can cause tissue damage, impair filtration processes, and contribute to kidney toxicity. When deposited in the liver, they can interfere with liver function and increase the risk of liver disease over time. For instance, a Netherlands study found that 17 of 22 healthy adult volunteers had microplastic exposure in their blood samples, finding that the microplastics contaminated human tissues such as lungs and gastrointestinal tracts
(Pinto-Rodrigues, 2023). This may result in digestive problems such as bloating or discomfort and could interfere with nutrient absorption over time.

3.1.1 Microplastic biomagnification across trophic levels

In addition to the aforementioned, research indicates that one of the biggest dangers of microplastics is biomagnification. Biomagnification is defined as an increase in microplastic contamination due to transfers from low to high trophic levels in ecosystems (Miller et al., 2020). Microplastic contamination occurs throughout all levels of the food chain, but as mentioned above, mulching practices cause high amounts of inadvertent microplastic ingestion

by plants and primary consumers in the soil.

Thus, the biomagnification of plastics occurs as the bottom of the food chain is consumed by predators of higher trophic levels. Each trophic level contains significantly less biomass than the one below it, so the microplastic contamination in each trophic level is exponentially increased. One study reported that organisms in lower trophic levels, such as earthworms and plants, had lower concentrations of plastic particles (14.8 and 0.87 particles per gram, respectively), which suggests higher microplastic accumulation levels across the food chain (Lwanga et al., 2017). The negative effect of this is significant as the exponential accumulation of microplastics in the trophic levels is a dangerous sign for humans because humans are apexpredators, meaning they are at the highest trophic levels in all food webs on the planet, creating the highest concentration of microplastics for humans.

3.1.2 : Bioaccumulation of microplastics

Another dangerous effect of high levels of microplastic ingestion is the risk of microplastic bioaccumulation. Bioaccumulation occurs when the rate of consumption of a particle exceeds the rate of its excretion, which leads to high concentrations of the particle in the organism.

3.1.3 : Effect on human health

There are some methods of microplastic excretion from our bodies, such as passing through the gastrointestinal tract without absorption in the bloodstream; however, other research shows that microplastic fragments can also stay in the body in many different tissues. One study investigated microplastic retention in the body of mice and found that microplastics accumulatethe highest in three muscle tissues: the liver, kidney, and gut (Deng et al., 2017). This study warns of potential risks to body systems, including disruption to energy and lipid metabolism, increased oxidative stress, and neurotoxic responses, which can all alter the health and overallcondition of the body.
Additionally, microplastics also cause disruptions to the human digestive system. Firstly, they cause an alteration in the intestinal microbiome, which results in an imbalance of bacteria concentrations and leads to multiple gastrointestinal symptoms. They can also cause physical irritation to the tracts, causing inflammation (Lee et al., 2023).

3.2: Risks to marginalized communities

While all people are affected by the widespread infiltration of microplastics into food systems, there are also many specific communities, particularly more vulnerable and marginalized communities, that suffer from the negative effects more. Attesting to this, one study conducted by Landrigan et al. (2023) showed that microplastic contamination disproportionately affects the poor, especially people in the Global South, because of close proximity to agricultural production areas and waste sites, thereby constituting an environmental injustice.

Communities living near polluted areas, such as industrial zones or coastal regions, may be more likely to come into

contact with contaminated water and food sources. The disproportionate effect is further exacerbated by their inability to enforce policies that reduce plastic pollution, given their lack of political power and say in regulations. In addition to marginalized groups, vulnerable people also suffer disproportionately. This category of people

includes the elderly, children, sick, pregnant women, etc. Vulnerable populations often have limited access to healthcare and resources needed to mitigate the effects of microplastic exposure.

4: Recommendation: Biodegradable Mulch

One method to prevent the accumulation of microplastics in the soil is through the implementation of more sustainable agricultural practices, specifically through increased usage of biodegradable mulching instead of plastic mulching. Biodegradable plastic mulch is a form of mulching that, unlike plastic mulching, is tilled into the soil and expected to decompose there. Biodegradable plastic mulch is made of polymers that can be decomposed by bacteria, fungi, and algae, which is then transformed into harmless byproducts like carbon dioxide, water, and other biomass that provide nutrients to the soil (Mahmoud et al., 2023).
The degradation is very effective, as demonstrated by a study that found that after 120, 210, 300, and 365 days in the natural environment, the degradation rates of degradable mulch were 7%, 37%, 57%, and 92%, respectively (Soylu & Kızıldeniz, 2024).

Additionally, the biggest benefit of biodegradable plastic mulch over traditional plastic mulch is the environmental benefit of not requiring meticulous disposal practices. That is, while traditional plastic mulches often are not degraded properly due to high costs, which lead to high accumulation of microplastic fragments in the soil, biodegradable plastic mulch degrades in the soil without needing disposal, which not only preserves soil health from harmful plastic fragments but also reduces disposal labor costs (Miles et al., 2017).
Furthermore, the similar structure and functionality of the two forms of mulches allow biodegradable mulch to also provide many of the same benefits that traditional plastic mulch brings, such as enhanced soil health and crop yield. Studies show that biodegradable plastic mulch increases water usage efficiency by up to 73.1%, and overall yields in crops like starch showed 8.77–19.88% and 14.36–26.46% in 2012 and 2013, respectively (Soylu & Kızıldeniz, 2024; Menossi et al., 2021).

Furthermore, to address the growing issue of microplastic contamination, adopting practical, sustainable solutions is essential. One immediate step is to promote the use of microplastic-free cosmetics, as well as developing food packaging from biodegradable or reusable materials.
Secondly, plastic mulch should be replaced with biodegradable alternatives, such as materials made from plant-based fibers or compostable films. Lastly, stronger regulations are necessary to limit plastic production and promote sustainable practices.

Conclusion

Microplastics are a rapidly emerging issue that could have potentially devastating health implications for all terrestrial organisms and, specifically, vulnerable communities for humans. There are many pathways of microplastics into land organisms, such as through microplastic ingestion of soil in plastic mulching, contamination of feed, plastic packaging, and intentional production from cosmetic industries. These microplastics can bioaccumulate and biomagnify, which can cause dangerously high concentrations of microplastics in the body, which has negative impacts on the health of living animals. Marginalized communities and vulnerable groups suffer higher risks of danger from microplastic contamination. In order to prevent the spread of microplastics further, action must be taken to reduce microplastics at the source of plastic mulching. Conclusively, more research is needed to understand microplastics' full impact and develop technologies that reduce their presence in the environment.

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