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Commentary

Microplastics in Animals: The Silent Invasion

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Abstract: Microplastics, defined as plastic particles less than 5 mm in size, have become a pervasive environmental contaminant detected across a wide range of ecosystems. While the presence of microplastics in marine life and humans has been extensively documented, there remains a significant gap in understanding their full health impacts. Moreover, the effects of microplastics on animals, particularly those in close proximity to human activities, remain underexplored, representing a key area for future research. In this study, we found high levels of microplastic accumulation in animal tissues, particularly in the lungs, intestines, and reproductive organs. Our results also indicate that ingestion of microplastics occurs through multiple environmental sources, including contaminated food, water, and air, reflecting their widespread distribution. Evidence of microplastics crossing biological barriers and accumulating in critical organ systems suggests potential long-term health risks for animals that may also have implications for humans through environmental and food-chain exposure. Given the interconnectedness of ecosystems and the potential for these contaminants to enter the food chain, the presence of microplastics in animals raises serious concerns for broader ecological and human health. The findings underscore the urgent need for further research to clarify the long-term effects and to develop effective strategies for mitigating this emerging global threat.

Keywords: microplastics; animals; plastic polymers; concentration; contamination; adverse effects

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1. Introduction

Microplastics, defined as plastic particles smaller than 5 mm, are a growing concern due to their pervasive presence in the environment. These particles originate from the breakdown of larger plastic items, the shedding of synthetic fibers, and the use of microbeads in personal care products. Once released, microplastics persist in the environment for centuries owing to their resistance to natural degradation processes. They have been detected across a range of ecosystems, from the deepest ocean trenches to mountain peaks, and in various human and animal tissues [1,2]. This widespread distribution raises significant concerns about their potential impact on both human health and the well-being of domestic animals, which are closely tied to human food chains [3,4]. Figure 1 provides a visual representation of the key sources of plastic particles, such as plastic debris, vehicle tires, and clothing fibers, as well as various types of plastic polymers associated with microplastic pollution. In addition to these sources, tire-wear particles and biodegradable microplastics also contribute significantly to environmental pollution, especially in aquatic ecosystems [5]. The terms "plastic debris" refers to larger plastic chunks that break into smaller fragments, whereas "plastic litter" encompasses discarded plastic items found in the environment, including those that may not yet have fragmented [1,6].

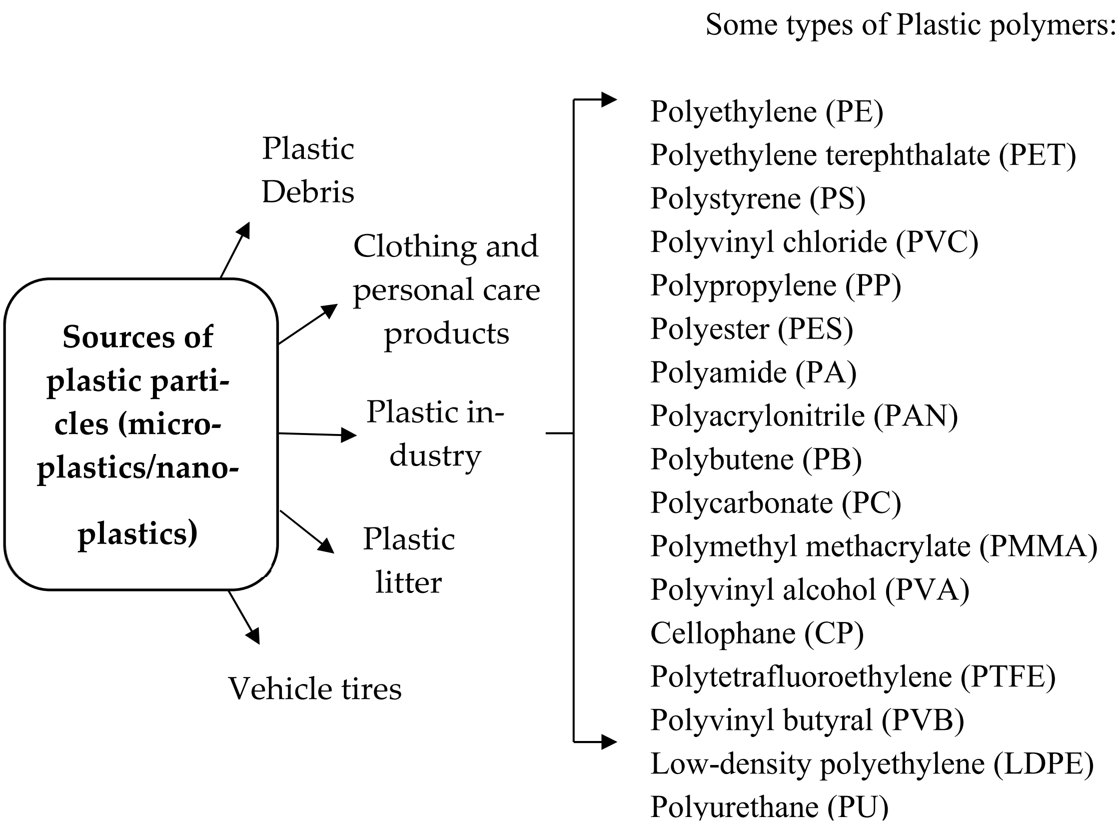

Figure 1. Sources of microplastics and different types of polymers.

The presence of microplastics in the atmosphere is particularly concerning, as studies show that microplastics can become airborne, leading to inhalation by humans and animals [7]. Urban areas with high levels of plastic use and waste are especially prone to higher concentrations of airborne microplastics, which can travel long distances and settle in environments far from their origin [8]. In aquatic environments, microplastics pose significant risks due to their ability to absorb and concentrate toxic chemicals from surrounding water. These particles are ingested by organisms at all levels of the food chain, from tiny plankton to large fish and marine mammals, leading to potential physical harm and the transfer of toxic substances into their tissues [9]. The widespread distribution of microplastics in both marine and terrestrial environments underscores the urgent need for comprehensive strategies to address this pollution at a global level.

Research on microplastics has significantly expanded in recent years, focusing on their environmental distribution and health impacts. Early studies primarily examined the accumulation of microplastics in marine environments, where these pollutants pose risks to marine life and, by extension, to human health through the food chain. These studies revealed that microplastics are not confined to marine ecosystems but are also present in terrestrial and atmospheric environments, highlighting the global scale of the issue [10]. Microplastics present a dual threat: they act as both physical contaminants and vectors for environmental toxins. Studies have demonstrated that microplastics can absorb and concentrate toxic chemicals from their surroundings and are then ingested by marine organisms and can enter the human food chain, potentially impacting human health. Concerns about the health impacts of microplastics are further supported by findings that these particles can cause oxidative stress, inflammation, and cellular damage, potentially exacerbating chronic health conditions [11]. Recent research has expanded beyond marine environments to reveal the presence of microplastics in terrestrial and atmospheric systems [12]. In soil, microplastics can disrupt microbial communities, affect soil fertility, and potentially enter the food chain through agricultural practices. The discovery of airborne microplastics has also raised concerns about human exposure through inhalation, particularly in urban areas with high plastic use and waste generation [13].

Despite extensive research on microplastics in humans and marine fish, there remains a significant knowledge gap regarding their presence in domestic animals. This is concerning, as these animals share the same environments as humans and are thus at high risk of microplastic contamination. Furthermore, microplastics have been shown to accumulate in various human organs, raising critical questions about the long-term implications for both animal and human health. This discussion aims to explore this issue further.

2. Microplastics in Animals

In the following section, a comprehensive overview of the specific microplastics identified is presented, as well as their respective concentrations for animal organs and food items, as shown in Table 1.

Zhang et al. [14] investigated the potential presence of PET and PC in 58 pet foods, including 13 dry and 22 wet cat foods, and 7 dry and 16 wet dog foods produced in the USA, Thailand, and Canada. Additionally, they analyzed 78 pet feces samples (41 from cats and 37 from dogs) from Albany, NY, USA. They found that the estimated daily intake (EDI) of PET and PC for cats was 35 ng/kg and 1.7 ng/kg, respectively, while the EDI for dogs was 19 ng/kg for PET and 1.8 ng/kg for PC. The study also highlighted that a significant portion of ingested microplastics is egested through feces, with concentrations of PET and PC in feces being orders of magnitude higher than in food. It remains uncertain whether all microplastics are fully egested or if some persist in the body. The retention of microplastics may vary depending on particle size, polymer type, and biological factors. Larger particles are typically egested more rapidly, while smaller nano-sized particles may evade immediate egestion and accumulate in organs, potentially posing greater health risks due to prolonged retention [15].

Susanti et al. [16] studied the presence of microplastics in domesticated ducks, collecting 25 samples from five cities in Indonesia. They analyzed biological samples from local ducks, specifically focusing on tissues such as the intestines and digestive tracts. The highest levels were found in ducks from Salatiga (lowland area), with 49 microplastic filaments per individual, followed by Semarang (coastal area), with 39 filaments, and Magelang (highland area), with 27 filaments. This contamination likely originates from duck feed, such as rough fish from the Java Sea. Wu et al. [17] identified polymer types of microplastics in livestock and poultry manure, confirming their presence in the samples. The study focused on the identification of microplastics, specifically highlighting that PE and PP were dominant, characterized by colorful fragments and fibers in manure and feed samples. However, the distribution of microplastics across different farms was not directly investigated but could be inferred from the types and quantities present in the analyzed samples. Prata et al. [18] carried out a study to investigate the presence of microplastics in the internal tissues of cats and dogs from Porto, Portugal. The animals were categorized into three age groups: junior (less than one year), adult (1 to 7 years), and senior (over 7 years). The maximum weights recorded were 6 kg for cats and 53.6 kg for dogs. Samples were collected from 24 cats and 25 dogs. The study revealed the presence of suspected microplastics in 22 kidney samples, 19 lung samples, 17 ileum samples, 14 liver samples, and 8 blood clot samples. Most of these microplastics (1 to 10 μm) constitute 69.4% of those in the ileum, 53.5% in the lungs, 44.2% in the kidneys, 42.6% in the blood clots, and 26.7% in the liver.

Liu et al. [19] found the presence of microplastics in eggs purchased from local supermarkets in China, with an average of 11.67 ± 3.98 particles per egg. A majority of microplastics were spherical and 50–100 μm in size, primarily composed of PE. It was also found that egg yolks contained more microplastics than egg whites, with no significant change after cooking. Li et al. [20] carried out a study where microplastics were detected in the lung tissue of both domestic and fetal pigs. The study found an average of 12 microplastic particles/gram in domestic pig lungs and 6 particles/gram in fetal pig lungs, with sizes ranging from 20.34 µm to 1370.43 µm. Notably, the composition of microplastics differed between domestic and fetal pig lungs, with PA being the most common polymer in domestic pig lungs (46.11%), and PC in fetal pig lungs (32.99%). Hu et al. [21] investigated the presence of microplastics in the testes of both dogs and humans and explored the association with sperm count. They identified 12 types of microplastics in the testes of 47 dogs and 23 humans. These included PC, PET, PE, PS, PVC, PP, PMMA, and PU. The study observed that PE microplastics were present in 36.4% of the dogs' testes, while the human testes contained three times more microplastics compared to the dogs' testes. Bahrani et al. [22] explored the presence of microplastics in the tissues of cows and sheep. They collected samples from the liver, meat, and tripe, identifying three types of microplastics: nylon, LDPE, and PS. The study found that nylon was predominant in cow tissues, with a presence of 98%, while LDPE and PS were found in sheep tissues at levels of 40% and 42%, respectively.

Table 1. Types of animals, microplastics, and concentrations.

Ref.	Animals and Types of Microplastics (MP)	Concentrations and Percentages of Microplastics
[14]	Animals: cat, dog MP: PET, PC	Cat's food: PET: <1500 ng/g–12,000 ng/g; PC: <6.3–630 ng/g Dog's food: PET: <1500–4600 ng/g; PC: <6.3–2000 ng/g Cat's feces: PET: 2300–340,000 ng/g); PC: <32 to 13,000 ng/g Dog's feces: PET: 7700–190,000 ng/g; PC: <32 to 26,000 ng/g
[16]	Animal: duck, MP: PE, PVC, PET	Organ: Duck's intestinal tract, filament microplastics: 53.06% in Salatiga, 38.46% in Semarang, 66.67% in Pati ducks
[17]	Animals: pig, layer, cow MP: PP, PE, PET	Pig's manure: 64 MP items; layer's manure: 48 MP items; cow's manure: 2 MP items
[19]	Animals: chicken, MP: PE	Eggs: 11.67 ± 3.98 particles/egg; egg white: 3.40 ± 1.52 particles/egg; egg yolk: 8.95 ± 4.58 particles/egg
[20]	Animal: pig MP: PC, PA, PP, PE, PVC	180 particles/g for domestic pig, and 97 particles/g for fetal pig
[21]	Animal: dog, MP: PE, PVC, PU, PP, PMMA, PET, PC, PS	Mean: 122.63 mg/g in dogs and 328.44 mg/g in human Dogs' testes: PE: 36.4%
[22]	Animals: cow, sheep MP: nylon, LDPE, PS	Cow: 0.14 items/g; sheep: 0.13 items/g Cow: nylon (98%) and LDPE (2%); sheep: nylon (18%), LDPE (40%), and PS (42%)

Impact on Animals

Numerous studies have documented the vulnerability of marine animals to microplastic exposure. Research on organisms such as mussels and fish demonstrates that microplastic ingestion leads to physical harm, physiological stress, and altered behavior, increasing risks such as oxidative stress and predation [23,24]. For example, exposure to microplastics has been shown to affect reproduction in oysters and cause physiological disruptions [25]. This ingestion can cause physical harm, such as digestive blockages and malnutrition, and in severe cases, it can lead to death. Microplastics also act as carriers for harmful chemicals, including environmental pollutants like persistent organic pollutants (POPs) and heavy metals. These toxins can bioaccumulate in animal tissues, leading to adverse health effects, such as endocrine disruption and immune system impairment. Research on marine organisms has shown that microplastic ingestion can lead to physiological stress. For instance, studies on mussels have demonstrated that exposure to microplastics can cause tissue inflammation and oxidative stress—a condition where the body cannot effectively neutralize harmful free radicals [26]. Additionally, fish exposed to microplastics have exhibited altered behavior, increasing their risk of predation [27].

Terrestrial animals, including livestock, are also at risk of ingesting microplastics through contaminated feed or water. This can lead to similar toxic effects, as observed in marine species, with microplastics accumulating in tissues and affecting overall health. The impact on soil organisms, such as earthworms, can disrupt soil health and fertility, leading to broader ecological consequences. The potential health risks of microplastics in domestic animals, as well as the possible exposure to humans through animal products, require further investigation. Studies on domestic animals have identified significant levels of microplastics in food, feces, and tissues, indicating widespread environmental contamination. Preliminary research suggests that cooking and processing might reduce microplastic contamination in animal products, though more studies are needed to confirm the effectiveness of these methods [28]. A summary is presented in Table 2.

Table 2. Exposure and effect of microplastics on animals.

Animal Group	Microplastic Exposure	Health Effects
Fish	Ingestion via water	Digestive blockages, internal damage
Birds	Pecking at plastic debris	Ingestion of plastic fragments, nutrient deficiency
Marine mammals	Ingestion via prey	Tissue inflammation, bioaccumulation of toxins
Terrestrial animals	Contaminated feed/water	Reduced fertility, impaired organ function

3. Human Health Implications

The potential health risks of microplastic exposure to humans are increasingly concerning. Microplastics have been detected in human tissues, including the liver, lungs, intestines, and even blood, suggesting that these particles can circulate throughout the body and potentially accumulate in various organs [29,30]. This bioaccumulation raises concerns about long-term health effects, including chronic diseases such as liver damage, fibrosis, and neurological disorders [31]. One major concern is the ability of microplastics to cause oxidative stress and inflammation, which may lead to tissue damage and contribute to respiratory issues, cardiovascular diseases, and even cancer [32]. For example, the inhalation of airborne microplastics can cause lung irritation and inflammation, increasing the risk of respiratory conditions like asthma, bronchitis, and chronic obstructive pulmonary disease (COPD) [33]. Long-term exposure could exacerbate these conditions, leading to more serious health outcomes [34]. The gastrointestinal system is also at risk. Microplastics found in human feces indicate their passage through the digestive system, where they can disrupt gut microbiota, interfere with nutrient absorption, and potentially exacerbate conditions like inflammatory bowel disease (IBD) [35,36]. Additionally, microplastics can act as vectors for harmful chemicals, exposing humans to toxic substances that may disrupt hormonal systems, leading to endocrine disorders, reproductive issues, and developmental problems [37,38]. A summary is presented in Table 3.

Table 3. Exposure and effect of microplastics on humans.

Human Exposure Route	Microplastic Accumulation	Health Effects
Inhalation	Lungs	Respiratory issues, lung inflammation
Ingestion (seafood)	Intestines, liver	Digestive disruption, oxidative stress
Ingestion (contaminated water)	Intestines	Hormonal imbalances, reproductive issues
Skin contact	Skin	Skin irritation, potential absorption of toxic substances

4. Socioeconomic and Ethical Considerations

The pervasive presence of microplastics in the environment has far-reaching socioeconomic and ethical implications. Economically, microplastic contamination poses a significant threat to industries reliant on clean ecosystems, particularly fishing and agriculture. For instance, the contamination of seafood has led to economic losses in the fishing industry and raised concerns about food safety, especially in regions where seafood is a dietary staple [39]. Similarly, microplastics in agricultural soils can affect crop yields and soil fertility, leading to broader implications for food security and the agricultural economy [40]. The costs associated with mitigating microplastic pollution are substantial. Governments and industries must invest in advanced filtration systems, cleanup efforts, and public awareness campaigns to reduce the presence of microplastics in the environment. These efforts require significant financial resources, which can strain public budgets and increase the costs of goods and services [41]. Furthermore, the potential health impacts of microplastics may increase healthcare costs, placing additional burdens on healthcare systems and individuals. Socially, microplastic pollution disproportionately affects vulnerable communities, including those in low-income areas and developing countries, where waste management infrastructure may be inadequate. These communities are more likely to be exposed to higher levels of microplastic contamination and less likely to have access to clean water and safe food [42]. This unequal distribution of environmental hazards raises significant ethical concerns, as these communities bear the brunt of the consequences of pollution for which they are the least responsible. Ethically, the persistence of microplastics in the environment and their potential to cause long-term harm to both humans and animals challenge our responsibility to current and future generations. The continued production and disposal of plastics without adequate regulation and waste management reflect a failure to address this growing crisis adequately. Addressing the microplastic problem requires a multifaceted approach, including stricter regulations, public awareness campaigns, and further research into the long-term health impacts of microplastic exposure.

5. Conclusions

Microplastics have emerged as a significant concern in both environmental and public health domains, with evidence of their widespread presence in both marine and terrestrial ecosystems. The ingestion of microplastics by animals and humans raises critical questions about the long-term health effects, especially given the potential for these particles to accumulate in tissues and organs. The variability in microplastic retention, influenced by factors such as particle size and polymer type, underscores the complexity of assessing their full impact. While current research has highlighted the risks associated with microplastic exposure, particularly the physical and chemical harms, the true extent of these dangers remains uncertain. This uncertainty is compounded by the fact that the effectiveness of common practices, such as cooking and processing, in mitigating microplastic contamination is still not fully understood. Given these challenges, it is imperative that future research continues to explore the pathways of microplastic exposure and retention, as well as the effectiveness of potential interventions. Addressing the issue of microplastic pollution requires a collective effort across multiple disciplines, reflecting the interconnected nature of environmental and human health.

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Abbreviations

EDI	Estimated daily intake	LDPE	Low-density polyethylene
PET	Polyethylene terephthalate	CP	Cellophane
PC	Polycarbonate	PVA	Polyvinyl alcohol
PA	Polyamide	PAN	Polyacrylonitrile
PE	Polyethylene	PBS	Polybutylene succinate
PVC	Polyvinyl chloride	PAM	Polyacrylamide
PP	Polypropylene	PSF	Polysulfone
PU	Polyurethane	POPs	Persistent organic pollutants
PMMA	Polymethyl methacrylate	COPD	Chronic obstructive pulmonary disease
PS	Polystyrene	IBD	Inflammatory bowel disease

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