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Microplastic and Nanoplastic: Causation, Issues and Solutions

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Abstract:

Plastic has been a pressing subject for discussion ever since its invention. It is extremely convenient to use and produce. However, plastic poses increasingly problematic threats to both the health of the environment and the public. Especially for microplastic and nano plastic, which are the byproducts of the degradation of large pieces of plastic. These smaller pieces can infiltrate the bodies of animals and travel up the food chain, detrimentally affecting the ecosystem. Furthermore, when microplastic enters the bodies of humans through food consumption and respiration, it causes an array of health problems. The endocrine system can malfunction due to the harmful chemicals added into plastic present in microplastic. To solve this issue, more policies should be made regarding the treatment of plastic, the amount of plastic produced, and teaching the population about the issues regarding microplastic. This paper provides in depth research regarding the cause of the microplastic pandemic, issues that it can inflict, and potential solutions to combat these problems.

Keywords: microplastic, nano plastic, food chain, endocrine disruptors, bioaccumulation.

1. Introduction

The invention of plastic in the 20th century brought about a largescale global production and usage of the material. Plastic appears in various forms, including cutlery, bottles, stationery, clothing, and more. It is favored by different kinds of industries due to its versatile nature, low cost, and how it can be easily mass produced. In current years, plastic pollution became a serious problem for both human health and the environment due to one of its most signature traits: it is not biodegradable. Scientists began to research more about this material, and found several chemicals that gives plastic its integrity, yet is harmful for living organisms. Since they cannot be removed through a natural process, large amounts of plastic are burned, dumped in landfills, and spilled into the ocean.

Through the exposure of plastic to ultraviolet rays, heat, enzymes, microorganisms and oxygen, it will start to break down into microplastics, and release different chemicals into bodies of water, under the ground or into the air. The chemicals include endocrine disruptors, flame retardants, fluorinated compounds, bisphenol a (BPA), and phthalates [1]. Studies have shown that chemicals produced from microplastics are even more harmful than and unpre-

dictable for the environment and human health. Microplastics are usually only less than 5 millimeters in length [2], which increases their bioavailability, and they will inflict more harm on more animals than bigger pieces of plastic [3].

The million pieces of microplastic will detrimentally affect the environment. Their presence in the environment, movement up the food chain and the locations they inhabit all directly pose new threats to the ecosystem. Microplastic has the potential to kill marine creatures through tampering with their hunger signals, hormones, and neuron system. Unnatural deaths of animals in an ecosystem in large amounts will result in a sharp decrease in the population number of their predator, since their food source is being depleted. Ever step of the food chain is linked, and if once chain changes, the entire balance is upended. Microplastics can easily travel up the food chain due to its size. Animals in the start of a food chain can accidentally consume microplastic, and then it will travel up the food chain, causing harm to each organism. Once ingested, microplastics can migrate to various organs such as the liver, kidneys, reproductive organs, and even the brain [4]. Eventually, the largest consumers, humans, will also be affected.

Plastic degradation will directly affect the health of humans. Through the food chain, exposure to air, and consumption of unfiltered water, the plastics that are created and left untreated find their way back into the human bodies, causing a variety of different illnesses. As mentioned earlier, the endocrine disruptors released from microplastics can cause various cancers and interfere with the human reproductive system. Breathing the microplastic present in the air can inflict cardiovascular and respiratory diseases in the long-term [5]. Other effects such as hormonal imbalance, immune system weakening, and the poisoning of the nervous system are all health issues threatening the lives of people.

The purpose of the article is to point out the issue of microplastics, illustrate the scope of the problem, the magnitude of its impacts, the implications concerning the environment, and how humans will also be negatively affected. The problems outlined lead to the conclusion that it is crucial to evaluate the risks that plastic poses to human health, propose effective solutions, and educate the public on these scientific findings.

2. Types and characteristics of plastic degradation products

2.1 Microplastics and Nanoplastics

When studying microplastics and nanoplastics, it's essential to identify their sources, including industrial emissions and the degradation of plastic waste. Next, consider their size distribution, as smaller particles can more easily penetrate biological membranes, increasing bioaccumulation risks. Additionally, the chemical composition of these plastics, such as polyethylene, polypropylene, and the presence of additives, determines their behavior and toxicity in the environment. Finally, their physicochemical properties, including shape, density, and surface charge, influence their distribution in the environment and interactions with organisms.

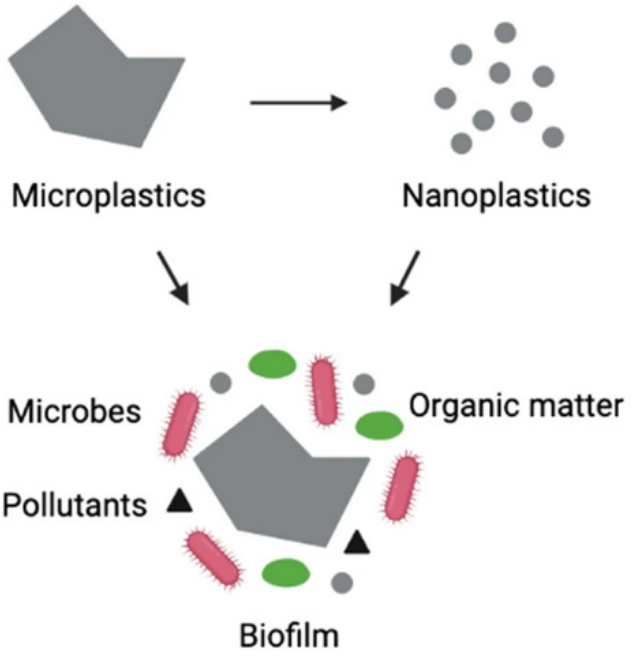

Fig 1. Difference of microplastic and nano plastic [6]

Microplastics are particles that measures less than 5mm, while nanoplastics are particles that measure less than0.1 μm. They can come from the breakage of larger plastic pieces, and microbeads, which are used in medical and cosmetic industries Micropastics are catergorized into either primary or secondary. Primary microplastics come from cosmetic, selfcare products, and they usually come directly from the sewers and wastewater. Meanwhile, secondary microplastics are formed from fragmentation, meaning they are big plastic pieces broken down into smaller pieces [7].Over 80% of all microplastics produced comes from land, degrading in landfills, and 20% derives from the ocean [8]. Distribution of plastic can vary based on the geographical location, with more microplastic typically concentration in areas of high plastic usage and production. Plastic are made up of polymer chains containing carbon and hydrogen atoms, also including 6 other types of polymers: polyamide (PA), polyethylene

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terephthalate (PET), polyethylene (PE), polystyrene (PS), polyvinyl chloride (PVC), and polypropylene (PP) [9]. Apart from the original polymers in the plastic, the degradation products also contain chemicals such as plasticizers and colorants. These toxic chemicals are bringing about serious issues regarding the environment and human health.

2.2 Toxic chemicals

It is crucial to understand toxic chemicals present in microplastic in order to fully grasp the scope of the effect that it has over the environment. Currently in the market, there are over 13,000 known and used plasticizers used to give plastic its signature physical traits. However, 3200 of those chemicals have been marked as concerning to the environment or the health of people [10]. Toxic chemicals in microplastics, such as BPA, phthalates, and heavy metals, can leach into the environment, posing significant health risks. These chemicals disrupt endocrine systems, cause cellular damage, and accumulate in food chains, leading to long-term ecological and human health impacts. Due to the prevalence of microplastics, these particles have been found in our saliva and our inner organs such as kidneys and liver. Furthermore, nanoplastics' size of less than 1 micrometer gives it the ability to enter cells, posing risks of cancer.

3. Impacts of plastic degradation products on ecosystems

It has been established that both larger pieces of plastic and microplastic pose threats to the environment due to their bioavailability, size advantage, and toxic component. Plastic can interfere with both aquatic and terrestrial life in 3 major ways: Polluting the environment, being accidentally consumed by life, and travelling up the food chain.

3.1 Aquatic life

The effect that microplastic has on the aquatic life is palpable. Studies have shown that if current trends continue, there will be more plastic than fish in the ocean by 2050. Microplastic can gradually sink to the ocean floor, mixing with the sediments at the bottom. Due to the chemicals that they emit, the plastic is responsible for changing the bacterial and microbial communities, changing the water composition. Furthermore, the nitrogen cycle in the ocean could be disrupted. Since nitrogen prompts plant growth, this can cause toxic algae blooms which can compromise the health of marine animals as well as the condition of the water. Changing the composition of the water means that plankton communities, which are responsible for oxygen levels in the ocean, may struggle for survival, further worsening the deoxidization of the ocean brought about by climate change [11].

Large pieces of plastic floating about in the ocean are easily mistaken for preys by marine creatures. For example, turtles can mistake plastic bags for jellyfishes, consuming them and harming their digestive organs. They can also tangle up in plastic debris, causing starvation and suffocation. Microplastic can be even more detrimental. Microplastic cannot be detected by the creatures of the ocean due to their size. Especially in shallow waters, this results in the microplastic being easily consumed by marine life, and can cause toxic contamination within their bodies. Studies have found that sea turtles who ingest just 14 pieces of plastic face more chance of death due to organ failure [12]. Bioaccumulation of toxins disrupts ecosystems, causing population declines and altering food chains, ultimately impacting biodiversity and marine health.

3.2 Terrestrial life

When animals eat more plastic, they obtain less energy since the plastic occupy their stomach spaces and reduce their signal for hunger. This applies to land animals as well as animals living in oceans. Regarding terrestrial organisms, the environment becomes a major factor as to why plastic is harmful. Around 86% of plastic waste is dumped in landfills [13], and it takes thousands of years to fully decompose. Toxic substances and microplastics can easily leak into the soil, contaminating the subterranean biomes, and also leaching into underground water sources. Since ground water is connected to lakes, rivers, streams, and the entire water system, toxic substance leakage can be devastating for an ecosystem. For example, in a mangrove ecosystem in Indonesia, the plastic waste problem resulted in a higher mortality rate of the mangrove trees [14], in turn threatening the egret species.

4. Threats to human health from plastic degradation products

4.1 Endocrine Disruption

Plastic degradation products, particularly microplastics and associated chemicals such as bisphenol A (BPA) and phthalates, are increasingly recognized as potent endocrine disruptors. These substances can mimic or interfere with the normal function of hormones in the body, leading to a variety of health issues. Endocrine-disrupting chemicals (EDCs) can bind to hormone receptors, alter hormone synthesis, and disturb the regulatory feedback loops of

endocrine systems.

BPA is a synthetic plasticizer to give plastic its shape, form and rigidity. It struggles to bind with estrogen receptors ERα and ERβ, resulting in the disruption of the endocrine system. Estrogen is responsible for the reproductive system, and its disruption can directly link to ovary, prostate, breast and colon cancer. On top of that, BPA has been shown to cause resistance of the immune system to chemotherapeutics like doxorubicin and cisplatin which are used to cure cancer.

Similarly, phthalates, if in the body, will lower estrogen and testosterone level. This is going to cause lower pregnancy rates, higher chance of miscarriages, early-menopause, and other complications related to the reproductive system. For instance, prenatal exposure to EDCs has been linked to reduced fertility and altered development of the reproductive system. Therefore, it can be inferred that endocrine disruption is associated with reproductive abnormalities, developmental disorders, and metabolic syndromes. Long-term exposure, even at low levels, can have cumulative effects, leading to chronic health issues such as diabetes, obesity, and thyroid dysfunction. The pervasive nature of EDCs in plastic degradation products underscores the urgent need for comprehensive assessment and regulatory action to protect public health.

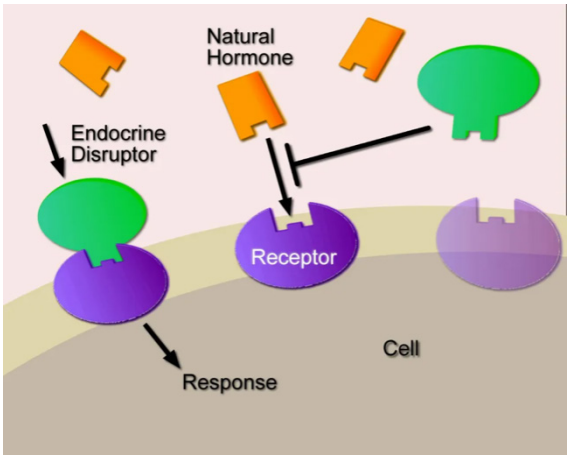

Fig. 2 How endocrine disruptors work [15]

4.2 Toxic Effects

Beyond endocrine disruption, the toxicological impact of plastic degradation products extends to a range of organ systems. Microplastics and nano plastics can serve as vectors for toxic substances, including heavy metals, dioxins, and persistent organic pollutants (POPs). These types of toxins are prevalent in animal fats and tissues due to microplastics' travel up the food chain, and its bio accumulative property means that it can be transported from host to host easily [16]. Furthermore, toxic metals like mercury are prone to attaching to these microplastic pieces, making them extremely toxic for animals and humans. Any kind of exposure to mercury, even in smaller amounts, can be the cause of serious health issues.

When ingested or inhaled, these particles can induce oxidative stress, inflammation, and cytotoxicity. Studies have shown that nano plastics, due to their less that 1 micrometer size, can penetrate cellular membranes, leading to potential damage at the cellular level, including DNA damage and apoptosis. The bioaccumulation of these particles in organs, particularly in the gastrointestinal tract, liver, and kidneys, can exacerbate toxic effects, potentially contributing to conditions such as cancer, neurodegenerative diseases, and cardiovascular disorders. The interaction between microplastics and the human microbiome is also an emerging area of concern, with potential implications for immune function and overall health. The toxicity of plastic degradation products, therefore, represents a multifaceted threat to human health, necessitating targeted research to elucidate the full scope of these effects.

4.3 Mitigation Strategies and Governance Measures

Addressing the health threats posed by plastic degradation products requires a multidisciplinary approach that combines scientific research, policy intervention, and public awareness. Mitigation strategies can be categorized into several key areas.

Firstly, policies can be implemented for lowering the usage of plastic in industries such as cosmetics, food, and tourism. Not only can this lessen the amount of plastic left in landfills, burned, and dumped in the ocean, but it can also lift the financial burden from industries. According to UNEP's report, if plastic is used more efficiently, at least 4.5 trillion dollars can be saved in the next 17 years [17].

Secondly, more plastic waste should be recycled instead of discarded after a one-time use. Only 9% of plastic in the entire world is recycled. 79% of plastic ends up in landfills or in nature, where they will do the worst damage to both the environment and human health. The reasons why less plastic is being recycled is the fact that there are harmful chemicals and labels can contaminate the plastic. Furthermore, recycling is expensive and not profitable for industries to focus their energy on. Since most of the world is still in development, reducing plastic pollution is not on the top of their agendas. To omit these concerns, plastic production must try to simplify plastic materials and reduce the production of plastic that can be replaced with other materials.

Lastly, the public must join in on the cause. People must try and advocate for policies that reduce plastic produc-

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tion. The culture of consumerism must be omitted. If plastic products are no longer purchased, then there will be less production. Cultures such as fast fashion all fall under consumerism category, and it can only worsen the problem of plastic pollution. Even though recycling is encouraged, on an individual level, it has little to no impact. Larger corporations must alter their practices to see major changes happen in the next few decades.

5. Conclusion

Microplastic has been a problem that is growing more and more dire by the day. Due to development of nations, the success of industries and the profitability of the material, plastic production and consumption has grown into a issue for both human and environmental health. Microplastic end up in the ocean and land, where it will be accidentally consumed by animals, hurting their health. Turtles mistaking plastic bags for jelly fish, whales getting tangled in plastic, and seagulls suffocating because it accidentally consumed plastic are becoming more and more common. Furthermore, the travel of microplastic up the food chain happens due to bioaccumulation and can have a wide sphere of influence on the ecosystem, eventually affecting humans. The harmful chemicals in plastic such as BPA causes hormonal imbalance, endocrine disruption, toxic poisoning and even cancer. It is more important than ever to come up with and implement a valid course of action which can create not just a ripple, but a wave of change. Policymakers, educators, business owners and citizens all around the world must cooperate and seek a way to stop plastic pollution and mitigate its harmful effects on the environment and people.

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