Review Article:

Microplastics - The Human Cost

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Abstract

This review examines the emerging microplastic issue with a focus on human health consequences while shedding light on the direction in which further research needs to head according to PRISMA guidelines.

Indexing services (SCOPUS and PUBMED) were utilized to select relevant studies (2018-2024), giving priority to original research, reviews, and meta-analyses. Non-English papers, those lacking full-text translation, proposals, opinions, studies on non-human samples/participants, and those showing statistically insignificant effects were excluded. Each study underwent a thorough evaluation for relevance and significance. After deduplication and application of exclusion criteria, 58 papers were shortlisted. Keywords used: "microplastic", "human health", "nano plastic", "pathogens", "bioaccumulation", "antibiotic resistant".

It was found that microplastics are ingested and act as vectors for pathogens and antibiotic-resistant bacteria. Human exposure may be linked with cytotoxic and genotoxic effects, especially in immune, gastrointestinal, pulmonary, and vascular cells. Vertical transmission is implicated during pregnancy. There is a need to identify novel sample collection and processing strategies.

In conclusion, the widespread presence of microplastics presents complex challenges for both the environment and human health. Urgent action is needed to address the risks posed by microplastic pollution through interdisciplinary research and collaborative efforts to develop effective mitigation strategies.

Key words:

Microplastic, human health, nano-plastic, pathogens, bioaccumulation, antibiotic resistance

Introduction:

In general, microplastic is the term used to refer to pieces of plastic that measure less than 5mm in length.[1] They may be of primary or secondary manufacturing origin and are insoluble in water.[2] Like any other pieces of plastic, these microplastics are extremely resilient and can persist in the environment for decades without any significant degradation.[3] One of the subdivisions of microplastics are nano plastics which are generally plastic particles smaller than 1 μm. For the sake of this review, microplastics will be understood to include this subdivision of nano-plastics. Microplastics, in addition to being in waterways, have also been found in drinking water and bottles of mineral water in many countries.[4] Additionally, microplastics have significantly infiltrated and accumulated in both marine and terrestrial food webs. Of note, this includes species that are of interest for human consumption, such as oysters and fish. [5]

In addition to ingestion of drinking water and contaminated wildlife, humans may also be exposed to microplastic consumption via the consumption of sea salt - a staple.[6] There is an imbalance between the rapid pace at which we produce and consume plastic products and the lack of efficient waste-management systems that are in place to deal with this mass-produced plastic. Instead, it is estimated that plastic waste has risen by 7.11% since 2021.[7] While this trend is a worrisome one, another emerging challenge that the world faces is that of microplastics. It is estimated that as of 2024, the United States will have approximately 267,000 tons of microplastics in its waterways - a staggering number no doubt but dwarfed perhaps by the even more gargantuan more than 787,000 tons of microplastics that China is expected to have in its waterways as of this year.[7] Evidently, the microplastic problem is one of the globally shared experiences.

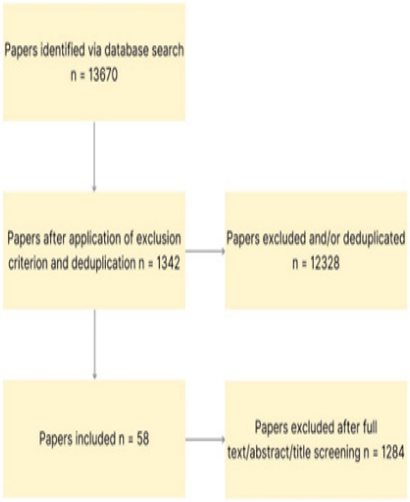
It is estimated that in 2024, nearly two hundred and twenty-two million tonnes of plastic waste will be created of which over 70 million tonnes will invariably find its eventual resting place to be in nature. As such, studies show that humans consume on average 50,000 particles of microplastic per year - a number that is found to increase significantly if bottled water is being consumed.[8]

It is therefore evident that we are facing a mounting challenge in the face of microplastics - unfortunately, due to the novelty of this issue, there is a lack of thorough understanding of its intricacies. This review serves three main objectives. Firstly, it consolidates scientifically noteworthy discoveries to provide a comprehensive understanding of the subject. Secondly, it delves into the human repercussions of microplas-

tic ingestion. Lastly, it illuminates the deficiencies in current research and highlights areas where further investigation is needed to enhance our collective understanding

Materials and Methods:

A literature review was conducted on Indexing services (SCOPUS and PUBMED). Pertinent studies, prioritizing original research, review articles, and meta-analyses were identified. The exclusion criterion included papers not published in English (or where full-text translation was not available), proposals, and opinion papers. Papers from before 2018 and papers that failed to reject the null hypothesis were excluded to maintain this review to only statistically significant findings. Lastly, papers that were found to have strong biases that may influence the findings and studies conducted exclusively on non-human populations/ cells were excluded. The author then conducted a thorough evaluation of each study to ensure relevance and significance. After deduplication of results and implementation of the exclusion criterion, a total of 58 papers were shortlisted for this review. The PRISMA flow diagram is available in Figure 1. The keywords used for this literature search were “microplastic”, “human health”, “nano plastic”, “pathogens”, “bioaccumulation”, and “antibiotic resistance”.



Results:

The proliferation of microplastics presents a growing challenge. Their remarkable durability means they can persist in the environment for decades without notable degradation.4

Humans may be exposed to microplastics either directly or indirectly. For instance, humans may indirectly consume contaminated marine or terrestrial animals or face direct exposure via direct ingestion or even inhalation. [6,9]

Microbial Infiltration and the Marine Biosphere: It's important to acknowledge that while the ingestion and buildup of microplastics in biological organisms pose inherent challenges, these are further complicated by co-ingestion of potential sources of illness. For instance, it is known that microplastics have an exceptionally long half-life, like all other forms of plastic. The half-life of estimated half-life of high-den-

sity polyethylene ranges from 58 to 1,200 years depending on environmental and intrinsic factors.[10] In contrast, microbial attachment to plastic surfaces occurs within a matter of minutes.[11] Of course, this is a worrying finding that microplastics can therefore persist for decades with colonies of attached microbes, waiting for biological ingestion.

Another note-worthy characteristic of microplastics is that they readily form biofilms.[12] Biofilm formation is a complex process that includes microbial attachment, release of polymeric proteins, and proliferation of microbial colonies in subsequently formed biofilms. Intrinsic physical properties of plastics such as hydrophobicity and microscopic "roughness" may influence and promote biofilm formation.[13] Additionally, Fungi, Algae, and Bacteria are all usually found in biofilms.[14] This type of multi-microbial cocktail has potentially disastrous effects in case of human consumption.

A study of biofilms that form on microplastics has shown the presence of pathogenic bacteria such as Pseudomonas, Vibrio, and Acinetobacter.[15] These microbial-infested microplastics are then readily uptake by marine life, including marine species that are of interest for human consumption.[16]

Interestingly, it is not as though these microbes lay benign within marine hosts and only cause disease in humans. They are responsible for major marine ecological disruptions too. For instance, Vibrio is a large contributor to bivalve (e.g. mussels) mortality.[17]

This comes at a great ecological and subsequent human cost, too. As the human population expands, we look for ways to ramp up food production to combat global food insecurity; the top sector of growing food production is aquaculture,[17] and when the marine ecology is invariably damaged, it contributes to a growing food insecurity problem.

Microplastics are also intrinsically harmful in nature, and this is amplified by their tendency to accumulate. They enter the marine food chain and bioaccumulate in organisms. They are toxic, accumulate in all levels of the food chain, and cause detrimental health effects including potentially causing death.[18,19]

Another way in which microbes may thrive in microplastics is the case of microbes that are present in the air - they may attach to microplastics (that are also present in the air) and be sheltered from potentially lethal ultraviolet radiation[20] and therefore flourish and be eventually ingested by humans. Microplastics in the air may be a consequence of agricultural erosion, a byproduct of waste management, degradation of synthetic fabrics and so on.[21]

Antibiotic Resistance:

Microplastics may also adsorb other harmful contaminants such as antibiotics.[22] This further compounds the issue of microplastic pollution and brings us to the next important sequelae of microplastic prevalence - the spread of antibiotic-resistant bugs and genes.[22] Antibacterial resistance Escherichia coli are readily available from wastewater in China.[23] Similarly, microbes resistant to beta-lactams were readily found in Ireland and associated with microplastic ingestion.[24]

In addition to serving as carriers for antibiotic-resistant pathogens,[25] microplastics also significantly contribute to the dissemination of antibiotic-resistant bacteria, with levels up to 5000 times higher on microplastics compared to water.[26] This holds immense significance, as while the microbial loads on microplastics may appear insufficient to cause immediate pathogenicity—E. coli typically requires a load of 105 Colony Forming Units per particle for disease onset, whereas microplastics typically contain a maximum of 104 Colony Forming Units per particle [27]—it's crucial to contextualize their role in admitting antibiotic-resistant genes.[28] Despite potentially sub-threshold microbial loads, microplastics carry genetic elements capable of conferring antibiotic resistance to other microbes, including those commonly found in the human digestive tract or other pathogenic strains. This underscores the critical importance of considering microplastics' contribution to rising antibiotic resistance trends and considering the multiple approaches via which microplastics may contribute to pathogenicity.

Human Exposure and Detrimental Effects:

It is evident human beings are being exposed to an abundance of microplastics.[29]

Human beings may be exposed to microplastics in a myriad of different ways. Studies show that an estimated 80g of microplastics per day may be consumed by humans from fruits and vegetables grown on polluted soil alone![30] Further, humans also risk exposure to microplastics from recreational aquatic bodies like swimming pools where there is a high usage of plastic products like spandex swimming suits, plastic swimming goggles and so on that may leech microplastics into the water.[31]

Another avenue through which humans may encounter microplastic exposure became apparent during the recent COVID-19 pandemic. Our increased dependence on disposable plastic items such as face masks, personal protective equipment, and face shields, coupled with their disposal in vast landfills, exacerbates the microplastic problem.[32] These plastics, resistant to rapid degradation, release microplastic particles that

can contaminate soil and water; and may even disperse through the air. Moreover, the COVID-19 pandemic has highlighted pathogens, especially viruses, tend to endure longer on plastic surfaces compared to others.[33] For instance, SARS-CoV-2 RNA was found to persist on face masks for up to a month,[34] reinforcing the notion that microplastics (and plastics in general) can prolong the survival of pathogens.

As mentioned earlier, human beings may also be exposed to microplastics via inhalation.9 This is cause for concern as it was shown that microplastics may induce apoptosis, disrupt protein expression, and arrest the cell cycle in epithelial cells of the lungs.[35] Further, higher microplastic levels have been linked with a higher risk of chronic obstructive pulmonary disease.[36]

Microplastics have also been shown to exert oxidative stress and apoptosis on human cells.[37, 38] In addition, they may promote the release of pro-inflammatory chemicals such as Interleukin 6 and activate the immune response.[39] Further, human lymphocytes are shown to be particularly vulnerable to microplastic-induced toxicity, a finding that raises concern for potential disruption to the homeostatic immune system. There is also evidence that microplastics may be a cause of genotoxicity for human cells.[40,41]

Microplastics have also been discovered in human blood,[42] further cementing the idea that they may travel around the body and accumulate in different organs. This is further problematic still because microplastics have been shown to cause direct cytotoxic damage to cells lining the vessel walls, namely vascular endothelial cells.[43]

Further, in-vitro experiments have also shown that microplastics - owing to their physical properties - may directly cause haemolysis for human red blood cells.[44]

Human exposure to microplastics and the subsequent ingestion of them is further solidified by the existence of microplastics in human faeces.[45] The human gut microbiota was also shown to be altered via the influence of microplastic exposure, an effect that may be potentially linked to the ability of microplastics to form biofilms.[46] This is an interesting finding that may potentially explain why higher concentrations of microplastics in faecal matter were found to be linked with a higher prevalence of inflammatory bowel disease in study subjects.[47] Further, microplastics were also linked with impaired gastrointestinal lipid absorption.[48]

There is also some emerging evidence that microplastics could act as a cancer risk factor for humans, specifically in a gastrointestinal environment but more high-quality research is required before any concrete conclusions can be made.[49] Potential in-

trauterine exposure is another domain of concern with microplastic exposure. Microplastics were found in the placenta and meconium of infants born via Caesarean deliveries.[50,51] Although worrisome on its own, this cause for concern is further compounded when considering that human ventricular valve development is shown to be significantly affected by microplastic exposure.[52] That being said, there is much to be discussed about the potential for contamination of samples and the issues with sample collection as a whole that may put into question some of the findings of microplastics in meconium and placenta. This will be further discussed in the "Future Research" subsection of this paper.

Propagation:

Microplastics are not susceptible to easy environmental degradation. They may travel very far distances in oceans, and this is cause for concern because of their ability to carry pathogens, antibiotic resistance, and their inherent ability to accumulate. There is therefore a potential for increased outbreaks of disease and easier propagation of foreign, non-indigenous pathogens.[53]

This is perhaps best seen in the results of a study that looked at the stool sample of a rural village in Indonesia - as many as 63% of participants were found to have microplastics in their gastrointestinal tracts.[54] The implications of this finding are concerning, indicating the significant exposure to and ingestion of microplastics even within rural farming communities. This underscores the environmental cumulative burden of the issue, as microplastics, potentially originating from distant marine sources, persist without degradation and find their way into communities. Thus, it suggests that despite minimal plastic usage or waste generation within these communities, they remain susceptible to microplastic ingestion.

Floating microplastics might also facilitate the spread of invasive species across natural boundaries.[55] This occurrence has the potential to significantly modify the native ecological balance of an area and cause disturbances to its indigenous biological communities.

As previously discussed, microplastics serve not only as surfaces for pathogenic species to attach to but also actively promote their proliferation and spread.[56] This significantly amplifies the potential for microplastic-bound pathogens to enhance their virulence, as the conducive environment provided by microplastics can facilitate the rapid multiplication of these harmful microorganisms. Consequently, this heightened virulence poses an increased risk of potentially devastating effects on ecosystems and human health.

Further Research:

Research into the potentially harmful

effects of microplastics faces a variety of challenges. First, there isn't a universally accepted, established method for sample collection that can ensure no sample contamination.

This is an issue in a lot of research studies - sample collection, storage, and analysis, all invariably use plastic materials in multiple steps of the process, and this can very easily contaminate the sample and skew the accuracy of results.[51]

Additionally, microplastics, owing to their small size and chemical inertness are extremely difficult to meaningfully test hypotheses upon, at least in humans.[57]

Yet another hurdle in the field of research is the vast diversity in the types of microplastics. Plastics and by extension, microplastics are of a variety of different types and may have different properties, physical and chemical. To then try to hypothesize an umbrella assumption that blankets all of their effects is a daunting task, perhaps one that isn't even doable.

Lastly, it is essential to segregate the effects caused by microplastics owing to their inherent qualities, from effects caused by additives or attached pathogens.[58]

Novel research methods need to be developed and concise questions need to be asked in to determine precisely whether the potential disease-causing aspect of microplastics is an inherent, fundamental quality or is attributable to attached pathogens or other additives.

Conclusion:

In conclusion, the pervasive presence of microplastics poses significant challenges to both the environment and human health. As evidenced by this review, microplastics have infiltrated various ecosystems, from marine environments to terrestrial food webs, and have become a ubiquitous presence in everyday life.

The implications of microplastic pollution are far-reaching and multifaceted. Not only do microplastics persist in the environment for decades, but they also have the potential to accumulate in organisms, leading to detrimental effects on ecosystems and biodiversity. Additionally, human exposure to microplastics through various routes, including ingestion and inhalation, raises concerns about potential health risks.

Human exposure to microplastics poses significant health risks, including potential respiratory and gastrointestinal effects, as well as implications for systemic inflammation and immune function. There is also concern regarding trans-placental transmission of microplastics in humans.

Addressing the issue of microplastic pollution requires concerted efforts from all sectors of society. Strategies to mitigate microplastic pollution must include improved waste management practices, the

development of environmentally friendly alternatives to plastic, and public awareness campaigns to reduce plastic consumption.

Collaborative interdisciplinary research is needed to better understand the full extent of the environmental and health impacts of microplastics. This research should prioritize the comprehensive characterization of microplastics, mechanistic studies to elucidate their biological effects, and the development of strategies to mitigate their impact on ecosystems and human health. It's crucial to distinguish between the effects triggered by the inherent qualities of microplastics and those induced by additives or attached pathogens.

Ultimately, addressing the challenge of microplastic pollution requires a collective effort to reduce plastic use, improve waste management practices, and develop sustainable alternatives. Only through coordinated action can we effectively protect the environment and safeguard human health for future generations.

Conflicts of Interest:

There is no conflict of interest to declare

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