The Impacts of an Invisible Hazard: Microplastics in Beauty and Fashion

GSR Beirut, LB

Jana Abou Jaoude, Amira Hijazi, Mariam Hoyek, Perla Mahfouz, Rosa Kalout

Faculty of Health Sciences Student Society

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By : Perla Mahfouz, Mariam Hoyek, Amira Hijazi, Jana Abou Jaoude, and Rosa Kalout(poster)

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Introduction

Microplastics (MPs) are defined as plastic particles less than 5 millimeters in size. These microscopic molecules have escalated exponentially in the scale of environmental concern due to their unsafe presence in ecosystems and the potential adverse impacts they may cause on human health and biodiversity. In fact, there is an estimate of 5.25 trillion plastic particles weighing over 250,000 tons floating on the surface of oceans worldwide (Eriksen et al., 2014).

A significant source of microplastics originates from their intentional addition into numerous products used by consumers, such as facial scrubs and glitter, which were found to contain up to 360,000 beads per tube. Microplastics are also prevalent in toothpaste (Chengappa, 2023). Moreover, they are being used extensively in the textile industry which relies heavily on synthetic fibers like polyester and nylon, constituting approximately 60% of global clothing (Ellen MacArthur Foundation, 2017). These numbers demonstrate that there are millions of tons of microplastics that are being released into the environment from various sources on a daily basis.

Understanding the toxicokinetics of microplastics is essential for understanding their potential impact on human health. Microplastics can be absorbed through various routes, including ingestion, inhalation, and dermal contact, leading to systemic exposure. Once absorbed, microplastics may undergo metabolic transformations and distribute throughout different tissues and organs, where they can persist for extended periods due to their resistance to degradation (Chen et al., 2016).

Microplastics have been implicated in a range of adverse health effects on humans, including neurotoxicity, reproductive and development problems, and chronic diseases. Microplastics can accumulate in neural tissues, ultimately resulting in cognitive malfunctions and neurodegenerative disorders. Additionally, microplastic exposure has been associated with disruptions in hormone regulation and adverse effects on fertility and fetal development (Liu et al., 2019). They can also lead to chronic diseases such as cardiovascular diseases, metabolic disorders, and cancer. These health effects urge for the expansion of research on the topic.

Despite the widely known toxicity and environmental hazards associated with microplastics, they continue to be used due to their unique characteristics and cheap cost. Plastics are durable, lightweight and moldable, making them essential in the production of consumer goods (Andrady, 2011). The convenience and economic benefits that come with the use of plastic explain why they are still extensively used to this day. This calls for the urgent need for innovative strategies to replace microplastics in consumer products.

Addressing the issue of microplastic pollution necessitates the exploration of solutions and alternatives to minimize their use. Finding alternatives to microplastics in consumer goods is a plausible approach. Research has found promising alternatives, one of which are Chito beads. They are derived from chitosan, a biopolymer found in the shells of crustaceans (Ma et al., 2018) Furthermore, big makeup companies like L'Oreal are starting to rely on natural ingredients in their manufacture, reducing the use of synthetic microplastics (L'Oreal, 2022). This paper will explore the miscellaneous issue of microplastics by expanding on each of the points addressed in the introduction; that is addressing its sources, toxicological pathways, effects on human health and proposing solutions.

How do Microplastics Reach Humans?

Microplastics are ubiquitous in numerous manufactured products, including clothing items and cosmetics. They pose a heightened risk due to their concentration in the fashion and cosmetics industry. The increasing use of microplastics in such products raises concerns about their potential entry into our bodies and subsequent detrimental effects. These microscopic particles can infiltrate our system through inhalation, ingestion, or dermal contact, with dermal contact being the least likely route of entry and thus the least harmful (Wu et al., 2022).

In the realm of cosmetics, two main types are distinguished: rinse-off and leave-on cosmetics (Anagnosti et al., 2021). Rinse-off products like exfoliating scrubs, shampoo, and toothpaste are washed down the sink, eventually reaching the wastewater stream. Conversely, leave-on cosmetics such as body lotions, powders, and mascara may either be washed off directly into wastewater or disposed of in landfills. This distinction between beauty products implicates a dual pathway of entry into the waste stream as well as our system. As for clothes, microplastics may be the result of shedding from synthetic fibers while laundering which will end up in the wastewater stream (De Falco et al., 2019).

A study has shown that 7 % of micro plastics in the environment in the EU originate from rinse-off cosmetics (L'oreal Groupe, 2021). This is the result of the rinse-off products, irreversibly contaminating the wastewater influent because most wastewater treatment plants are not designed to filter out microplastics. On the other hand, leave-on cosmetics infiltrate and contaminate the soil causing a huge risk of infiltrating groundwater aquifers. Whether this waste flow ends up in landfills or open dumps, there is a high probability of this incidence to occur due to the size and properties of these MPs that gives them the ability to overcome the landfill liners as well as the most impermeable of soils.

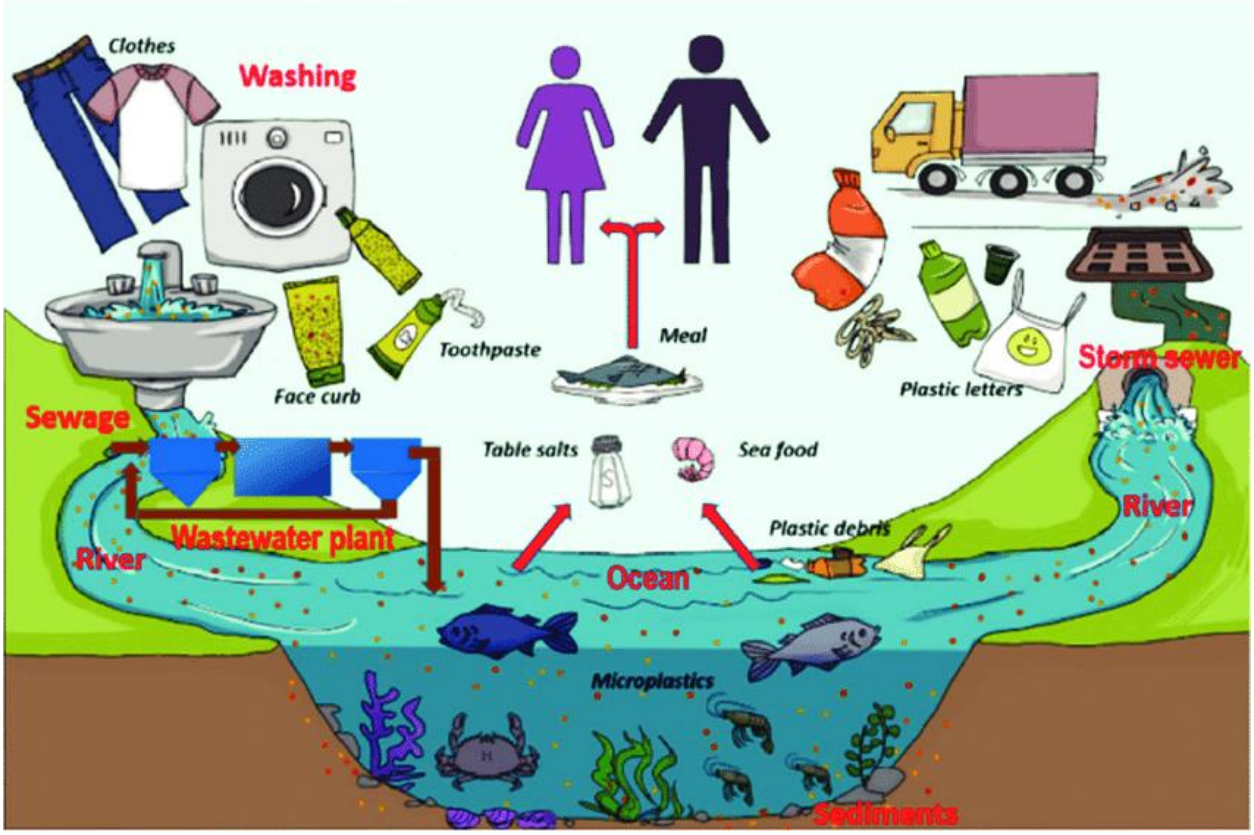

Figure representing the life cycle of Microplastics (Westphalen & Abdelrasoul, 2018)

Through these portals of entry, both cosmetics types and clothes affect diverse ecosystems. Organisms inhabiting the soil or the water like fish or plants will suffer from the toxicity of MPs. Knowing that MPs don't decompose (Wu et al., 2022), they have the ability to bioaccumulate, especially in marine life due to their hydrophobic nature. Therefore, paving the way to biomagnification, increasing the concentration of MPs when going up the trophic levels, eventually reaching humans who are most affected (Parolini et al., 2023). Microplastics are proven to be harmful towards ecosystems and organisms, but their effects remain unclear since they are dependent on their chemical and physical properties as well as the concentrations they penetrate in (Wu et al., 2022). Not to forget their synergistic effect in the presence of other contaminants or chemicals, some magnify the toxic effect and others tune it down, depending on diverse factors including the portal of entry which is a pivotal aspect. However, some findings on these characteristics have aided in explaining their toxic effects.

Toxicokinetics of Microplastics

Microplastics' unique chemical and physical characteristics dictate its toxicokinetics. MPs are generally defined as particles smaller than 5mm while nano-plastics are particles smaller than 100 nanometers (Illinois Environmental Protection Agency). Their microscopic size facilitates their entry and absorption into the bloodstream. As for their chemical structure, most MPs like polyethylene are hydrophobic in nature, further enabling them to cross cell membranes, even the nuclear membrane (Dutchen, 2023). Studies have shown that these microscopic particles are

mostly concentrated in the gut followed by the kidney and liver (Yang et al., 2018). Also, MPs (5 or 20 micrometers) have a residence time of about 16 days in the kidney, liver, and gut (Yang et al., 2018). Other important toxicological characteristics of microplastics like absorption, metabolism, excretion, and its ability to transport foreign material into the body will be discussed next.

Absorption:

After microplastics enter the body through the three routes of exposure (inhalation, ingestion, and dermal contact), they are absorbed through multiple ways. If they were ingested, insoluble MPs having a size smaller than 1.09 micrometers are absorbed in the gut epithelium and enter the bloodstream. Larger MPs can penetrate human tissues via paracellular transport (desorption) (Wu et al., 2022). As for inhaled MPs, they first deposit in the alveolar regions then reach the epithelial layers through gas exchange (Wu et al., 2022). Lastly, MPs may penetrate the skin, although to a limited extent, through pores. These may include NP(<100 nm) and synthetic fibers (<25 micrometer) (Wu et al., 2022).

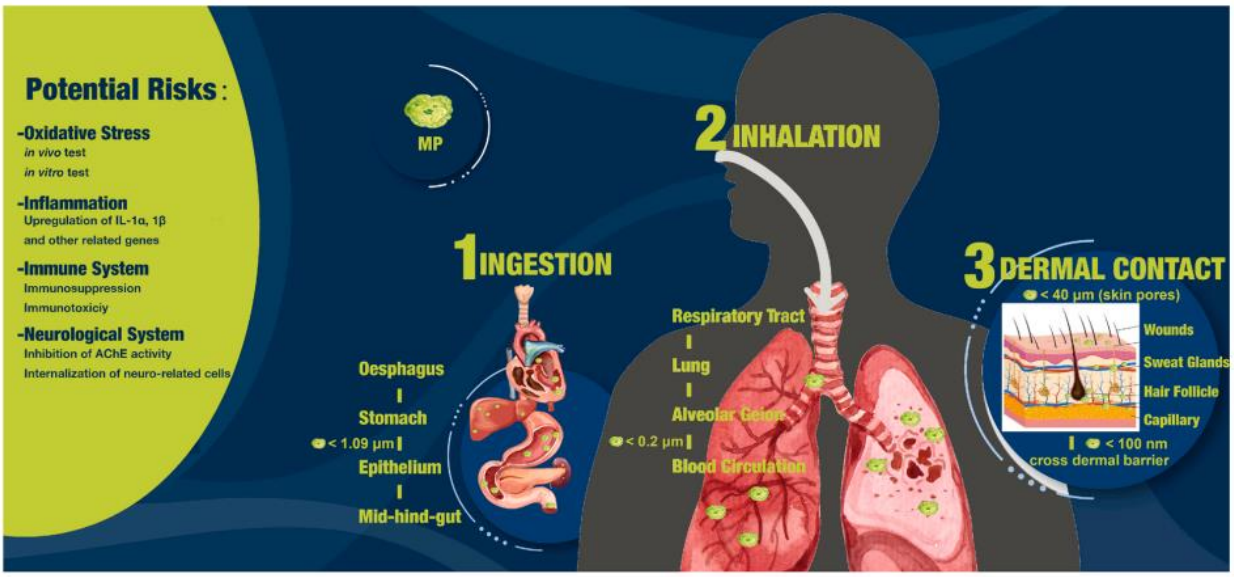

Figure showing the routes of entry, absorption, and potential risks of MPs (Wu et al., 2022)

Metabolism:

Microplastics are inert substances that do not undergo metabolism. This doesn't mean they don't affect metabolism. MPs have been linked to an increased generation of Reactive oxygen species (ROS) and the disturbance of antioxidants like superoxide dismutase(SOD), catalase (CAT), and glutathione peroxidase (GSH-Px). This in turn leads to various health effects on the body (Wu et al., 2022).

Excretion:

In general, Microplastics may be excreted through urine and feces. Although MPs are inert, some digestive enzymes can degrade and turn them into hydrophilic substances that can be excreted through urine and feces (Wu et al., 2022). On the other hand, undegraded MPs are directly excreted through feces. MPs' excretion is also influenced by their size. For instance, MPs smaller than 10 nm penetrate the kidney and are directly excreted through the renal pathway (Wu et al., 2022). Other nano-plastics may be excreted through tears, saliva, sweat, and breast milk (Wu et al., 2022).

Transporters of Foreign Substances:

Not only do microplastics hold their own detrimental health impacts, they also carry toxic substances and microorganisms that affect the body negatively. Their hydrophobic nature and large surface area increases their ability to absorb heavy metals like cadmium, lead, and mercury, which may easily leach into the body (Gao et al., 2022). Potential health risks may arise from such leaching. Other substances like PFAS (polyfluoroalkyl substances), phthalates, and BPA involved in the manufacturing of plastics may also pose their own detrimental health effects when leached (Gao et al., 2022). Both MP and the foreign substances were shown to have synergistic health effects (Gao et al., 2022). For instance, PCBs and MP may have a synergistic interaction on the immune system, liver metabolism, and oxidative stress (Gao et al., 2022). MP also enhanced the toxicity of Cd and Cu by increasing its bioaccumulation in the body (Gao et al., 2022).

Effects on Human Health

As previously mentioned, MPs can cause oxidative stress. This imbalance between oxidants and antioxidants may lead to DNA damage and mutations. Subsequently, this leads to organ dysfunction, to which the consequences can be organ failure, systemic complications and appearance of chronic diseases like lung disease (Ghosh et al,2023). Another result of oxidative stress is metabolic disorders (Ghosh et al,2023). It leads to liver damage, an imbalance in the intestinal flora, and the disruption in the functioning of the intestine since it targets the intestinal enzymes (Ghosh et al,2023).

Effects on Immune System:

MPs have been also linked to weakening the immune system. Cells get loaded up with microplastics and begin to behave differently. In turn they do not properly function and lose their ability to provide protection from harmful bacteria and pathogenic invaders, putting the immune system at risk(Ghosh et al,2023). In vivo studies demonstrate immunosuppression and abnormal immune responses like fathead minnow as a result of exposure to MPs (Wu et al., 2022). A decrease in phagocytosis and altered cytokine levels were also observed (Wu et al., 2022). Other studies suggest the decreased secretion of immune-related genes (Wu et al., 2022).

Effects on Nervous System:

Microplastics have been also observed to induce neurotoxicity in humans. In vivo studies showed MPs ability to inhibit acetylcholinesterase (AChE), alter the expression of neuro-related genes, and induce apoptosis and necrosis (Wu et al., 2022). This increases the risk of

neuroinflammation and impaired learning and memory (Wu et al., 2022). MPs can also damage the blood brain barrier, causing inflammation of the brain (Ghosh et al,2023).

Effects on Reproduction and Development:

Finally, reproduction and development are also affected by exposure to microplastics. Sperms in contact with microplastics will be of weak quality (Ghosh et al,2023). Moreover, exposed pregnant women may have a weakened immune system which affects the fetus (Ghosh et al,2023).

Effects on the Environment

Humans are not the only living organisms to be threatened by microplastics. The environment is also facing changes with the development and overuse of those microscopic substances nowadays.

MPs are found to disturb soil fauna's health and function. This is mainly due to Earthworms' inability to properly make their burrows in the soil (Ghosh et al,2023). Consequently, this leads to a different soil structure that is not aerated, altering physical properties that affect nutrient cycling and root growth in soil (a very important property since it prohibits soil erosion) (Ghosh et al,2023). Soil's fertility is also affected, making it difficult to grow crops (Ghosh et al,2023).

MPs from cosmetics and clothes that end up in water bodies also affect marine life negatively. According to National Geographic, ingestion of MPs diminishes the urge to eat, blocks digestive tract, and alters feeding behavior. This reduces reproduction and growth rates (Royte, 2021).

Solutions and Alternatives

MPs are very appealing for cosmetic and fashion industry manufacturers due to the ease of production and cheap cost. MPs are also produced at fast rates, which is in favor of the fast fashion era we live in (Anagnosti et al., 2021). Manufacturers also claim that MPs enhance product performance like viscosity of creams and elasticity of jeans (Anagnosti et al., 2021). However, as previously mentioned, their use has been linked to various detrimental impacts on both humans and the ecosystem; thus outweighing their benefits. Fortunately, alternatives have been discovered and used by many cosmetic and fashion companies.

Scientists have developed a new promising alternative – Chito beads. These beads are the result of natural, organic substance, chitin that consists of polymers of N-acetyl-D-glucosamine repeating units found in the hard-tissue component of crustaceans, fungi, and insects (Ju et al, 2021). Chitin is the second most abundant natural polymer (Ju et al, 2021). Chito beads possess biocompatible, antibacterial, antifungal, and hemostatic properties that make them ideal for replacing polyethylene microbeads (Ju et al, 2021). Other than their cleansing efficiency, they are

also biodegradable (Ju et al, 2021). This overcomes the issue of bioaccumulation in the food chain (Ju et al, 2021). Chito beads are produced via an inverse emulsion process, making their production relatively easy and fast (Ju et al, 2021).

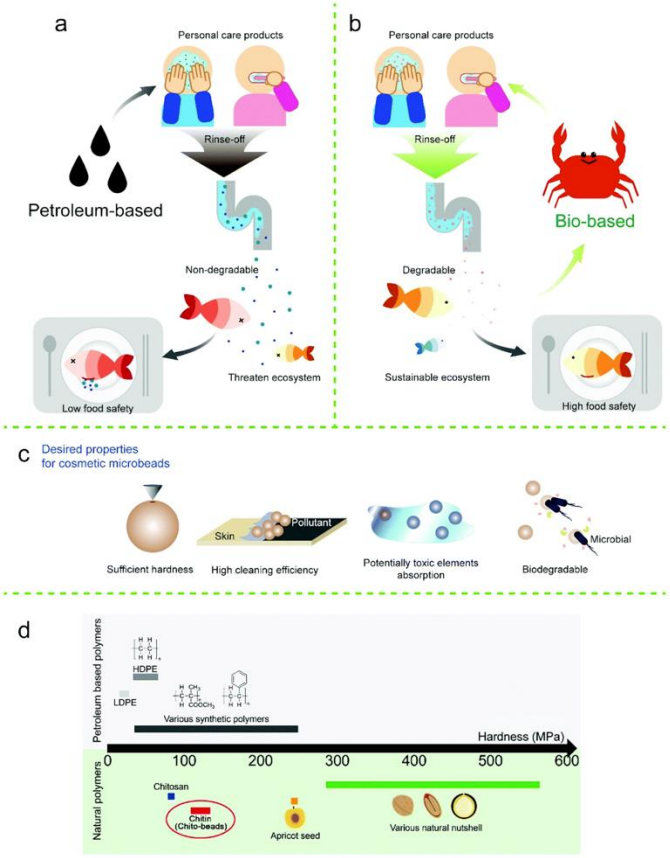

Figure showing the difference between petroleum-based microbeads and bio-based microbeads (Ju et al, 2021)

Other alternatives to microplastics are also being used today. Companies like L'Oreal use minerals such as clays or the powder of fruit kernels. These alternatives are natural and biodegradable, surpassing the negative environmental and health effects microplastics pose (Prance-Miles, 2018). After this shift, L'Oreal maintained and even had an increase in their profits and revenue due to many reasons, one of which is the increased demand for microplastic free products (Loreal Finance, 2024). A study conducted on AUB university students showed that 89.3% of respondents are willing to pay more for microplastic free products. Another study showed that 70% of respondents want to ban microplastic use in cosmetics (Regnier, 2020).

Some fashion companies are using biobased plastics made from plant-based origins as well. Cork from tree trunks, for example, is one promising alternative to plastic (Vidal,2024). Ancient Egyptians, Greeks, Persians, and Romans used cork to make fishing gear, barrels, and sandals (Vidal, 2024). Cork was used because it is waterproof, durable, light and pliable (Vidal, 2024). Today this substance regained popularity due to its appealing properties and is being used in manufacturing of clothes, shoes, flooring, insulation, and much more (Vidal, 2024). Cork is the outer layer of an evergreen tree found in many parts of the world but mostly located in Portugal, Spain, Morocco, Algeria, Italy, and France (Vidal, 2024). What makes cork very attractive is that

it doesn’t require cutting down any tree (Vidal, 2024). It simply entails stripping off the outer layer without damaging the tree (Vidal, 2024).

These alternatives are the best approach to manage the Microplastic crisis (World WildLife Fund). Mitigation measures are more sustainable than adaptive measures like recycling, putting filters and so on (World WildLife Fund). This is not to say that the adaptive approach is not promising and efficient, but it is favorable to prevent the problem from occurring in the first place (World WildLife Fund).

Conclusion:

As proposed in this research paper, microplastics present in cosmetics and fashion products pose a threat to human health and the environment, invading ecosystems and disturbing the mechanisms of vital organs. This paper examined the various sources, the pathways by which they reach the body, as well as the toxicological effects associated with these tiny particles. Furthermore, this research highlights the urgency for new solutions and the necessity of taking effective measures to regulate and manage microplastics pollution. By casting light on the intricate relationship between microplastics, human health and the environment, this paper adds on the expanding body of knowledge on microplastics. Evaluating long-term effects and putting forward policies to deal with this global issue is a must for the well-being of humans and ecosystems.

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