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Microplastics as Vectors for Metals from Mines and Fuels: Environmental Pathways and Implications

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Abstract

Microplastics can interact with metals, mines, and fuels in the environment through various pathways, including contaminant sorption, transport, bioaccumulation, and toxicological impacts. Understanding these interactions is crucial for assessing the environmental risks associated with microplastics and developing effective strategies for pollution mitigation and environmental remediation. Due to their widespread use in modern society and aquatic systems, micro/nano plastics, a subset of plastics with an effective width less than 5 mm, have emerged as a new type of micro contaminant. These tiny fragments of tarnished microplastic beads from cosmetic products, particularly from detergents and shampoos, have been discovered by researchers to be present in air, soil, lakes, and even the oceans. The pollution of our environment with microplastics is seen as a severe threat to ecosystems, particularly aquatic environments. The negative impacts of microplastic pollution can be effectively reduced by excluding them at the locations where they are discharged. Although the waste water treatment systems of today, are capable of eliminating microplastic to a limited extent. Due to their structural flexibility and multifunctionality, nanomaterials are being utilised more frequently today to treat drinking water and wastewater, which increases treatment efficiency. In particular, the versatile properties of nanomaterials have been employed to create high performance adsorbent and use it as a photocatalyst for removing microplastic from an aqueous environment. This review examines the removal and effects of microplastics while providing proactive ways to deal with any process bottlenecks.

Keywords: *Degradation, Environment, Micro/Nanoplastics, Pollution, Waste Water Treatment, Water Bodies.*

1.0 Introduction

As a class of developing contaminants of concern, microplastics (MPs) are pervasive in almost all environments on Earth, including the ocean, river, groundwater, soil, and even the Polar Regions. Microplastics, along with associated metals, can be transported through aquatic systems, including rivers, lakes, and oceans. They can serve as vehicles for the transport of metals released from mines or industrial activities, potentially spreading contamination to distant locations. Polyethylene, polyester, and polyvinyl chloride, which are found as microbeads, fibres, pieces, and granules, are among the plastic materials that make up MPs. These micro- and nano-particles are created when massive plastic trash is degraded chemically, physically, or biologically. MPs are dangerous because they pose a major risk to numerous life forms, including humans, whether consumed immediately or accidentally. They increase the risks to people, marine life, and the environment either by themselves or by reacting with other substances, such metals or other industry-based contaminants[1]. Large-scale mechanical breakthroughs have been made in recent years, and new materials and techniques are still being researched to further this subject. A major empowering

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innovation that may help with many everyday problems is nanotechnology. Nanotechnology-enabled developments present compelling chances for a notable improvement in the detection limit, characterisation and identification as well as the removal efficiency with regard to the treatment of microplastics. Without significantly altering the entire effort, they can probably be adapted into the current treatment procedure. It is not surprising given the flexibility of nanomaterial uses that they can be used to treat and remove microplastics. Without significantly altering the operation as a whole, they can be adapted into the current treatment process. As a result, the goal of this review is to emphasise the effectiveness of currently used treatment or removal approaches while also shedding light on the potential of designed nanomaterials in doing so. The state of our understanding of the methods used to remove microplastics is first discussed. The main obstacles of putting nano-enabled microplastic cleanup techniques into practise are also covered in the review.

2.0 Environmental Microplastics

MPs are constantly present as a robust structure in a variety of densities and contaminations (Figure 1). They come from various materials, including garments, plastic bags, containers, etc[2]. Recently, it was explained that the widely used flush-off beauty care products contain an abundance of necessary MPs exfoliators, including as microbeads/miniature sheds.

The degradation and enduring of necessary plastic waste, particularly the material fibre pieces and plastic pellets, yields optional MPs. The majority of these plastic flakes are discovered in different bodies of water. Microfibers in water typically have a size of 0.02 to 25.8 strands per litre[3]. The washing processes at various stages of assembly are the main source of microfibre release in the textile industry[4,5]. As a result, it should be noted that the majority of microplastics come from the clothing industry. The measurements show that most MPs in diameters ranging from 0.1 to 5.0 mm are dull. Fish is seen as a promising source of protein and necessary fatty acids for humans. Microplastics were absorbed by many living things, including humans, who consumed a variety of fish and shellfish (MPs). In light of this, there may be a risk to human health, which has recently become a cause for concern. MPs have been found in the tissues and organs of a variety of sea life, including fish and whales (Figure 2) MPs can also be found in tinned fish like sardines and sprats. As a result, the presence of MPs in large quantities in canned food has become concerning. MPs have since been discovered in food products, such as ocean food sources, table salt, drinking water, and more, in addition to in water bodies. Studies have revealed that MPs are present in human tissues and organs[6-8]. In general, MPs contamination can be reduced through meticulous monitoring of the MPs sources. Amazingly, there is compelling evidence that rice roots can absorb nano- and miniature-sized polystyrene, which is then transported to airborne components.

These shocking findings highlight the danger that nano/microplastics pose to our health by infiltrating the food chain.

3.0 MP Remediation Methods

Separation and degradation are key phases in MPs clean-up. These stages call for a variety of physical, synthetic, and organic techniques (Figure 3). Grids, primary sedimentation, flotation, quick gravity sand filtration, disc filtering, Dissolved Air Flotation

Figure 1. Microplastics from environment.

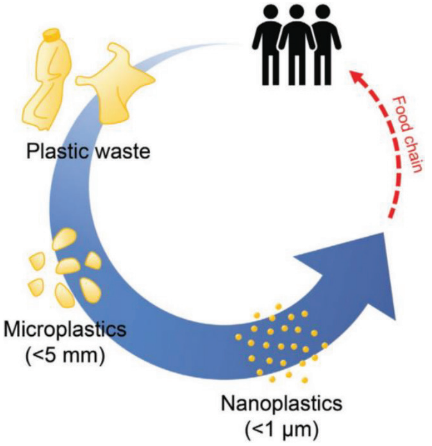

Figure 2. Micro/Nano plastics in food chain.

(DAF), Membrane Bioreactors (MBRs) and Reverse Osmosis (RO) are examples of traditional wastewater treatment techniques[9]. Plastics can be broken down by microorganisms using photodegradation, thermooxidation, hydrolysis and biodegradation. The natural degradation process known as photodegradation is carried out by the sun's UV radiation. Thermo-oxidative degradation provides the energy needed to integrate the oxygen molecules into the polymer. This cycle progressively degrades the polymer into useful, lighter-than-atom particles that are more conducive to microbial activity. Microbes have the ability to convert the polymer's carbon to carbon dioxide or incorporate it into proteins. Plastics may not entirely decompose for several years due to the interaction's extreme sluggishness. This method also has certain inherent drawbacks, such as increased time consumption and complexity despite the inability to distinguish between different polymers. Reverse Osmosis (RO) is a layer invention in which water is forced through a semi-film under strain. This invention can remove 90% of the MPs in wastewater and is used to remove a lot of water contaminants. In any event, it was unable to remove more MPs, which may have been caused by flaws in the film or tiny gaps in the pipes[10]. Low-thickness MPs that are suspended are removed with DAF. In this cycle, air is given at atmospheric pressure after being disintegrated in wastewater under high tension. These results take the shape of microbubbles that MPs adhere to, allowing them to be removed using a skimming device. DAF is less sensitive to stream fluctuations and MP attachment is made feasible by positively charging cationic surfactants and polymers.

The most noteworthy advancement for MP remediation is MBR, a technique that combines physical and biological remediation advancements. It includes both physical segregation using micro or ultra-filtration and biological catalysis[11,12]. The framework initially reduces complexity by allowing natural materials to biodegrade, helping to separate MPs through filtration in the process. As a result, the MPs in the following stream relocate. With MBR, 99.4% of MPs, including small amounts of biogenic litter, may be removed from the wastewater. Moreover, the marine microbial communities in marine sediments stimulate metabolic reactions that speed up the breakdown of chemicals connected to MP[13]. Numerous microorganisms, like *Antarctic krill* (planktonic scavanger)[14], *Aspergillus flavus* (growths) (Zhang *et al.*, 2020a), *Bacillus cereus* and *Bacillus gottheilii* (microbes)[15], *Fucus vesiculosus* (green growth), and *Egeria densa* (macrophytes) are fit for seggregating MPs. For treating MPs removed from wastewater, bioengineering these organic substances becomes essential. The same principle is used in actual oozing processes. The microorganism's extracellular polymeric discharges adsorb MPs, which causes the particles to degrade.

4.0 MP Remedial Approach through Bionanotechnology

Several more opportunities have been created as a result of nanotechnology and bioremediation working together. Due to the increased reactivity of nanoparticles, using tailored bionanomaterials for cleanup ensures more effective and affordable methods than traditional procedures (Figure 4). As a result, using nanotechnology in conjunction with bioremediation can shorten the remediation process without having an adverse effect on other natural systems[16]. Nanomaterials are adaptable substances that can be used as membrane filters, adsorbents, catalysts, or flocculants. An adsorbent, for example, can adsorb MPs in water. Adsorption is an exchange cycle when a particle from a fluid/gas interface bonds to a strong surface naturally or artificially. The most complicated strong adsorbent for residential water sanitization is activated carbon. A successful adsorbent is actuated carbon, which may be inferred from the material's large porosity and vast surface area. However, due to its high cost, its use is limited. As a result, different carbon allotropes and functionalized carbon nanomaterials are used because they are more efficient and cost-effective[17]. For the removal of MPs from wastewater, photocatalytic nano semiconducting materials make great candidates.

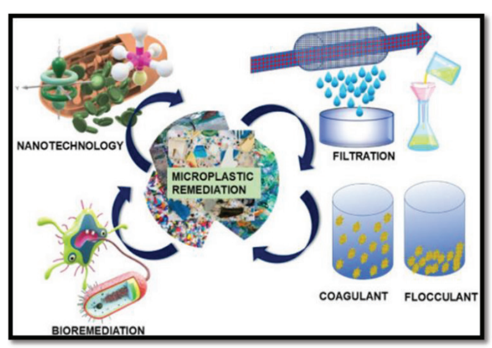

Figure 3. MNP remediation technologies through various methods.

Due to their high surface-to-volume ratios, which allow for more oxidation of contaminants than ordinary bulk materials and result in a superior synergistic effect, nanomaterials are of tremendous interest.

Both photo oxidation and photo reduction are included in photo catalysis as a whole. A filled valence band and an unfilled conduction band make up nano semiconducting materials. The electron-hole recombination that results from light being consumed by these materials with ideal energy to traverse the semiconductor's forbidden gap causes an electron vacancy to form in the valence band. The adsorbed molecule receives a positive charge, known as a hole, from this, which sets off a series of photooxidation and photoreduction processes that eventually damage the MP[18]. Round nanoparticles consistently have a lower surface area than hexagonal nano rods, which are also more durable and efficient.

5.0 MP Remediation by Bionanomaterials

Bionanomaterials are defined as nanomaterials with biological origins or those contain natural products. At the scientific level, bionanoremediation has proven to be extremely effective and worthwhile due to how simple it is to use in order to produce a superior product with less energy consumption. A bionanomaterial water filtering layer with a non-woven cellulose texture was used. A cast covering technique was used to impregnate several polysaccharide nanocrystals. Together, the nanocrystal or nanofiber coating increased the texture's hydrophilicity, stiffness, and flexibility. Each of these biomaterials demonstrated the ability to remove MPs as small as 500 nm[19]. The mechanical properties of the nanocomposite were improved by the addition of zeolite nanoparticles and heat treatment. A separation method called magnetic extraction uses hydrophobic Fe nanoparticles to bond to plastic and then be revived by magnetic recovery[20]. More than 90% of the MPs in seawater and other types of water, as well as from other sediments, can be recovered by these particles. Via the use of an outside magnet, MPs adhering to nanocomposites' surface were successfully removed from the water. Moreover, certain plant-derived nanoparticles have been discovered. These organic nanoparticles can produce excellent results while having less of an effect on the environment.

As a clever organic bio-flocculant, lysozyme amyloid fibrils were used. The flocculant is extremely likely to be termed a nano biomaterial because of its nanoscale size. For both dispersed polystyrene MP and humic acid separately, this flocculant offers excellent turbidity evacuation efficiency of more than 95% due to its higher reach pH surface[21]. It has been revealed that a photocatalytic Au-Ni-TiO_2 micromotor frames a reliable mechanism for molecular expulsion[22]. On this micromotor, nickel (10 nm) and gold (30 nm) were applied on TiO_2 particles that were 700 nm in thickness. A single micromotor's evacuation was triggered by phoretic interactions, whereas tied congregations relied on pushing interactions, according to two alternative processes for MP expulsion that were postulated. The final framework operates effectively, free of water and fuel in diluted peroxide solution, which is beneficial for MP evacuation under normal circumstances. They also showed that specific types of materials and forms were not necessary for the expulsion or removal of matter by light-driven micromotors. Controlling the nanomaterial size, which is particularly important for photocatalysis, is the test in green synthesis. There is little question that thorough research into green blending processes will improve green innovation.

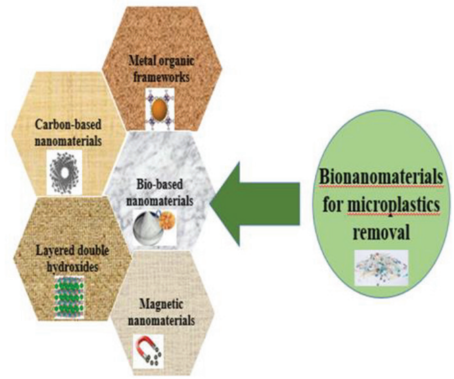

Figure 4. Bionanomaterials for MPs removal.

6.0 Conclusion

The interaction between microplastics and metals may also have implications for environmental remediation strategies. Microplastics could potentially be used as sorbent materials for the removal of metals from contaminated water or sediment, offering a novel approach for remediation efforts in areas affected by mining activities or fuel-related pollution. Micro/Nano plastics explosive growth is having a significant negative impact on human health and our biological system. In this way, there is a great interest in the need for novel monitoring and surveillance techniques to deal with these various poisons. In this context, we've discussed the many causes and effects of micro/nano contaminations as well as how bionanomaterials can be used to identify these toxins and get rid of them. The emergence of new technologies has led to the development of new ways to communicate. Bioremediation using a nanotechnological approach is one of the techniques. For the remediation of MPs, a combination of bionanomaterials and nanotechnology has been used. Bionanomaterials are naturally protected because there have been no reports of adverse effects. Moreover, bionanomaterials have adaptable qualities like adsorption and photodegradation that can be exploited to effectively remove MPs from the environment. Upcoming developments in nanotechnology will improve their ability to subtly destroy MPs. Nonetheless, it is essential to develop and work on ecosystem-safe repair methods.

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