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REVIEW ARTICLE

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Microplastic menace: a path forward with innovative solutions to reduce pollution

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Abstract

Microplastics are a very complex, diverse, and persistent contaminant class in aquatic ecosystems, providing significant challenges for scientists in developing analytical methodologies, fate and transport models, identification of exposure routes, and toxicological risk evaluation are all key difficulties for scientists. Despite a considerable and developing body of thought concerning the effects of microplastics on aquatic species, nothing is known about the effects of microplastics on humans. Microplastics have been found in food all across the world. As a result, human exposure to microplastics through tainted food is unavoidable, possibly creating health risks. In recent years, a major research effort has added to our understanding, but there is an urgent need to simplify and integrate the findings. This review focuses on the effects of microplastics as well as methods for decomposing plastics without creating microplastic particles. Among the various plastic breakdown methods, employing microorganisms and nanotechnology might be a long-term solution in preventing environmental microplastic contamination.

Keywords Microplastics, Pollution, Microorganism, Aquatic ecosystem, Nanotechnology

1 Introduction

Mankind has created an incredible variety of plastic materials. The fate of plastic particles is a complicated topic that is heavily impacted by the specific features of each type of plastic, such as form and size, polymer concentration, additives, contaminants, and environmental degradability. Although some nations such as Bangladesh, Kenya, Thailand, and Cameroon have banned plastic bags, there is still a curse chasing the world in the image of plastic. In consideration of the worldwide plastic toxicity crisis, several critical research needs as well as policy consequences should be explored (Rillig et al., 2021). Trash incineration is a widespread procedure all around the world to eradicate waste. Even though it is commonly practised throughout many worldwide locations, including India, roadside garbage burning is relatively unstudied as a factor that impacts air quality, radioactive forcing, and human health (Vreeland et al., 2016). Thermal insulation boards consisting of foam plastic construction materials such as phenolic, polyurethane foam, and polystyrene are also becoming extremely prevalent and highly used. If burnt, this might result in uncontrollable adverse effects (Morikawa & Yanai, 1989). PVA more than any other plastic polymer, has been blamed for the most significant problem today because it emits hydrogen chloride gas when burned (Dyer & Esch, 1976). Apart from this, e-waste plastics are regarded as one of the world's biggest trash streams. Some of the fastest-growing outdated products in the stream of electronic trash are waste mobile phones. Toxic chemicals including heavy metals and brominated flame retardants have been widely employed in electrical and electronic equipment's polymers. The current technical breakthrough in electrical gadgets, along with high and rising utilisation, has resulted in a massive waste of electrical and electronic equipment creation (Singh et al., 2020).

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The abundance of plastic debris in the aquatic realm is more than a complete disaster. Although pictures of garbage and floating material on the beach may jump to mind first, the majority of the current burden is about microplastic particles that are too small to be seen with the human eye (Cox et al., 2019). Numerous researchers have explained the terms 'microplastics' and 'microlitter' in different ways. Microliter is described as scarcely detectable granules with a diameter of about 0.06–0.5 mm, whereas mesolitter is described as granules bigger than this. Microplastics with sizes of 5 mm are often found in seawater (Andrady, 2011). In general, microplastics are divided into primary and secondary microplastics. Based on their inception, primary microplastics have been classified according to their size. Plastic beads used as exfoliators in cosmetics and as abrasives in toothpaste are examples of primary microplastics. Secondary primary microplastics are particles formed as a result of the abrasion and degradation of larger plastic components (Dris et al., 2016). Microplastics constitute a major potential danger to marine ecology and have rightly prompted a focus on environmental and physical study. However, the properties of the polymers that comprise them govern their formation, destiny, fragmentation, and tendency to adsorb or release persistent organic pollutants (Andrady, 2017). Because of bioaccumulation and long-lasting properties, persistent organic pollutants are known as silent killers. Persistent organic pollutants are found in virtually everyone's body in the current contaminated environment. Persistent organic pollutants have been discovered in foetuses, embryos and larvae, which is very difficult to believe. In this polluted world, foetuses are being born with persistent organic pollutants and have begun to collect more contaminants. Persistent organic pollutants concentrations are observed in people of all ages, with older populations having the highest amounts (Alharbi et al., 2018). Persistent pollutants include thermosetting resin pellets are melted and moulded into a large number of low-cost commercial products, many of which are abandoned after a short time of usage and then dumped indiscriminately into waterways where some are swallowed by marine life (Rios et al., 2007). It is scientifically proven that the microplastic level in the ocean is rising and presumably increasing the bioavailability of aquatic organisms such as fish, crustaceans, and seabirds like the Northern Fulmar. Microplastics are ingested by both filter-feeding and deposit-feeding invertebrates, according to laboratory research (Bakir et al., 2014). The fate and transport behaviour of microplastics is less comprehended with key determining factors which are solubility, product emissions, interactions, clustering, human uptake and accumulation (Coffin et al., 2021). In order to reduce the environmental and health impact of microplastics, appropriate biodegradable technologies must be used. By looking into the subtle human health consequences, identifying information gaps, and suggesting a novel biodegradation approach, this review contributes to the advancement of current research on microplastics. It also provides a complete framework for tackling the complex difficulties that are connected with microplastic contamination.

2 Potential effects of microplastics in the environment

The effects of microplastics are primarily toxicological in nature. When plastic pieces are leached carcinogenic chemicals are released. Microplastics are generated by the process of hydrolysis, fragmentation, incineration and ageing as shown in Fig. 1.

2.1 Microplastics — packets of curse to aquatic ecosystem

Microplastics are highly found in ocean sediments and surfaces as a debris patch. Microplastics are found in large quantities in urban waste streams and industrial effluent. Farm soils had been shown to contain microplastics. After intake, microplastics might be ejected, fermented, or retained. Microplastics have the capacity to attract hydrophobic chemicals in the biosphere (Kiran et al., 2022). They are swallowed or absorbed via the gills and such ingested microplastics could accumulate in the biological system. Hundreds of aquatic creations were discovered with microplastics in their stomachs (Singh & Devi, 2019). These absorbed microplastics undergo material leaching on the plastic matrix which promotes bioaccumulation in marine creatures (Shim and Thomposon, 2015). Microplastic ingestion has been recorded in a variety of marine creatures, including Copepods, euphausiids, larval fish, salps, and medusa have all been detected with microplastics in their guts. Microplastics have been found to build in blue mussel haemolymph, producing granulocytoma and lysosomal membrane instability as well as weight loss and reduced eating activity in lugworms, which have all been linked to microplastic consumption (Desforges et al., 2014). According to numerous researches, particles may be able to sink deeper, because saltwater volume increases with depth, microplastics remain suspended at the depth where their density matches the seawater. The pycno- and thermocline depths have been hypothesised to be similar to the depths at which microplastics are suspended (Courtene-Jones et al., 2017). Microplastics have been found on the ocean floor while the transport processes are unknown. Within days bio fouling develops and algae fouling colonies emerge on the plastic surfaces (Kooi et al., 2017). Defouling can occur due to a lack of light, grazing or the dissolving of carbonates in acidic

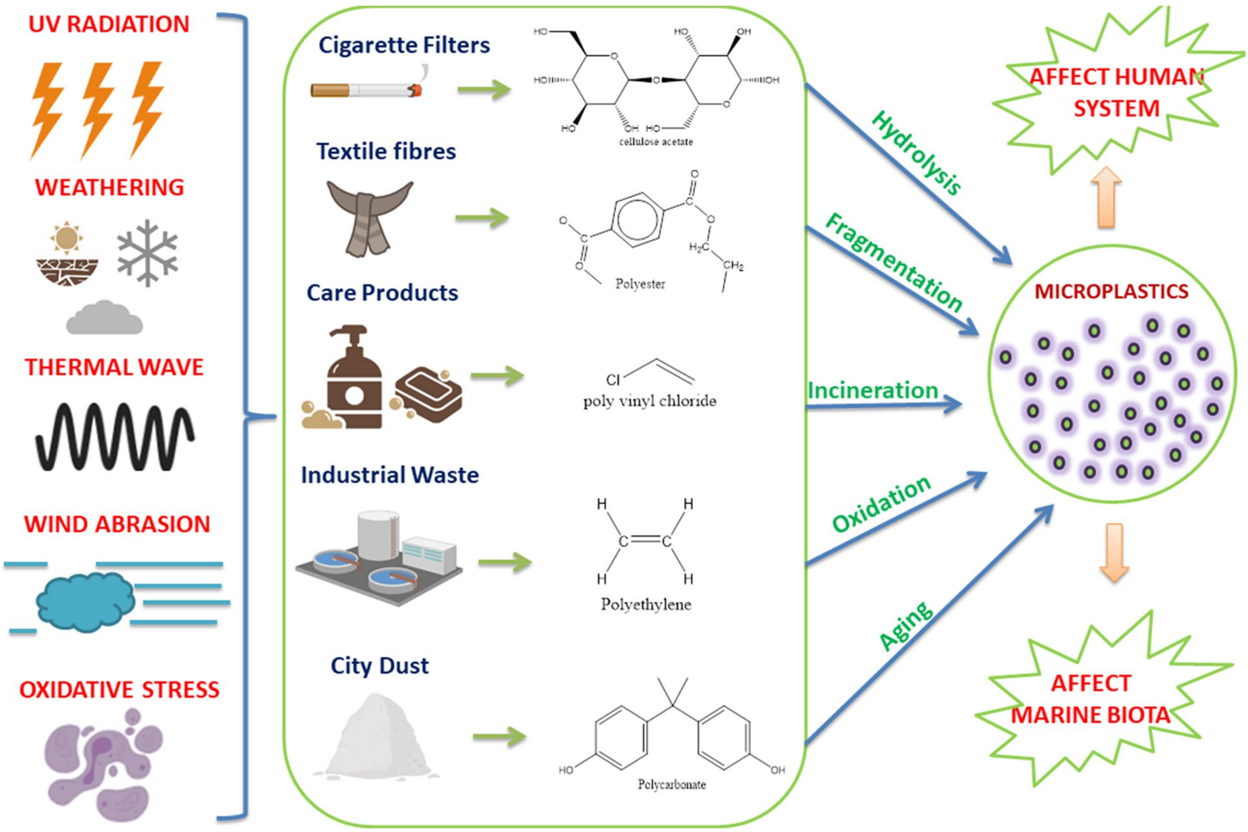

Fig. 1 Generation of microplastics

waters. Submerged fouling occurs as well, albeit with different algae species and at a slower rate (Kooi et al., 2017). Far beyond the shelf, the primary agents for the transport of microplastics are by gravity-driven transport in sediment-laden flows, secondly by settling or biological conveyance of material that was previously floating on the surface or suspended in the water column and also by transporting thermohaline currents, either during settling or by reworking of deposited microplastics (Kane & Clare, 2019). The sources of microplastics in the ocean are represented in Fig. 2 (Pandey et al., 2023).

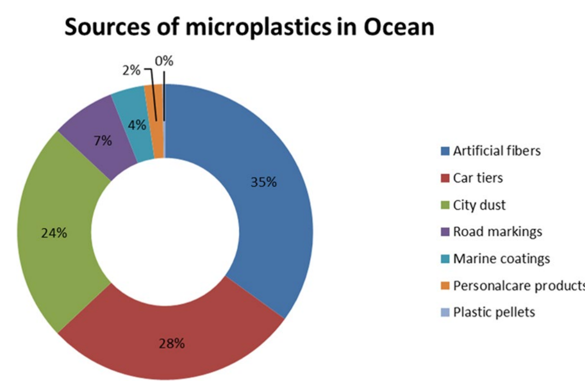

Fig. 2 Sources of microplastics in ocean

2.2 Microplastics — an intruder in Earth's atmosphere

According to a recent publication, the atmosphere should not be ignored as a possible source of microplastics because 29% of Synthetic fibres are partly plastic polymers. These microplastics might come from a variety of places: landfills or garbage incineration, decomposition of macroplastics and synthetic fibres from clothing and dwellings (Dris et al., 2016). Atmospheric fallout has been shown to include microplastics. Human lung biopsies have revealed the presence of synthetic fibres and particles with low toxicity can cause illness in those who are sensitive. Dust overload, oxidative stress, and translocation are all ways that microplastics might cause illness. Prolonged exposure to atmospheric microplastics might result in injury or death (Prata, 2018). Recently, microplastics have been discovered in the atmosphere of metropolitan, suburban and even remote locations far from microplastic supply regions, showing that microplastics may travel over exceptionally long distances. Microplastics in the atmosphere scatter sunlight effectively, indicating a cooling influence on the climate. They also absorb radiation emitted by the Earth, therefore they contribute to global warming to a lesser extent (Zhang et al., 2020). Studies on microplastics in terrestrial ecosystems are infrequent. Nonetheless, various investigations on the consumption of terrestrial organisms have been published. Plastic litter can penetrate the terrestrial ecosystem through airborne deposition and polluted water sources. Furthermore, plastic mulching in farming areas is a major source of plastic trash. Because of its widespread use and inappropriate disposal, plastic mulching is suspected of being a substantial source of microplastics in terrestrial settings (Huang et al., 2020). While studies prove that wastewater treatment plants play a potential role in elevating the microplastic in the environment. Microplastics can travel a considerable distance through the atmosphere, therefore they may be found all over the planet, even in inaccessible mountain catchments and polar locations. As a result, microplastics in the air are a source of pollution in both terrestrial and aquatic environments. The number and deposition of airborne microplastics have been shown to be influenced by human activities and environmental variables such as rainfall, snowfall, and wind. Microplastics can induce tissue irritation when inhaled or consumed (Chen et al., 2020). The sources of microplastics in Atmosphere are represented in Fig. 3 (Wang et al., 2020a, 2020b).

3 Exposure to microplastics

Airborne microplastics are known to induce sickness in industrial employees despite the fact that ambient exposure has not been examined. In contrast, typical exposure to low ambient levels of high-quantity microplastics results in occupational illnesses. Synthetic textiles, flock and polyvinyl chloride industries are three industries that potentially demonstrate the effects of airborne microplastics (Prata, 2018). Emitted particles from these industries can impact health by accumulating in the system. The aerodynamic diameter of the lung affects particle accumulation. The diameter of the fibre determines its breathability, whereas the length determines its persistence and toxicity. Pleural mesotheliomas are frequently seen in fibres that are over 8 m long and less than 0.25 m in diameter. Additionally, it is well known that the potency of fibre deposition rises as the diameter of the fibre decreases (Amato-Lourenço et al., 2020). Raman spectroscopy characterisation of the inhalation exposure to microplastics revealed that the size of the particles trapped in the lung tissue ranged between 1.60 and 5.56 μm (Amato-Lourenço et al., 2021). In Iraq, human exposure to microplastics was measured quantitatively from the skin of hands, faces, hair on their heads and saliva samples. Over 16,000 microplastics were found with the majority coming from head hair and the least from saliva. The most common microplastics were polyethylene-PET and polypropylene fibres with a diameter of less than 100 μm (Abbasi & Turner, 2021). It is also reported that the microplastic exposure may possibly cause colorectal cancer. According to evidence from occupational risk studies on colorectal samples suggested that microplastic exposure can induce colon cancer. Individuals with increased intestinal permeability, such as those suffering from inflammatory bowel illness, may be at greater risk of microplastic translocation into blood vessels and can penetrate into deep tissue which might have systemic consequences (Ibrahim et al., 2021). Microplastics are also found in table salt and drinking water creating unavoidable threats of exposure in humans. Microplastics in the human body were predicted ranging from 7.4×10^4 to 1.2×10^5/year through table salt and drinking water. Inhalation of microplastics, particularly indoor air, resulted in substantially greater microplastic intake than other exposure routes (Wang et al., 2020a, 2020b). Pet animals are also susceptible to microplastics since they share living space with humans. Studies on microplastic exposure to pet dogs and cats revealed that the polyethylene terephthalate was identified in all dog faeces samples at values ranging from 247,700—190,000 ng/g and polycarbonate in dog faeces ranged from 32—26,000 ng/g. Polyethylene terephthalate in dog faeces was two times lower in cat faeces. Polyamide thermoplastic elastomer was discovered at quantities ranging from 254 to 690 ng/g in all dog faeces and free-BPA was found ranging from 2.9 to 51 ng/g (J. Zhang et al., 2019). On the other hand, fishes consume enormous amounts of virgin microplastics. According to recent studies, huge amounts of virgin microplastics are found in fish liver and have a poor retention rate in the gastrointestinal tract of fish. Some large particles persisted in the liver, and at least one microplastic particle was discovered in 5.3% of the livers analysed. The

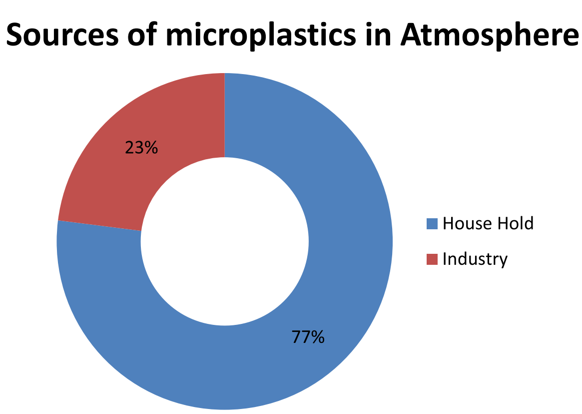

Fig. 3 Sources of microplastics in the atmosphere

researchers discovered that feeding six distinct types of virgin microplastics to *S. aurata* caused stress, slow development, promote pathology and accumulation in the fish's gastrointestinal system (Jovanović et al., 2018). Microplastics and other synthetic plastics have also been found in human food and components used to create it, as well as in human drinking water, according to the literature. Microplastics were discovered in tinned sardines and sprats, salt, alcohol, honey, and sweets (Barboza et al., 2018). In human, toxicity may result oxidative stress and inflammation. Inflammation can cause neoplastic and enhanced particle translocation. Microplastics may have a role in immune system disturbance and neurotoxicity (Prata et al., 2020). Depending on their dispersion and host response, microplastics can cause local and systemic immune responses after exposure. Environmental exposure can impair immune function in genetically vulnerable people, leading to autoimmune disorders or immunosuppression (Rahman et al., 2021). Few consequences of microplastic exposure are represented in Fig. 4.

The microplastic ingestion, stemming from contaminated food, water, air, and environmental sources, not only presents immediate health risks due to the potential release of toxic chemicals but also raises profound concerns about the long-term impact on human well-being and the environment, necessitating global efforts to mitigate plastic pollution at its source and understand the intricate complexities of this pervasive issue.

4 Ecological consequences of microplastics

According to current research, microplastics come from a variety of places especially synthetic fibres, rubber tyres, personal care products, and natural macroplastic degradation and their occurrence, transport, and fate in different environments are influenced by a variety of natural factors like UV radiation, thermal wave, and wind abrasion, as well as their own physicochemical properties like size and density (Wang et al., 2021). Mostly, rivers with high levels of plastic trash are adjacent to major cities, posing a serious threat to fish biodiversity and, in particular, general fish, and are linked to the consumer market. As a result, the prevalence of microplastics in fish consumption has created a significant dilemma in terms of the potential for human transference (35). Microplastics in the atmosphere are deposited on terrestrial surfaces and in aquatic ecosystems as a result of gravity and varied meteorological conditions. Rising cumulative

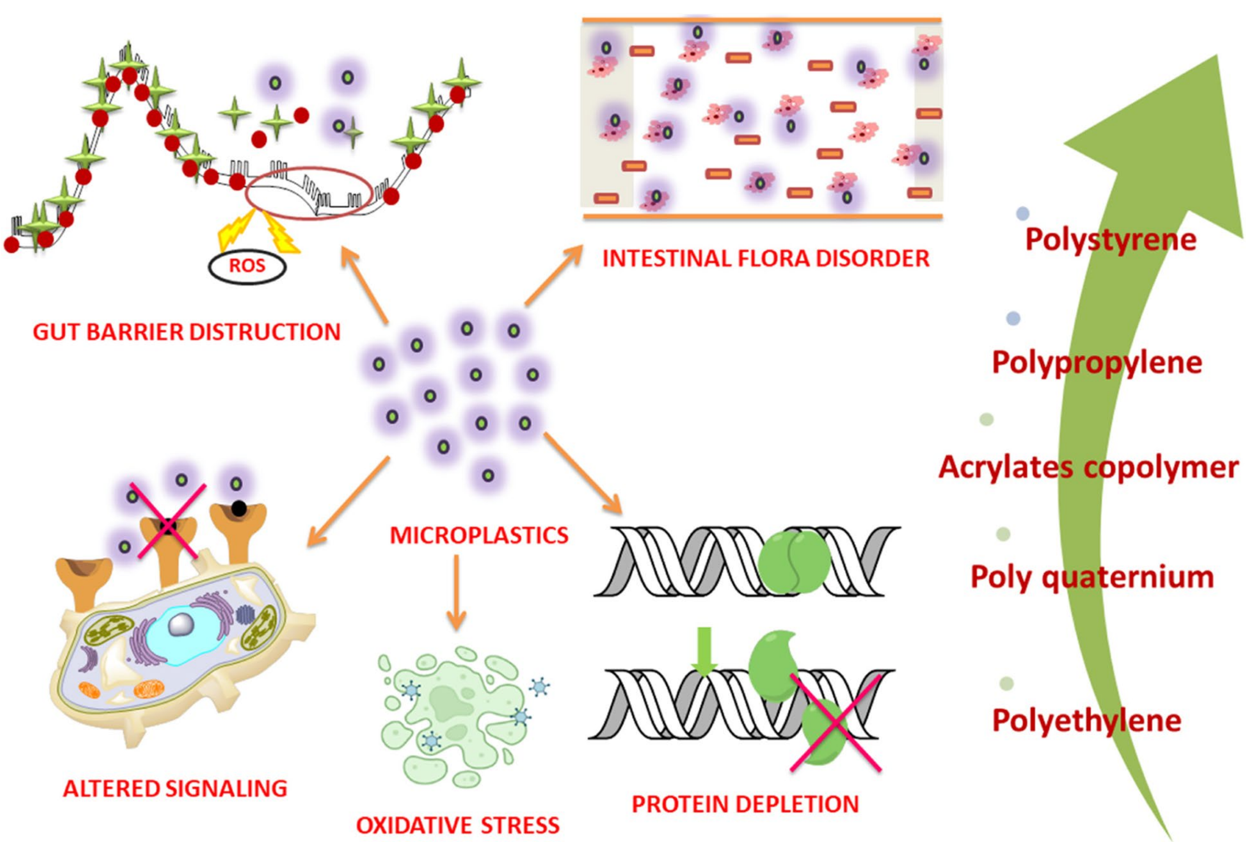

Fig. 4 Health consequences of microplastics

output and accumulation pose a serious threat to aquaculture systems, aquaculture product health, and human health via food chains (Chen et al., 2021). River Akora contains microplastics, and people are aware of their presence. This has a negative impact on their lives. It has also been discovered that the River's gutters/drains are the major source of pollution, since they feed the River with microplastics (Adu-Boahen et al., 2020). The negative consequences of microplastics were characterised as follows based on its fate after ingestion.

1. Build-up in the gastrointestinal tract, resulting in physical harm such as blockage and injury.
2. Pseudofeces are released followed by disrupting the energy flow of organisms.
3. Microplastics are exposed to tissues and organs due to translocation inside the body (Ma et al., 2020b).

Study on Euphausia superba in Antarctica krill revealed that microplastic consumption leads to dose-dependent weight loss. The majority of people were able to eliminate microplastics without any signs of bioaccumulation (Ma et al., 2020a). Microplastics enhance the deregulation of gene expression essential for oxidative stress management and activation of the transcription factor nf E2-related factor signalling pathway in marine vertebrates and invertebrates in biological systems. Microplastics induce oxidative stress, immunological reactions, chromosomal aberrations, endocrine system disruption, neurodegeneration, reproductive abnormalities, embryo toxicity and trans-generational toxicity due to these changes (Alimba & Faggio, 2019). Another study on prolonged exposure of microplastics on marine medaka with actual level-induced oxidative stress and histological alterations in the gill, gut, liver, and gonad. Furthermore, microplastics affected the HPG axis and steroid genesis pathway in a sex-dependent manner, disrupting sex hormone balance, delaying gonad maturation and impeding offspring development. These findings showed that microplastics have a negative impact on marine fish reproductive and may pose a threat to marine fish populations. (Wang et al., 2019). Chronic exposure in Japanese medaka resulted in excessive mucus production in the form of long strands across the gills primary and secondary lamellae. The buccal cavity, kidney and spleen all showed abnormalities on histological analysis. Epithelial thickening and roughening occurred in the headgut and neck, as well as cellular alterations in the spleen. The head kidney was the most commonly affected area. In exposed fish, glomerulopathy and nephrogenesis were seen, with the severity of glomerulopathy and nephrogenesis increasing with the level of exposure (Zhu et al., 2020).

While there are gaps in understanding long-term effects and standardised quantification methods, as well as ongoing research on effective strategies for eliminating this health concern, the current state of knowledge on the human health implications of microplastics suggests that there may be potential risks through ingestion and accumulation.

5 Strategies to overcome microplastic pollution

The most dependable strategy to avoid the development of microplastics is to minimise the production of new plastics entirely whenever feasible (Prata et al., 2019). Although local and national initiatives try to decrease microplastic's negative effects, worldwide policies and reduction objectives are crucial. Existing wastewater treatment facilities should be improved to effectively remove microplastics and prevent them from accessing surface waterways like rivers and the ocean. Even a smaller concentration of microplastics released per litre of effluent can significantly increase the microplastics entering the environment (Murphy et al., 2016). One easy and successful technique to prevent microplastic fibres from entering sewers is to modify filters in washing machines (Wu et al., 2016). Under neutral pH and sun irradiation circumstances, the inclusion of low molecular weight organic acids and low molecular weight organic acids-Fe has been shown to considerably accelerate the photo-transformation of PVC-Microplastics in aquatic settings by photo-generated hydroxyl radicals (Wang et al., 2020a, 2020b). Few considerations to reduce microplastic pollution are represented in Fig. 5.

5.1 Microbial degradation of plastics

Among various methods of microplastic degradation, Microbial reduction of microplastics appears to be a viable technique to eradicate microplastics among other treatments. Microplastic breakdown strategies, both biological and non-biological, are being investigated in several studies. Studies show that microorganisms including algae, fungi, and bacteria have aroused scientist's curiosity as a possible way to combat microplastics. Microbial enzymatic operations are inextricably linked to the degradation of microplastics (Othman et al., 2021).

Only a few studies on the elimination of microplastics have been conducted. Microorganisms such as bacteria, fungi, and biofilms can destroy microplastics. Microplastic biodegradation is influenced by microbial characteristics and ambient circumstances. The microbial degradation of microplastics involves a number of metabolic pathways. It is necessary to develop functional microbial agents in order to reduce microplastics (Yuan et al., 2020). A recent research on the vertical distribution of microplastics and microorganisms revealed that

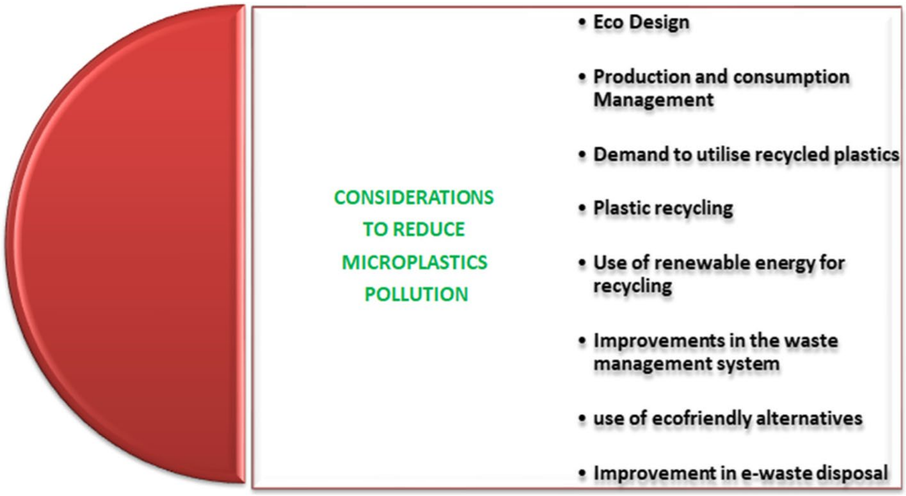

Fig. 5 Considerations to reduce microplastic pollution

plastic-degrading bacteria were abundant in the surrounding sediments with 4.33%. The amount of plastic-degrading bacteria increased considerably from shallow to deep levels, as did their betweenness centrality in the co-occurrence network, indicating that these bacteria may play a critical role in the breakdown of microplastics in deep layers (Niu et al., 2021). The mechanism of microbial reduction of microplastics is shown in Fig. 6. As society focuses increasingly on ecologically benign pollution and reduction measures, microorganisms for

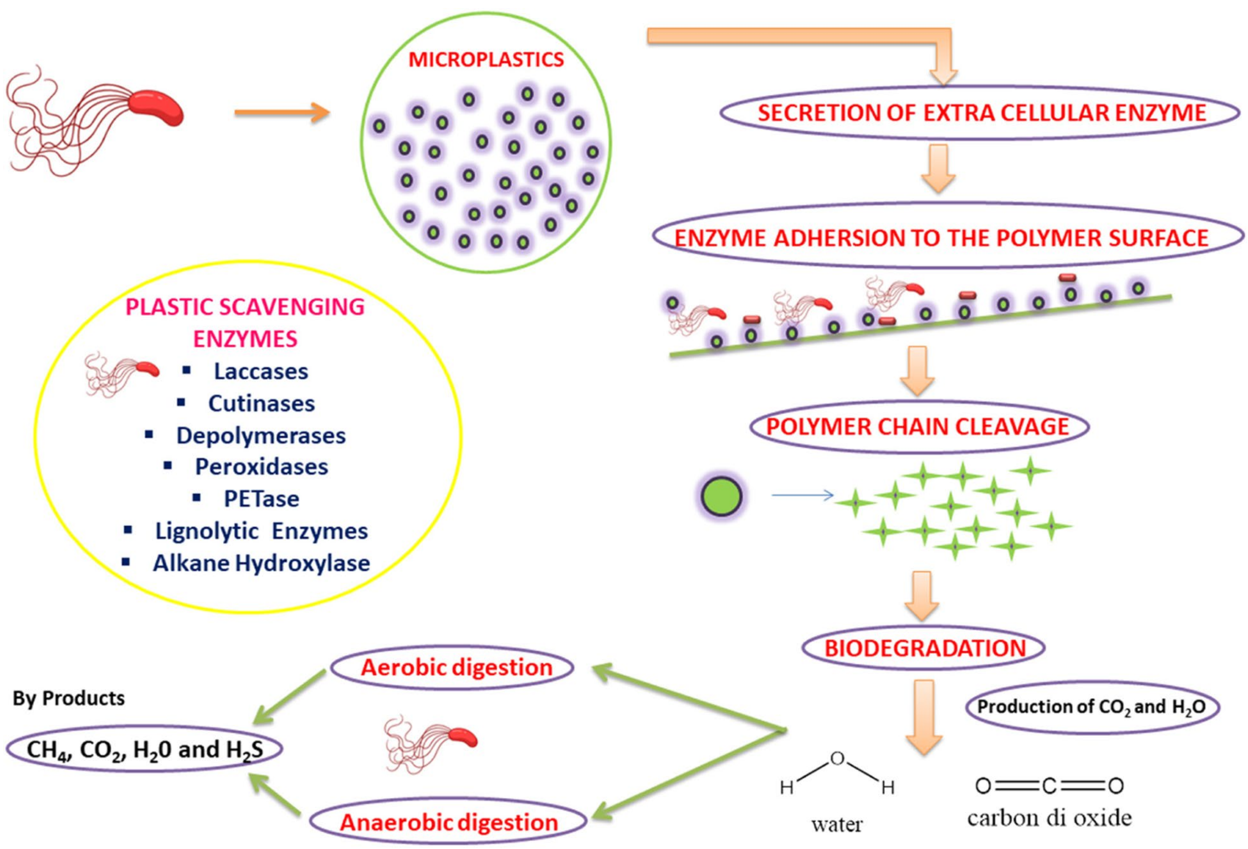

Fig. 6 Mechanism of microbial reduction of microplastics

microplastic breakdown have become environment-friendly pollution reduction strategies. Few plastic-degrading microorganisms are tabulated in Table 1.

Biodegradable technologies, particularly microbial reduction, play an important role in mitigating the environmental impact of plastics by utilising the capabilities of microorganisms, as these microbes contribute to the breakdown of microplastics through the formation of a plastisphere, a microbial community adhering to plastic surfaces, where enzymatic activities and metabolic processes facilitate the degradation of plastic polymers into less harmful byproducts, offering a promising avenue for sustainable plastic waste management as shown in Fig. 6.

5.2 Nanotechnology in microplastic degradation

Nanotechnology has the ability to improve energy efficiency, assist in cleaning up the environment, and tackle severe health issues. It is claimed that it will be able to greatly boost industrial output at much lower prices. Since microplastics are seen as a growing source of worry, nanotechnology could be a possible strategy to overcome the microplastic pollution (Biswas and Wu., 2005). Photocatalytic degradation of plastics results in the development of lower molecular weight intermediates, which can then be employed as raw materials in the chemical industry to produce new petrochemical products or plastics, or in organic synthesis (Bratovcic, 2019). In microplastic degradation, the catalytic efficacy and stability of functionalized carbon nanosprings are significantly improved, with significantly lower activation energy. The results show that the functionalized carbon nanosprings system can remove 50% of the microplastics by assisting with hydrolysis (Kang et al., 2019). Studies on photocatalytic degradation of microplastic residues using zinc oxide nanorods in visible light showed that the carbonyl index of residues increased by 30%, as did brittleness, which was accompanied by a large number of wrinkles, cracks, and cavities on the surface of the

Table 1 Synthetic plastic degrading microorganisms

Microplastic	Plastic degrading microorganism	Study outcome	Reference
Polystyrene	*Exiguobacterium* sp. strain YT2	Over a 60-day incubation period, a suspension culture of strain YT2 was able to destroy 7.4 ± 0.4% of the PS pieces (2500 mg/L)	(Yang et al., 2015)
	Xanthomonas sp. *Sphingobacterium* sp.	Styrene and polystyrene were reduced by 40% (9 g) and 56% (34 g)	(Oikawa et al., 2003)
	Cephalosporium species sp. *Mucor* species sp.	Incubating polystyrene for eight weeks with Cephalosporium sp. resulted in a weight loss of 2.17 ± 0.16% and 1.81 ± 0.13%	(Chaudhary & Vijayakumar, 2020)
Polyether polyurethane	*Aspergillus tubingensis*	The PU film was completely deteriorated into tiny fragments after two months in liquid medium	(Khan et al., 2017)
	Pseudomonas putida	It took 4 days to degrade 92% of Impranil DLN(TM) in order to maintain its development	(Peng et al., 2014)
	Aspergillus flavus	The weight of PU was reduced by 60.6% after incubation with Aspergillus flavus	(Mathur & Prasad, 2012)
	Bacillus subtilis	Bioremediation activities were reported	(Nakkabi et al., 2015)
Polypropylene	*Psychotria flavida and Humboldtia brunonis*	Laccase-producing Lasiodiplodia theobromae degraded irradiation polypropylene film with a weight loss of 0.3 mg	(Sheik et al., 2015)
	microalgae Spirulina sp.	The tensile strength of microplastic PET fell by 0.9939 MPa/day, whereas PP declined by 0.1977 MPa/day	(Khoironi & Anggoro, 2019)
	Lysinibacillus sp.	By incubating polyethylene and polypropylene for 26 days without pretreatment, they were deteriorated by 9% and 4%, respectively	(Jeon et al., 2021)
Polyethylene terephthalate	Engineered *Clostridium thermocellum*	After 14 days of batch culture incubation, more than 60% of the original mass of a PET film was transformed into soluble monomer feedstocks, suggesting significantly improved degradation performance	(Yan et al., 2021)
	Delftia sp.	Degrading 94% of microplastics	(Liu et al., 2018)

microplastics. The extent of oxidation was proportional to the surface area of the catalyst. (Tofa et al., 2019). Another study utilised zinc-cadmium photocatalysts to reduce microplastics and showed that the photocatalytic system accomplished H^2 evolution while also degrading PET (Cao et al., 2022). Polyvinyl chloride (PVC) microplastics were degraded using an electro-Fenton-like system with a TiO2/graphite cathode. PVC was effectively destroyed using TiO2/graphite cathode electrocatalysis. PVC dechlorination efficiency 75% and weight reduction 56% were both reported. Direct cathodic reduction was employed to dechlorinate PVC. During PVC degradation, oxy-organic species with C=O or O–H bonds were formed (Miao et al., 2020). Nanotechnology, with its capacity to enhance degradation rates, overcome microbial limitations, and provide tailored solutions for diverse plastic types, offers a more effective and eco-friendly strategy than microbial reduction for the efficient eradication of plastics.

6 Conclusion

Environmental pollution is a big issue in today's world. We are constantly ingesting microplastics through our food, drink, air, and other sources. It is critical to overcome this problem in order to keep human life on the planet. Despite their pervasiveness in many aspects of life and environment, little is known about potential methods for eliminating such a health concern. This study elaborated the available research on the human health implications of microplastics, knowledge gaps, and an alternate method to improve microplastic decomposition. In order to reduce the environmental impact of plastics, appropriate biodegradable technologies must be used. Microbial reduction is an alternate sustainable strategy to overcome such pollution. Microorganisms create a biofilm on the outside of pollutants resulting in a plastisphere, where they interrelate and produce acid and other enzymes for microplastic breakdown. Although microorganism-based biodegradation methods for microplastics are workable, nanotechnology-based techniques prove to be a more effective strategy. Hence this could be an efficient method to eradicate plastics in an eco-friendly manner.

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All aspects of this work, including the conception of the review topic, literature review and analysis of existing research were conducted solely by Jino Affrald. R.

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This review article does not contain any new data generated by the authors. The information and analyses presented in this review are based on previously published studies, datasets, and publicly available literature. The references for all the reviewed articles and data sources are cited appropriately within the manuscript.

Declarations

Competing interests
I confirm that there are no competing interest pertaining to the content or findings presented in this article.

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