

## Microplastics and Environment: A mini Review on Detection, Removal, Health Issues and Regulation on India's Perspective

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### Abstract

Plastics production has increased due to its flexibility, stability, lightweight, and low production costs. These plastics degrade through a variety of processes and lose their structural integrity. Plastics degrade extensively, eventually forming microscopic-sized plastics known as microplastics (MPs). MPs are small-sized and easily passed throughout the food chain. Exposure to MPs through ingestion, inhalation, and skin absorption can harm human health. Interdisciplinary collaboration will provide a comprehensive view of MP's effects. Researchers will collaborate with politicians and the public to improve the waste management practices of MPs by emphasizing recyclability and altering plastic manufacturing methods. This review provides an insight into the occurrence, detection, removal, and toxicological effects as well as challenges and regulations for MPs in a nutshell.



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### Introduction


The global demand for plastics<sup>1</sup> has increased exponentially due to its flexibility, mechanical strength, lightweight, and affordability. Plastics are integrated into our day-to-day lives. It has been widely used in utensils, packaging materials, the automobile industry, electronic appliances,<sup>2</sup> construction,<sup>3</sup> furniture,<sup>4</sup> sports equipment,<sup>5</sup> and more. Globally plastics production has increased tremendously and by 2050<sup>6</sup> the production is projected to stretch per year by 34 billion metric tons. In recent decades<sup>7</sup> remarkable rise in the extent of single-use plastic

waste has been noted and only around 20% of plastics only recycled for further use. Plastics that enter the environment slowly break down into micro- and nano-particles<sup>8</sup> under the influence of constant external forces like wave washing, UV radiation,<sup>9</sup> weathering, biodegradation,<sup>10</sup> aerial oxidation,<sup>11</sup> etc. It is an increasing contaminant that has raised a lots of concern in the community. MPs have the potential to move through various environmental media<sup>12</sup> and can be found in soil, air, and water.<sup>13</sup> The majority of MPs in the atmosphere are carried by wind, and they can deposit by both wet and dry media on soil

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and water. Recently, a number of research on the origins of MPs and the analytical techniques required for detection<sup>14</sup> have been conducted. MPs mostly enter in the human body through the skin, food, and respiratory systems. MPs have the potential to be consumed and stored by organisms,<sup>15</sup> impacting

the ability to survive, grow, immunity system and reproductively etc. Human health<sup>16</sup> is significantly harmed by MPs. This review's primary goal is to shed light on the incidence, identification, elimination, and toxicological effects of MPs in a nutshell.

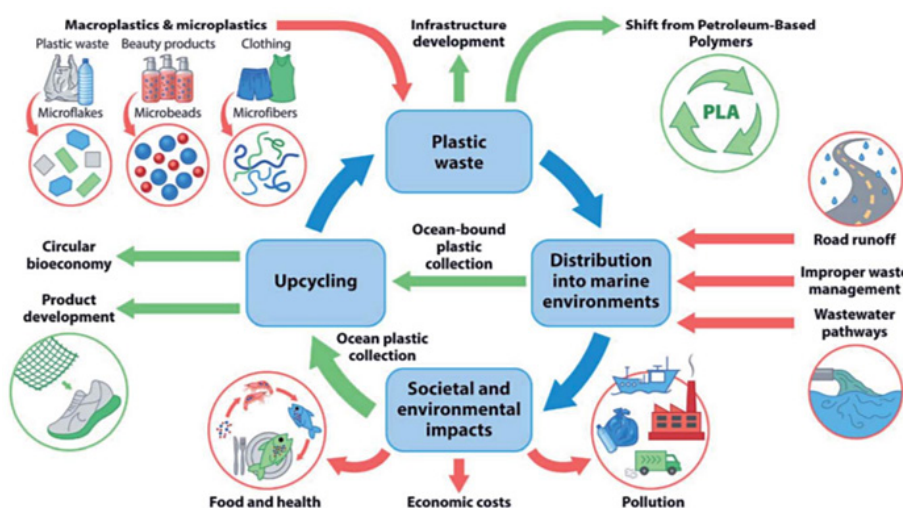


Fig. 1: Sources and transportation of MPs

Microplastic Category	Source
Polyethylene (PE)	Facial cleanser, toothpaste, etc
Low density polyethylene (LDPE)	Plastic bags, bottles, fishing nets, straws, etc
High density polyethylene (HDPE)	Milk, juice cans, cosmetic packaging, etc
Polyvinyl chloride (PVC)	Plastic film, plastic cup, etc
Polyethylene terephthalate (PET)	Bottles etc.
Polypropylene (PP)	Rope, bottle caps, etc
Polystyrene (PS)	Food containers, plastic utensils, etc
Polyamide (PA)	Fishing nets etc
Foam polystyrene (FPS)	Buoys, bait boxes, disposable cups, etc

Fig. 2: Main categories of MPs.

**What is Microplastics (MPs)**

The term "microplastics" was first used by Thompson *et al.*<sup>17</sup> in 2004. MPs are plastic pieces that are smaller than 5 millimeters in size.<sup>18</sup> Natural polymers such as rubber and cellulose can also be categorized as MPs, in addition to synthetic ones. MPs are utilized in the manufacturing sectors<sup>19</sup> and in the process of 3D printing. They can be found in everyday items like synthetic clothing material, toothpaste, and beauty products etc. These microbeads are also created

when plastics disintegrate into small particles. MPs come in various colours, compositions, sizes, and shapes.<sup>20</sup>

In accordance with sources, MPs are classified into primary MPs and secondary MPs. Plastics that are directly produced in the course of production and finally released into the environment are referred to as primary MPs. Personal care products, medical products, wastewater, and water-based

coatings<sup>21</sup> are the main sources of primary MPs. Secondary MPs are characterized as broken pieces of bigger plastic objects that are prevalent in both terrestrial and marine environments and suffer from fragmentation. Figure 1<sup>22</sup> shows the sources and transport of MPs. Large plastic also breaks down into little fragments<sup>23</sup> due to weathering. Oxidative photodegradation process<sup>24</sup> also breaks down the polymer and forms MPs. Figure 2 shows the main categories of microplastics.<sup>25</sup>

### Detection Techniques

Due to inadequate waste management systems in developing countries, the majority of plastic garbage is dumped in vacant landfills. When embedded plastics get the exposure of sunlight, bacteria, aerial oxygen, and mechanical stress they degrade into MPs.<sup>26</sup> Detection and quantification techniques for MPs are yet to be standardised. However, available approaches are often divided into two categories: physical and chemical procedures.

MPs can be identified by a physical method using visual inspection or by microscopy due to their unique physical properties. Though this method has several advantages, such as the fact that it does not require a trained analyst, costly apparatus, or

poisonous reagents, this method is not precise as soon as the particle size decreases to below 500  $\mu\text{m}$ .<sup>27</sup>

Common methods for the characterization of MPs incorporate chemical methods, in this method, more precise results can be obtained. Raman spectroscopy, FTIR spectroscopy along with  $\mu\text{FTIR}$  or  $\mu\text{Raman}$  are used for the distinguishing proof of MPs. Pyrolysis-gas chromatography/mass spectrometry (Pyr-GC-MS)<sup>28</sup> is also very popular for the detection. Another strategy to examine the recognizable proof of MPs is scanning electron microscopy (SEM). In SEM morphological information can be obtained from the pictures usually taken in high-resolution. Furthermore, SEM along with energy-dispersive X-ray spectroscopy (EDS<sup>29</sup> or EDX) provides a high-pitched image. Novel strategies too created for the detection such as thermogravimetry and differential scanning calorimetry (TGA-DSC), desorption, thermal extraction, gas chromatography, and mass spectrometry.<sup>30</sup> The integration of several approaches can complement one another and help to overcome the obstacles associated with the recognition of MPs.<sup>31</sup> Figure 3 summaries the different detection methods for MPs.

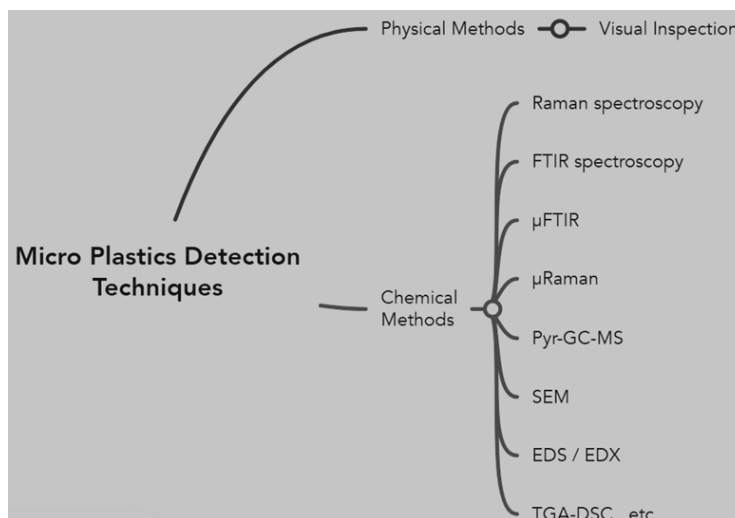


Fig. 3: Detection methods of MPs.

### Removal Techniques

It is important to isolate and remove MPs. The physical nature like shape and the chemical nature of MPs, including size, texture, density,

and other sediments could affect the separation process. Several techniques have been developed over the years. These techniques in general are categorized into physical, chemical, and biological

methods. Every technique has both advantages and disadvantages also. Here the latest solutions of some of the techniques are mentioned below.

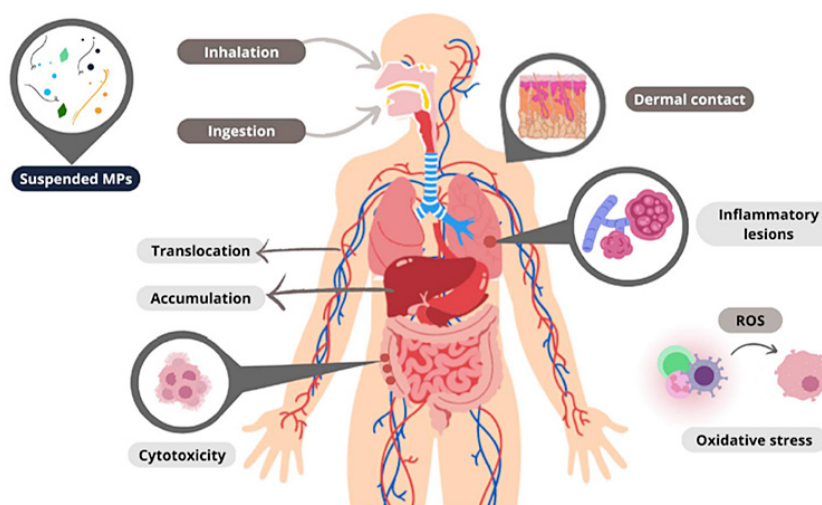
The physical methods to remove particulate matter and toxins include conventional activated sludge process (CAS),<sup>32</sup> Rapid sand filtration (RSF),<sup>33</sup> Dissolved air flotation (DAF),<sup>34</sup> microfiltration (MF), Disc filter (DF),<sup>35</sup> Dynamic membrane (DM),<sup>36</sup> Magnetic nanoparticle method<sup>35</sup> and ultrafiltration.<sup>36</sup>

In addition to physical methods numerous chemical methods are also available, which include electrocoagulation,<sup>37</sup> photocatalysis,<sup>38</sup> Micromotors,<sup>39</sup> and Microsubmarines.<sup>40</sup> Separation by chemical methods are generally done by adding definite chemicals to interact with the polymer particles and followed by flocs formation, these flocs need to be collected afterwards.<sup>41</sup> Research is currently going on to optimize parameters for the effective removal of MPs. The parameters under consideration are the proper types of coagulant,

the right dosage, and interaction time.<sup>42</sup> By biological methods of removal, microorganisms are added to disintegrate organic matter and MPs by aerobic and anaerobic processes. Recent research<sup>43</sup> suggests that aerobic processes are advantageous over anaerobic processes. Results show that microorganisms can remove MPs through enzymatic activities.<sup>44</sup> Bioremediation techniques have the potential to control the MP's pollution<sup>45</sup> in a sustainable way.

### Human Health Issue

There are three main established<sup>46</sup> routes unambiguously consumption, breathing, and dermal contact through which MPs are incorporated to humans<sup>47</sup> as shown in Figure 4. In spite of the fact that the documented proof of MP's contamination in the environment and food web is already established, but their intake and movement within the body system remain questionable for a long time.<sup>48</sup> Therefore, all results should be considered to be suggestive.



**Fig. 4: Exposure routes and potential effects of MPs in humans**

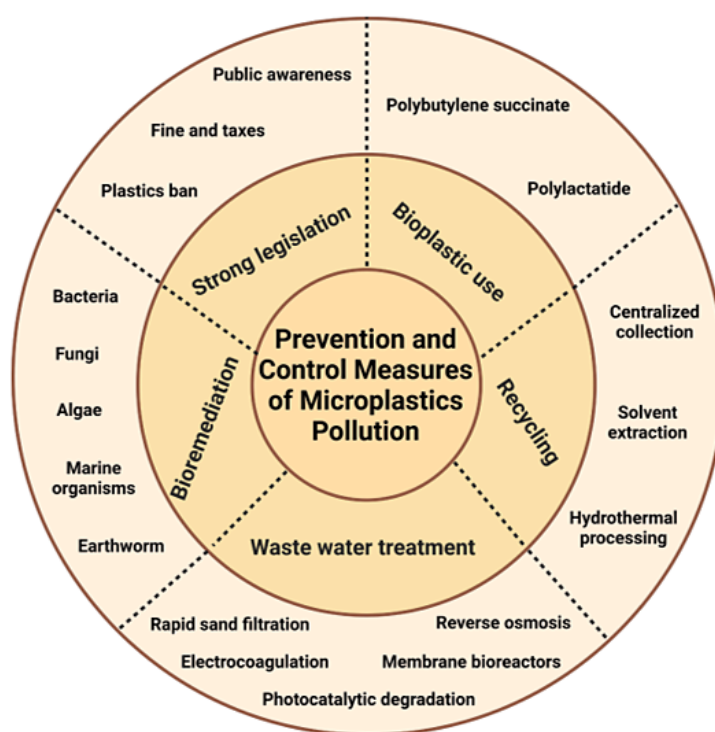
These will guide studies aimed at assessing the toxicity of particles at levels relevant to humans. Accumulation of data<sup>49</sup> shows that MPs of significant size can penetrate deep into human anatomical structures. The presence of MPs in different human tissues has been reported. MPs have been shown to induce toxicity by causing oxidative stress<sup>50</sup> and the formation of lipid peroxide which indirectly causes DNA damage product. MPs can also affect

the immune system<sup>51</sup> by altering the cytokines production levels, which in the long run may be a cause of cancer. Chronic exposure<sup>52</sup> to MPs through food can lead to intestinal damage, cell necrosis, changes in the metabolism of fat, and a decrease in energy reserves. Exposure to MPs might also cause neurotoxicity and have endocrine-disrupting effects leading to infertility.

### Regulation

Available reports have convincingly demonstrated the negative impacts of MPs on living creatures, indicating the need for global control over MPs pollution. To overcome these issues, an integrative approach is encouraged, which includes source control and the concepts of reduce, reuse, recycle, recover, and replace.<sup>53</sup> Plastic waste generation must be controlled by legislation and adequate monitoring, single-use plastic items should be reduced, and more attention should be placed on the transition to plastic alternatives. It is advised that conventional petroleum-based plastics be replaced with more environmentally friendly bioplastics.<sup>54</sup>

Some countries have implemented stringent rules and legislation to reduce plastic mess generation. To address this issue, public awareness efforts are important. A centralized recycling facility with the active participation of people can minimise the plastic pollution. The primary source of MPs is typically linked to wastewater treatment facilities; thus, eliminating MPs from water effluents with modern water treatment technology can significantly reduce plastic pollution. A combination of traditional methods with modern approaches can remove MPs to a greater extent.<sup>55</sup> Figure 5 Summarizes possible control techniques<sup>52</sup> for preventing and controlling MPs.



**Fig. 5: Summarizes possible control techniques for preventing and controlling MPs.**

### Regulation in India

India is one of the 12 countries responsible for more than 50% of the world's mismanaged plastic waste.<sup>56</sup> India recycles only 8% of its plastic waste.<sup>57</sup> There aren't many recycling and landfilling facilities in India, and many of them are poorly run. Because of this, it is challenging to gather and properly dispose of plastic waste without harming the environment.

India's Plastic Waste Management Rule has been amended<sup>58</sup> different times to decrease the pollution caused by plastics. The nationwide ban on single-use plastic bags has been implemented since 2016, but it has yet to be fully enforced due to a lack of awareness and insufficient adherence to regulations. Thus banned items are still easily available in the market. United Nations Development Programme

(UNDP) India,<sup>59</sup> in partnership with Hindustan Coca-Cola Beverages Private Limited (HCCBPL), Hindustan Unilever Limited (HUL), HDFC Bank and Coca-Cola India Foundation (CCIF) is encouraging assembling, separation, and recycling plastics to move towards a circular economy. As UN member states India is committed to 'End Plastic Pollution' by 2024. Recently the Ministry of Environment, Forest and Climate Change has implemented amendments in Plastic Waste Management Rules, 2016, by the Plastic Waste Management (Amendment) Rules,<sup>60</sup> 2024 targeting MPs and setting stricter criteria for biodegradable plastics.

Recently, on August 18, 2024, the Food Safety and Standards Authority of India (FSSAI) launched<sup>61</sup> a project with the collaboration of different research institutes like CSIR-IITR, ICAR-CIFT, and BITS-Pilani to collect data on MPs exposure levels as well as to develop standard techniques for micro/nano-plastic analysis. Every stakeholder has to work unitedly to address the problems.

### Challenges

It is critical to prioritize improvements in MPs sampling, detection, and removal technologies. A uniform approach for the testing, assessment and characterisation of MPs is critically needed. It is essential to plan new MP detection techniques that are easy, quick, and inexpensive. Interdisciplinary approach will give a complete view of MPs impacts. More focus is needed on the regulation of plastic waste management and plastic production processes. Moreover, the plastic pollution does not terminate with MPs because these MPs might further fracture and form nano-plastics, which are even smaller in size and so their collections, detections, movements and interactions with the surroundings are unknown are more complex.

### Conclusion

This article provides comprehensive information on MPs as an emerging environmental pollutants.

Primary MPs and secondary MPs influence the overall number of MPs available in the surroundings. The development in uniform standard procedure for the estimation of MPs is the important task. Available analytical methods for detection and estimation have their own merits and demerits, so improvements in test methods will provide more focused and comprehensive knowledge about MPs.

Future research should focus on a comprehensive assessment of the hazards connected with MPs exposure, more particulars on their mechanism and their associative activity with other organic molecules as well as heavy metals. Furthermore, the creation of operative guidelines, encouraging public awareness about reduce, reuse, recycling and the use of materials alternatives to plastics with worldwide cooperation to limit MPs pollution.

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### Conflict of Interest

The authors do not have any conflict of interest.

### Data Availability Statement

The manuscript incorporates all datasets produced or examined throughout this research study

### Ethics Statement

This research did not involve human participants, animal subjects, or any material that requires ethical approval."

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