Assessment tools for monitoring microplastics from surface water bodies: Challenges and future scopes

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Abstract

The term "microplastics (MPs)" refers to solid particles of size less than 5 mm made of non-biodegradable polymers like PE, PP, and PET. In India, plastics account for around 60% of the overall municipal solid waste generated, finding an easy way to drift into the river bodies and deteriorating water quality. MPs pose a potential threat to the biosphere. MPs can be classified based on their origin and morphology. These characteristics can be used to find an efficient technique for assessing MPs. This review discusses various analytical techniques for monitoring MPs from surface water bodies with their advantages and limitations.

Keywords

Microplastics; potential threat; monitoring; analytical techniques

Introduction

Plastics have been in use since the 1970s, and by then, they have immensely become an integrated part of all of our lives in a way that we start our day by holding a plastic brush to switching off the plastics buttons for lights before going to bed. We come across their use in a much more significant way than what we can think of and there start the problems of microplastics (MPs). MPs are a subtype of plastic polymers that can be referred to any microscopic solid particle made up of polymers having a size range of 5 mm and below. There are a vast number of examples lying in this category like PP (polypropylene), PE (polyethylene), PA (polyamide), PET (polyethylene terephthalate), PS (polystyrene), PUR (polyurethane), RY (rayon), NY (nylon) and PVC (polyvinylchloride). Out of which PE and PS are found to be dominantly existing in aquatic systems [1], [2].

MPs can be classified on a different basis. For example, on the basis of the source and their origin of development, there are of two types: primary MPs and secondary MPs. As the name suggests, primary MPs are those that are directly synthesized as microscopic particles in the form of microbeads and pellets. Primary MPs are very commonly seen in skin care products, cosmetics, toothbrushes, dust from cars, truck

tires, cigarette filters and textile fibres. Whereas, the secondary MPs are created by the natural degradation process of macro or bigger plastic fragments into microscopic particles with due course of time undergoing the weathering process [3],[4]. This process is mediated by environmental factors like solar energy, wind energy, thermal energy and radiation. Some of the potent sources for secondary MPs include plastic water bottles, fishing nets, plastic bags, and synthetic clothes.

Another important basis for classifying MPs could be their morphology and appearance bearing a variety of shapes, sizes, and colours. Different possible shapes include planar and sphere (as beads, pellets, granules) produced mainly from primary MPs sources. Other forms could be fibres (including filaments and lines), films, fragments, and foams that are mainly seen to originate from secondary MPs sources as depicted in Fig. 1. The different possible colours of these MPs can be seen as white, transparent, or translucent in appearance. Translucent MPs prominently constitute about 47% of the total MPs followed by yellow to brown color (about 26%) and blue to green shades (about 9%). The size range varies from 5 mm to 1 nm in diameter [5],[6]. So, the magnitude of risks these MP fragments would carry along them can be imagined.

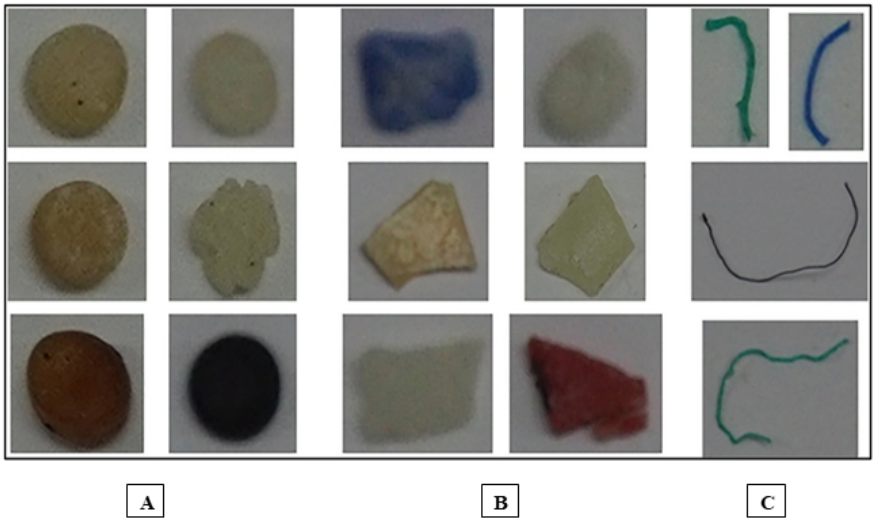

Figure 1. Different types of microplastics available in various forms in the environment: (A) Pellets, (B) Fragments, (C) Lines or fibres. Adapted with permission from [7].

This review critically tries to enumerate and summarize the sources and pathways of MPs generation, their abundance in environmental matrices focusing on aquatic systems, and potential threats caused by MPs. The other part describes all the major analytical techniques along with their principle of working, merits, and demerits for assessing MPs from the water bodies, mainly freshwater bodies.

Potential Threat of MPs These MP fragments has been recognized as a potential threat in many ways. There are multiple properties exhibited by these MPs that can create several issues and complications. For example, these MPs are highly stable molecules giving them a very high residence time and thus can exist for ages in nature once produced. Also, they carry a high potential of getting fragmented, thus increasing their surface areas, so the chances of adsorbing harmful chemicals like poly organic polymers (POPs) also increase to many folds. Considering these factors, the harmful effect of MPs to living organisms can be clearly assessed. [8] MPs bear a high chance of entering the food chain. This results in the lowering of nutritional diet, and as a consequence, many physical and physiological damages like oxidative stress, reduction in predatory performance, negative impact on reproduction, reduction in feeding rate, increased mortality, and decreased neurofunctional activities. The development of various pathologies has already been reported in many living organisms due to the accumulation of MPs in their bodies, including aquatic

species like fishes, zooplanktons, and molluscs [9],[10],[11],[3]. Ultimately MPs are damaging the quality of environmental matrices, causing harm to the environment, economy, and health-related issues as a whole.

Abundance of MPs No environmental matrix is left untouched without having MPs existing in them. From the drinking water bottle to the air, we are breathing in, MPs have already made their way into them. So, whether it is soil, water, or air, every component of the environment is now suffering from the adverse effects of these MPs. An alarming situation is that human beings are directly or indirectly affected by MPs. Fig. 2 represents the concept that "MPs are everywhere today." It shows the presence of primary and secondary MPs in the biosphere. So, it becomes a need of the hour to realize the situation, come up with effective strategies to assess them, and remove them from the different environmental matrices.

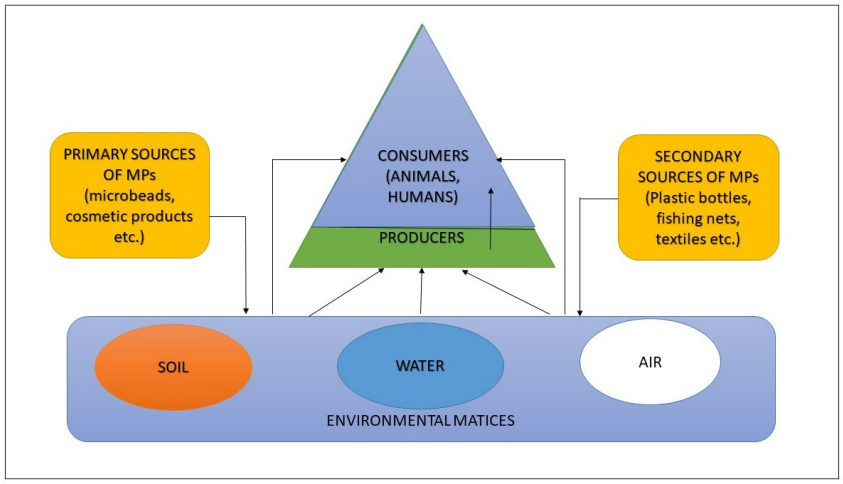

Figure2. Represents the ubiquitous nature of MPs in every environmental matrix today making their way from primary or secondary sou
into the food chain and reaching us(directly or indirectly).

3.1. Sources of MPs and Pathways of Pollution of Aquatic System

There are multiple sources of MPs coming from various primary and secondary origins that make their way into the water bodies. Some of the prevalent sources of getting these MP fragments into the aquatic system include garbage dump sites, anthropogenic activities, shipping industry, fishing, sewage treatment plants, plastic manufacturing and recycling industries, land and marine littering, and tourism and pilgrim centers.

MPs from these sources then easily make their way to reach out to the major aquatic systems, hence polluting them. Some very common pathways for MP pollution could be the rivers and streams, rain or stormwater runoff, sewage discharges, beach littering, tides, waves and of microplastic polymers found to be present in different environmental components, winds, industrial effluents, and likewise many more [12]. Though there are different varieties including various water bodies. Fig. 3 depicts the relative availability of various polymers including PE, PP, and PS in MPs. There are some polymers like PE and PP which are relatively more common than others.

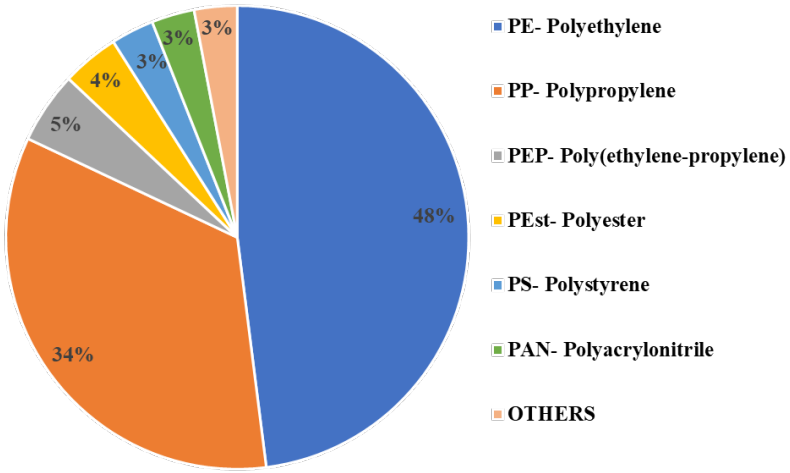

Figure 3. A pie-chart showing the relative abundance of various polymer types of MPs available in different water bodies. The data for this figure is taken from [13], [14], [15] .

3.2. MPs Level in Indian Rivers

In this review, MPs in the aquatic system have been mainly focused based on various surveys and experiments conducted to identify and assess the different levels of MPs. Various polymer types of varying shapes have been found in some rivers of India [16]. Fig. 4 summarizes the data of MPs in different coastal states and union territories of India having a river or a coastline around them. It reports the data of MPs per unit mass or volume of sample collected. It also indicates the data where polymers are yet to be identified in MPs [17]. Table 1 [18] lists the concentrations, shapes, and types of MPs present in some of the east and west coast regions of India along with the assessment technique utilized to identify and separate them.

Figure 4. Indian map showing west and east costline regions for available MPs concentration (along with the polymer type in red and yellow), and with inadequate data about polymer type (in green). Adapted with permission from [17].

Table 1 . Investigation of MPs in water samples collected from the east and west coast of India in terms of concentration, types, and assessment methods. Information extracted from [18].

S.N.	Location	Sample type	Size	Shape
1	Chennai	water	<5 mm	Fragment, fibre
2	Port Blair Bay, Andaman Island	water	<5 mm	Fibre, fragment, pellet
3	Bey of Bengal	water	0.355- 4.75 mm	Fragments, fibres, foams, films, pellets
4	Tuticorin, Gulf of Mannar	water	0.5 – 1 mm	Fibres, fragments, and films
5	Tuticorin	water	150 µm- 5 mm	Fragments, fibres, foams, and films
6	Kerala coast	water	0.3 – 4.75 mm	Fragments, fibres, foams, and films
7	Kochi, Kerala	water	1 – 5 mm	Fragments, fibres, foams, films, pellets, and fil

It can be referred from Fig. 4 and Table 1 that there are various coastline states like Andhra Pradesh, Odisha, West Bengal, Maharashtra, and Gujarat that still need to be extensively explored. Also, major

rivers like Ganga, Mahanadi, Narmada, Godavari, and Brahmaputra needs to be studied. This demands urgent future research to be done in terms of MPs detection using suitable means (assessment techniques).

Assessment Techniques for Detecting Surface Level MPs

One of the crucial and initial steps for dealing with the issues of MPs lies in the assessment part of these microplastic fragments. To date, a plethora of different analytical tools has been applied for detecting and assessing MP fragments from water bodies. As a matter of fact, the MPs are more abundantly found in freshwater bodies than saline waters due to differences in densities [24].

MPs are detected on basis of physical or chemical characteristics. The physical features include size, colour and shape and chemical characteristics mainly comprise the chemical composition. The challenges associated with MPs include their identification, isolation, quantification as well as characterization. The various methods for the detection of MPs on the basis of physical or chemical characteristics and the challenges allied with MPs are shown in Fig. 5. Apart from visual inspection, the analytical techniques discussed in this section are: Fourier Transform Infrared (FTIR), Raman spectroscopy, thermal analysis (including thermogravimetry, pyrolysis-gas chromatography coupled with mass spectrometry, differential scanning calorimetry), Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM), X-ray Fluorescence Spectrometry (XPS), hyperspectral imaging and centrifugal liquid sedimentation [25],[5], [24], [26].

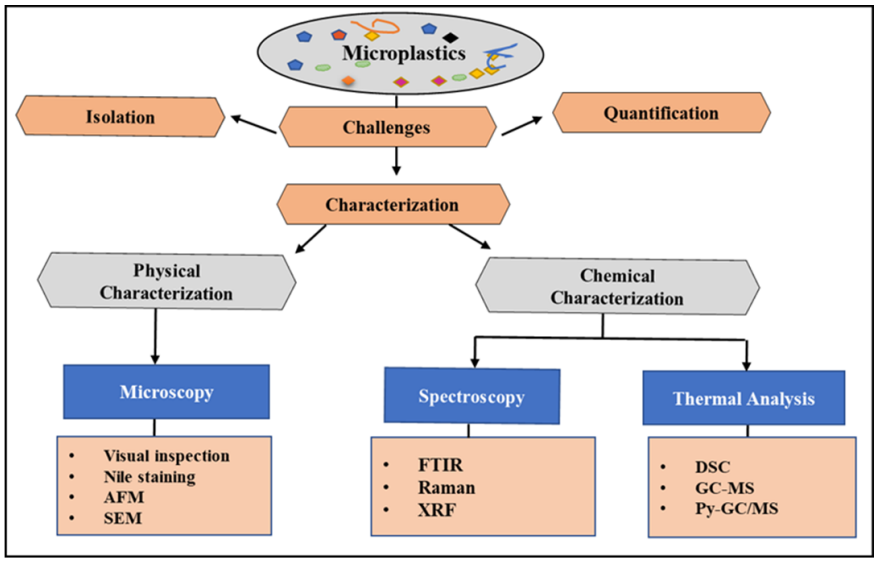

Figure 5. A flowchart representing different challenges associated with MPs abundance and the available physical and chemical characterization techniques for MPs assessment.

Visual Inspection

The visual identification of MPs is either directly observed or using stereoscope/microscopes it is performed. It is one of the very widely used quantification methods. It is usually performed on three bases; (i) the comparatively larger MP fragments are detected under the direct visualization method, depending upon some features like the color, absence of cellular structures, and brightness of MPs (ii) for the smaller MPs, microscopes are used. (iii) sometimes, the visual inspection of MPs is coupled with the hot-needle test, wherein the confirmation of MP particles as organic or inorganic matters is done [27], [28], [15].

The points that are emphasized while performing the visual identification technique are: (a) the microscopic particles observed should have no cellular organization or organic structure associated with them, (b) if the particles are colored, they should be uniformly colored, (c) the fibre form of MPs should not be segmented

or present as twisted flat ribbons like structure and (d) if performed hot needle tests, MPs should undergo melting. These are some of the important attributes that set the criteria for undergoing this assessment technique. The lengthy procedures of individually inspecting and then counting the MP fragments can be overcome by making use of digital tools i.e., counting software.

Because of owing several advantages, this technique has been widely used. For instance, light microscopy was used to detect different types of MP particles, observing a total microplastic recovery of 96.1 ± 7.4 % [29]. Being one of the simplest and easiest methods to perform, visual identification has been in use for the MP detection purpose for a long ago and still remains a widely used initial approach in combination with other more accurate and sophisticated techniques [30],[31], [32].

FTIR

FTIR is again a very commonly used technique that provides accurate identification of the nature of MPs polymer. In this technique, an interference wave produced from two beams is separated by a beam splitter, and the detected waveform is Fourier-transformed, thereby obtaining a spectrum by separating each wavenumber. This provides a characteristic fingerprint spectrum of different molecular vibrations for different types of polymers. For the identification of MPs, a mid-infrared region lying in the range of 400-4000 cm^{-1} is often used. The most popular modes of FTIR spectroscopy are found to be Attenuated Total Reflectance (ATR) and transmission modes.

Many studies have applied the FTIR method for the detection of MPs [33], [34], [30]. In a study performed by Harrison et al., 2012, the micro-FTIR technique was optimized, which resulted in efficient PE (MPs) detection from marine sediments [35]. Though this technique was able to analyze and detect PE at a concentration of 100 ppm with a mapping area of 3 mm^2. In another study, the micro-FTIR technique was used to identify and quantify MPs from wastewater samples, proving it to be a robust and reproducible method yielding a successful identification rate of 98.33% [36]. It has also been emphasized the urgency and need to develop a more reproducible and idealized technique for MPs detection and separation from sediments due to certain unavoidable challenges possessed by techniques like micro-FTIR [35].

Raman Spectroscopy

It is a very commonly used technique to determine the nature of polymer in MPs. It's a non-destructive technique allowing low-frequency modes like (rotational and vibrational interactions) to provide a structural imprint for the identification of MPs (as they exhibit characteristic Raman spectra) within a few minutes. Spectra for this purpose is mainly obtained in a range of 200-3500 cm^{-1}. It is based on the principle of the variation in the wavelength of radiation that is scattered (whose kinetic energy is not conserved) and is inelastic, which gives information regarding the structure and chemical composition of the compound. Also, it depends upon the molecular composition and structure of atoms lying on the surface, and hence, the beam of laser that is shot at those MPs develops a unique pattern of backscatter that enables the molecule's detection [37].

In a study performed by Kniggendorf et al., 2019, Raman spectroscopy was found to be promising for the detection of MPs smaller than a size of 0.1 mm [38]. Similarly, the detection and isolation of microplastic fragments were conducted effectively using this method of Raman spectroscopy equipped with a phase contrast microscope from snow marine samples [39]. Combining Raman spectroscopy with multivariate analysis proved to be one of the efficient analytical tool for identifying and quantifying MPs [40].

Nile Red Staining-Fluorescence Microscope

Nile Red (NR) is a staining method used for identifying MPs based on the basic principle that the dye (NR) stains/adsorbs on the surface of plastic fragments, causing them to emit fluorescence upon irradiation with different light signals depending on the excitation/emission wavelengths. The emitted fluorescence is then detected by simple photography via an orange filter. This method was mainly implied to quantify MPs levels in samples where staining was carried out, taking 10 µg/ml of NR stain in acetone. 30 minutes prior to observation, the NR stain is spread on a filter paper. The filter paper is then seen using a fluorescence

microscope fitted with a camera. The blue light excitation range is kept at 420-495 nm for observing the MPs.

In a study performed by Shim, et al., 2016, the NR stain method was utilized to detect different types of MP particles like; PE, PP, PUR and PS. To prepare the stain, 5 mg/L of NR solution dissolved in n-hexane was used, which was effective enough to stain the MP particles and produce a green fluorescence for their recognition. The method yielded a 98% of recovery rate for PE with dimensions of 100 to 300 μm. Also, it was found to be expedient to distinguish between MP particles from the sand particles [41].

Scanning Electron Microscope (SEM)

This technique is taken into practice to determine the physical properties or morphology, origin (sources), or aging of MPs. SEM is mainly a kind of electron microscope where an image of a sample is produced by scanning the surface using a focused beam of electrons. For better results, this SEM technique is usually coupled with an energy dispersive X-ray spectrophotometer (EDS). Convincing data was obtained regarding the surface morphologies of MPs with a size of < 200 μm (from the yellow river, China) by using the SEM technique, indicating the nature of formation and aging of the plastic fragments [42].

Atomic Force Microscope (AFM)

AFM is used to determine the rubbing surface and patterns of weathering of MPs. Here, a nanoscale tip is linked to a tiny cantilever that acts as a spring. When the tip is in touch with the surface, the cantilever bends, and by using a laser diode and a split photodetector, the bending is then detected. The bending represents an indication of the interaction force between the tip and sample. It was extensively used to study the surface morphology of MPs in the Narmada estuary (west coast of India) [43].

In a study performed by Wu, et al., 2018, AFM nanomechanical mapping was successfully pursued to obtain the surface image of semicrystalline polymers (specifically, isotactic polybutene), determining their mechanical properties. Also using AFM nanothermal analysis provided with thermal properties (melting point) of the MP polymers [44]. Therefore, based on certain notable merits of the AFM technique, it could be further utilized to check on the similar aforementioned properties of several other MPs obtained from water body samples or other sources [45], [46].

Thermal Analysis

Thermo-analytical methods have very recently come into the picture to determine the variations in naturally bearing physical and chemical properties of the plastic fragments in regard to their thermal stability [5], [47].

4.6.1. Thermogravimetry

It is a thermal-based analytical method where a sample (having a particular mass) is analyzed for its dependence on factors like temperature and time. The temperature is controlled to maintain an isothermal condition at a particular atmospheric condition. This method is used for quantitative analysis of any loss in mass of MPs while the thermal heating program. Thermogravimetry method coupled with solid phase extraction (SPE) is being applied using a thermal desorption gas chromatography-mass spectroscopy, which offers many advantages like higher resolution, and much more effective identification of polymers like PE, PS, and PP [48].

4.6.2. Differential Scanning Calorimetry (DSC)

It is widely used to determine the thermal characteristics of unknown MP polymers by using reference materials for detection and identification. This method is being prevalently used in the identification of primary MPs by using polyethylene microbeads as reference material. Nowadays, the DSC method is applied along with thermogravimetric analysis that aids in the differentiation between polymers like PP and PE [49]. An experiment was conducted MPs detection from wastewater samples using a combined TGA-DSC approach. The endothermic phase transition temperature properties for seven different types of MP polymers were studied with the above-said approach, of which only PE and PP could be distinguishably identified.

While for the rest of the polymers, their phase transition signals showed to be largely overlapping with each other [47].

Further DSC can be integrated with optical techniques. In a study performed by Chialanza et al. 2018, a method combining DSC and optical microscopy was used to effectively assess the identification and mass quantitation of MP fragments (PE, PP and PET). It was found that both (identification and mass quantitation) was dependent on the particle size of MPs [50].

4.6.3. Pyrolysis-Gas Chromatography coupled with Mass Spectroscopy (Py-GC/MS)

Py-GC/MS is one of the very commonly used techniques for the identification of the polymer types of MPs. In this technique, a polymer is first pyrolyzed/heated in an inert atmosphere, which then is followed by gas chromatography (GC) coupled with mass spectrometry. A heating filament is used for pyrolysis. The GC is taken into use for the separation of the heated products, and a pyrogram is produced. The pyrogram obtained for the unknown sample is compared with the available reference pyrograms to identify the composition of the MPs.

This method has been used till now for the identification of various polymers and MP particles like; PA, CPE (chlorinated polyethylene), and CSPE (chloro-sulfonated polyethylene) [51]. In this direction, a study was carried out by (Hermabessiere et al. 2018) to optimize and validate the Py-GC/MS method for MP detection using samples collected from aquatic sources like sea water surface and beach sediments. A load of detection (LOD) for some commonly available MPs (like; PE, and PS) for this technique was found to be lower than 1 μg. Several other research utilized the Py-GC/MS technique for the identification of MPs and their characterization [52], [53], [54].

X-Ray Fluorescence Spectrometer (XRF)

This technique helps mainly in detecting the concentration of heavy metals in the MPs. It relies upon the principle that as the individual atoms undergo excitation by any of the external energy sources, they emit X-ray photons of a definite amount of energy, which is then used for elemental analysis of molecules. Using field portable XRF, heavy metal concentrations can be determined in four major types of MPs polymers found in coastal regions i.e., PE, PP, PS, and PA. The performance of a portable XRF spectrometer was determined in-situ at a beach, which could successfully lead to the detection of about 15 elements (including Cr, Fe and Zn) associated with MP fragments [55].

Hyperspectral Imaging

This technique has recently been advised for the identification as well as characterization of MP fragments in the monodisperse (containing particles of uniform size) and/or polydisperse (non-uniform spherical and non-spherical particles) forms of matters at the wavelength range of 400 to 1000 nm. It can detect MPs fragments up to a size range of 300 μm, having efficiency in the range of 80 to 100%. But, to date, this technique has been used to detect only certain types of polymers like PP, PE, and PS. It is mainly attributed to samples collected from surface-trawling plankton nets, and then reliable information regarding the shape, size, or nature of the polymer of an MP can be deduced from single hyperspectral images.

Hyperspectral imaging technique was regarded to be one of the very reliable and efficient analytical techniques by Serranti et al. 2018 group. A single hyperspectral image data obtained from a polluted marine sample was used to determine the shape, size, nature of MP fragments along with their quantification [56]. In another study by Piarulli et al., 2020, a rapid near-infrared hyperspectral imaging (NIR-HSI) technique was utilized for MPs from aquatic samples, and it could provide convincing data about chemical identification as well as characterization of MP particles of size up to 80 μm [57].

Some Other Techniques

To detect spherical PS MP particles in the size range of 1 to 2.5 μm, techniques like inductively coupled plasma mass spectrometry (ICP-MS) are used. This method operates in a single-particle mode, hence called

single particle inductively coupled plasma mass spectrometry (SP-ICP-MS). This technique relies on ultra-fast measuring of transient signals using quadruple-based ICP-MS in a single-event-based mode and then registering the signal spikes of individual MP fragments [58].

Settling down of MP fragments using carrier compounds like hybrid silica gels is another strategy. The MPs get trapped between an inorganic-organic hybrid of silica gels as a consequence of van der Waals interactions and hydrophobic forces. Later the accumulated substances can then be easily removed using various separation/desorption methods. However, exact information regarding the efficiency of such methods has not yet been experienced.

Comparison Between Some Major Assessment Techniques

As of now, none of the analytical methods used till date has been most appropriate or highly efficient for detecting MPs levels in aquatic systems. However, a comparative analysis of all the major assessment techniques discussed in this paper is provided in Table 2. The table lists commonly used techniques, which are in practice for MPs detection and compares based on their advantages and limitations.

Table 2. Comparison between different assessment techniques used for assessment of MPs on the basis of their advantages and limitations.

Analytical technique	Advantages
Visual inspection	Helps to classify the MPs based on their shapes, size, color, and origin. Easy t
FTIR	Can determine the weathering pattern or aging of MPs with the help of carbo
Raman spectroscopy	Better lateral resolution with larger spectral coverage. Can detect MPs of size
NR staining- fluorescence microscope	Allows classification of MPs in wide chemical groups based on fluorescent shift
Scanning electron microscopy	Used extensively to determine morphology and polymer nature (elemental com
Atomic force microscopy	Can provide images of nanometer resolutions. Can be operated in both contac
Thermal analysis	To study thermal properties of MPs. Effective in identification and quantificat
X-ray fluorescence spectrometer	Rapid and non-destructive process. Efficient in determining the elemental com
Hyperspectral imaging	Non-destructive method. Cheap and fast. Non-invasive and no prior sample p

Based on the advantages and limitations that each of the analytical techniques is associated with, Fig. 6 represents their percentage usage in general for the purpose of MPs detection [26]. Certain studies also compare the percentage utilization of thermal techniques (as it consists of many different subtypes) for the purpose of MP assessment. Fig. 7 [64] represents a funnel chart to demonstrate the comparative usage of different thermal techniques for the detection of MPs.

Figure 6. Percentage distribution of all the major analytical tools frequently used for MPs detection. Adapted with permission from [26].

Figure 7. A funnel chart showing percentage utilization of different thermal detection methods for MPs. Adapted with permission from [64].

As each of the techniques is associated with its own pros and cons, proper visualization is required in this field. We need to come up with much more effective alternatives in the coming future that could assure a promising detection outcome for the terribly challenging MPs not only in water bodies but also from other complex environmental matrices like food, and soil. Methods having good efficiencies should be worked upon more so as to further minimize any limitations or drawbacks with them, like that of Hyperspectral imaging or Thermo-analytical techniques. Then other aspects could be exploring methods like that of using hybrid silica gels and single particle inductively coupled plasma mass spectrometry (SP-ICP-MS) to come up with better substitutes that could allow cheap and effective methods of inspecting MP fragments, once they get accumulated into larger clumps of ball that would be easy to remove from the aquatic bodies once detected.

Techniques like asymmetric flow field-flow fractionation coupled to multi-angle light scattering (AF4-MLS) allow MPs detection in even complex matrices like in food along with in the aquatic system but also needs to be much more explored [65].

Challenges and Future Directions

Though at this moment, completely saying no to plastics would be impractical to bring it into practice. But certain steps can be taken by looking at the consequences of MPs and visualizing their future possibilities of creating havoc if the pace at which their abundance is increasing continues in the environment. These would work as initial yet significant steps following sincerely the 6 R's principle (Rethink, Reduce, Reuse, Recycle, Repurpose and Redesign). In India, nearly 60% of plastics are recycled; the rest are dumped as municipal solids wastes that find an easy way to reach out to the river bodies and then to marine aquatic systems.

Various parameters and properties exhibited by those microscopic MPs can be compiled together to first understand their root cause (origin) and then detect them via an efficient analytical assessment technique to remove them from water bodies (and other environmental matrices). There is hardly any sewage treatment plant in the current scenario that would have considered MPs as an issue to be tackled so as to assess their levels and remove or treat them in any of their treatment levels. This ultimately leads to the discharge of MPs into river bodies deteriorating the situation to even worse. So, treatment and planning of dealing with the MPs at initial levels are of utmost required.

The banning of single-use plastics could help in reducing secondary sources of MPs. Single-use plastics are related to problems with throwaway culture, where after using plastic materials, just once, like polythene bags and plastic cups are thrown away. This leads to the accumulation of plastics in the environment at a staggering rate, and as a result, we are producing about 300 million tons of plastics every year worldwide, where half of it comes from single-use items. Recently, India has banned the usage of single-use plastics [18]. This needs to be further effectively enforced across all the nations at a global level.

Switching to bioplastics like PHA (polyhydroxyalkanoate) or PHB (polyhydroxybutyrate) would act as bio-friendly substitutes for synthetic plastic polymers [66]. Bioplastics are bio-derived from algae or bacteria and are biodegradable. Also, banning MPs from primary sources like microbeads used in skin care products and cosmetic items would help to reduce the MPs load in the environment. For example, in India, to ensure the implications of the existing regulations for managing plastic wastes (plastic management rule 2016), manufacturing plastic particles below 50 μm has been banned by the ministry of environment and forest, India [67].

Conclusions

This review discussed about MPs and their characteristics, which are being exploited for detection. After comparing all of the major assessment techniques used to date, it can be visualized that until now, no such efficient assessment method for MPs detection in water bodies exists that could be completely relied upon, and so it needs to be researched intensively as the need of the hour. The adverse impacts of MPs on the biosphere have been highlighted. Monitoring data of MPs for a few sites have been presented. Also, in the context of India, many of the water bodies, estuaries, and rivers are still there to undergo effective assessment processes to evaluate the water quality, in terms of concentration, types, and occurrence of MPs (as clear from figure 2). The analytical tool used should be designed in a way such that the efficiency of its working does not get hampered depending upon the (a) volume or concentration of water sample, (b) size of MPs fragments, and (c) duration of executing the assessment technique. Affordability and feasibility to make them easily accessible should also be taken into consideration as many of the ongoing techniques are facing these challenges.

Competing Interests

Authors declare no Competing interests.

Data Availability

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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