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Microplastic Pollution with Particular Reference to Ponds: A Review

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Abstract: Plastics have become an indispensable part of our lives. Plastic waste management and disposal practices have harmed our world by contaminating the land and water. Moreover, plastics do not biodegrade and remain in the environment for a longer period of time. The emergence of microplastics (plastic particles <5mm) is a growing problem with plastics remaining in the environment. Because of their tiny size, these microplastics are easily able to cause pollution. Such microparticles are widely present, which negatively impacts the ecology and the life that resides there. This review, focused on consolidates existing research on the presence and impact of microplastics in pond water, summarizing findings from various studies to provide a comprehensive understanding of this environmental issue. It highlights sources, detection methods, ecological and health impacts. Additionally it also concentrated on sustainable approaches to keep pond water plastic-free for future generations and a healthy environment for aquatic plants and animals, as well as mitigation and management techniques to combat microplastic contamination.

Keywords: Microplastics, Plastic, Pond water, Sustainable approaches, Mitigation

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Introduction

Plastics are a category of artificial or partially artificial substances created from lengthy chains of molecules known as polymers. These materials can be reshaped or formed into various structures while in a pliable state, and then solidified to maintain their desired form. The characteristics of plastics encompass a range of qualities that render them valuable for diverse uses, including their lightweight nature, durability, flexibility, and cost-effectiveness. Because of these qualities, plastics are widely used in a limitless number of applications. Due to excess use, plastics are recognised as fastest pollutants to nature and environment, which causes contamination to water bodies and soil (Hopewell *et al.*, 2009; O'Brien *et al.*, 2023).

Due to their chemical inertness, plastic polymers were able to survive centuries without completely degrading due to their increased resistance to the normal deterioration process (Weinstein *et al.*, 2016). Millions of metric tons of plastics are produced each year, since the start the production of plastic in the 1950s (Plastic Europe, 2019; Gonzalez-Pleiter *et al.*, 2019). According to Geyer *et al.* (2017), only roughly 9% of the plastics produced as garbage are recycled. Of these wastes, only around 12% are incinerated, with the remaining plastics finding their way into the environment. Plastic waste can accumulate through blowing, dumping, or direct dropping of the material on land or in the ocean, which causes savior impact of environment and human life.

Plastic particles smaller than 5 mm (in diameter) are known as microplastics (MPs). The history of microplastic research is not much older if microplastics, often overlooked, have recently been discovered by marine researcher Richard Thompson stumbled upon tiny plastic fragments, comparable to the size of rice, on an English beach in 2004, coining the term "microplastics" in 2009. Since then, these microscopic plastic particles have been detected worldwide, from the depths of the Mariana Trench to the top of Mount Everest (Thompson *et al.*, 2004; Barnes *et al.*, 2009).

These plastic particles are formed due to breakdown of larger plastic items and become prevalent in the environment due to plastic pollution (Tirkey and Upadhyay, 2021). These are ubiquitous in nature and reported in all matrixes (air, water, and soil) of environment (Cole *et al.*, 2014; Ramaswamy and Harit, 2023). Indeed, the occurrence of MPs also witness in the pristine environments such as Arctic (Lusher *et al.*, 2015; Daana *et al.*, 2018; Ramasamy *et al.*, 2021) and pose a serious threat to the environment. Scientists speculate that these minuscule particles travelled through the air carried by the wind and then settled when it snowed and water bodies. Numerous channels, such as residential waste, agricultural runoff, and industrial discharge, might allow them to get into water bodies (Olesen *et al.*, 2019; Vijayaraman *et al.*, 2020; Long *et al.*, 2021; Wang *et al.*, 2022; Beni *et al.*, 2023). These small plastic particles have the potential to cause harm to ecosystems and animal health as they infiltrate natural habitats such as oceans, rivers, lakes, ponds, and soil. Especially, microplastics have been identified in marine organisms, seafood, salts, drinking water, and even human waste (Harit *et al.*, 2019; Ramaswamy *et al.*, 2019; Tirkey and Upadhyay, 2021; Pradhan and Harit, 2023, 2024; Ramaswamy and Harit, 2023). Plastic trash has accumulated all across the planet as a result of mishandling, high recycling rates, large-scale production, and the exceptionally durable plastics being developed.

Microplastics can be consumed by aquatic species, making their way up the food chain and perhaps endangering both humans and wildlife because of their small size and persistence. The purpose of this study was to summarize the state of the art on microplastic pollution in pond water, highlighting significant discoveries, approaches, and areas in need of further research.

Sources of Microplastics in Ponds

Microplastics in pond water originate from various sources, including urban runoff, agricultural practices and atmospheric deposition (Eriksen *et al.*, 2013; Dris *et al.*, 2016). Indeed, synthetic fibres pose a significant threat to the aquatic environment, with plastic fragments entering these ecosystems predominantly through the discharge of wastewater and runoff from both residential and industrial sources (Fig. 1). Plastic finds direct entry into aquatic environments via products like cosmetics, textiles, land applications, and waste from households and industries (Morritt *et al.*, 2014). This could change the plastic's chemical behaviour and increase its contamination with hazardous pollutants found in the aquatic environment by increasing the reaction sites at which the sorption of harmful toxic pollutants can occur (Davis and Raja, 2020). Water quality in

Fig. 1: Source of microplastics in Pond ecosystem.

pond ecosystems can be negatively impacted by MPs contamination, which can also alter the chemical and physical characteristics of water.

Microplastics in Pond water

According to the literature survey conducted on MPs pollution in pond water via Web of Science and Google Scholar (till 1 June, 2024) with the keywords Microplastics + pond water, Microplastics + estuaries, Microplastics + lake, Microplastics + fresh water, Microplastics + river water, and then Microplastics + marine water. The literature survey revealed that globally maximum number of studies reported on occurrence of MPs in marine water followed by fresh water (Fig. 2) while least importance was given to pond water. Figure 3 shows the number of studies reported in MPs pollution as per above mention keywords in India.

Occurrence of Microplastics in Pond water

Table 1 illustrates the MPs contamination on Ponds water, globally.Liu *et al.* (2019) reported 490–22,894 items/m^3 of MPs in various water samples of Denmark. These MPs consist of various polymers, including polyester, PVAC, acrylic, SAN, EVA, and PVA, as well as PP, PS, PE, PMVC, PA, and PU. Olesen *et al.* (2019) also confirmed the occurrences MPs from Denmark. This study discovered MPs ranging from 10- 500 µm, and abundance of 270 items/ L with five types of polymers that is PP, PET, PE, PVC, and polyester.

Bordós *et al.* (2019) examined the possibility of microplastics in various pond waters and reported less than 100 µm sized plastics with PS, PE, PP, and PET polymer types. While the number of MPs was found between 3.52 and 32.05 particles/m^3; Erdogan (2020) reported the abundance of MPs i.e. 233 particles/m^3. These MPs come in a variety of shapes and colors, including fragments, fibers, and films, and include PP, PE, PA, PVA, PVC, and PET. Turkey was the location of this study's execution (Table 1).

Xiong *et al.* (2022) reported fragments and fibers shape of MPs particles from water bodies of China. MP abundance of particles ranging between 100-1167 items/$m^3$and the size approximately 100 nm. PA, PET, PE, and PVC are the recognized polymers with different colors -- black, transparent, blue, white etc. A recent study reported by Hossain *et al.* (2023) from China found 1.5 ± 0.3 particles/L with various polymer

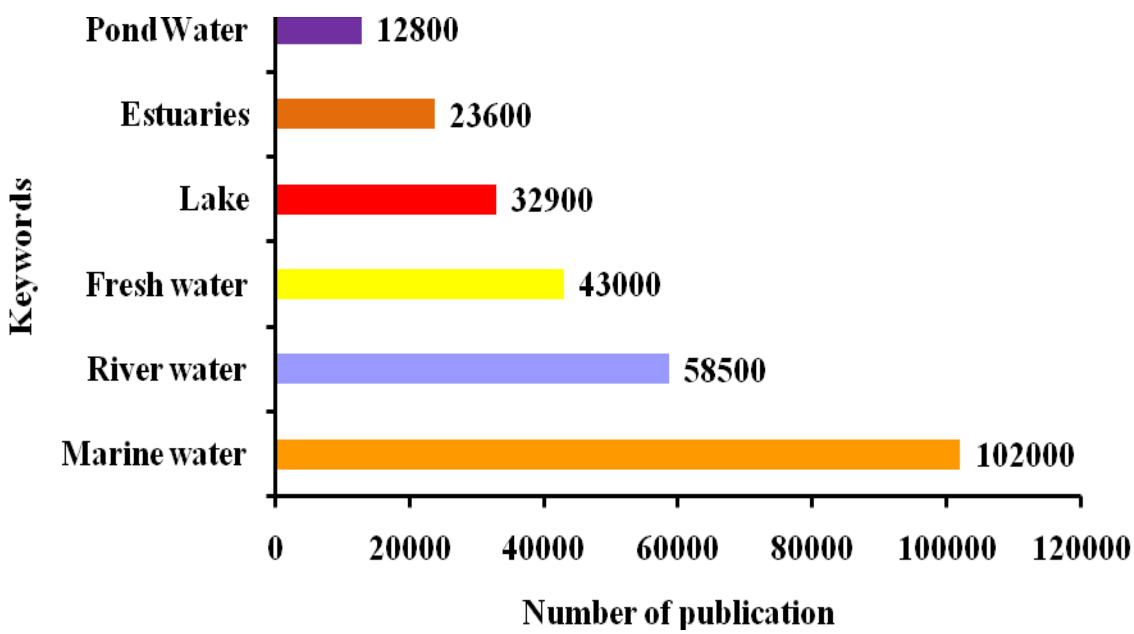

Fig. 2: Studies reported on microplastic pollution in different water bodies: A global Scenario (Source: Web of science and Google scholar).

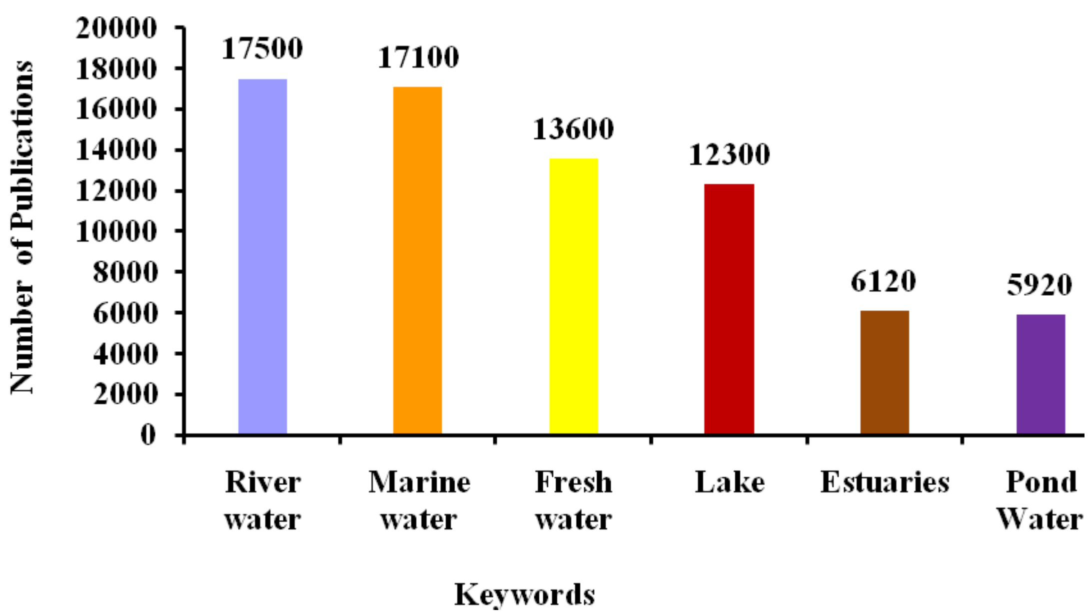

Fig. 3: Studies reported on microplastic pollution in different water bodies from India (Source: Web of science and Google scholar).

Table 1: Microplastic pollution in pond water

Reference	Country	Shape	Colour	Microplastics Polymer	Size (µm)	Abundance
Liu *et al.* (2019)	Denmark	-	-	PP, PS, PE, PVC, PA, PU, polyester, PVAC, acrylic, SAN, EVA, PVA	532- 1030	490 to 22,894 item m−3
Olesen *et al.* (2019)	Denmark	-	-	PP, PET, PE, PVC, Polyester	10–500	270 item/L
Bordós *et al.* (2019)	Europe	-	-	PS, PE, PP, PET	100	3.52 to 32.05 particles/m^3
Erdogan *et al.* (2020)	Turkey	Fragments, fibres, Films	Black, Blue, Red, White, Grey, Transparent, Yellow, Red, Green	PP, PE, PA, PVA, PVC, PET	100-250	233 particle/ m^3
Xiong *et al.* (2022)	China	Fragments, fibres	Black, Blue, White, Transparen,Yellow, Red, Green	PA, PET, PE, PVC	<0.1	100–1167 items/m3
Herath *et al.* (2022)	Australia	Fragments, fibres, Films, beads	-	Polyester, PP, PVC, PP, PE, PMMA	48.5-170 to 170-2500	2067 and 2133 MP/m^3
Le *et al.* (2022)	Vietnam	Fragments, fibres	Black, Blue, White, Purple	PE, PP, PET, EVA	-	2767 ± 240 to 2833 ± 176 items/kg^{-1}
Hossain *et al.* (2023)	China	Fragments, fibres, Films, microbeads, Foam	Black, Blue, White, Transparent, Red, Green	PP, PET, PE	500–1000	(1.5 ± 0.3) (particles/L)
Suriatna *et al.,* 2023	Indonesia	Fragments, fibres, Films, Pallets	Blue, Red, White, Black	PP, PS, EVA, PVC, HDPE, LDPE	-	33.87 ± 8.95 particles/L
Chaudhari *et al.* (2023)	India	Fragments, fibres, Films, Foam	-	PP, PET, PS, PVC, HDPE, LDPE	<0.1	0.008 -0.039 mg/L
Upadhyay and Bajpai (2024)	India	Fragments, fibres, Films, Foam, Sphere	Black, Blue, White, Transparent,Orange, Yellow, Purple, Red, Purple	PP, PE, PA, PET, PS, PVC	500- 1000	2.93 ± 1.34 (particles/L)

PP (Polypropylene), PET (Polyethylene Terephthalate), PE (Polyethylene), PVA (Polyvinyl Alcohol), PVC (Polyvinyl Chloride), EVA (Ethylene Vinyl Acetate), SAN (Styrene Acrylonitrile), PVAC (Polyvinyl Acetate), PA (Polyamide), PU (Polyurethane), PS (Polystyrene), HDPE (High-Density Polyethylene), LDPE (Low-Density Polyethylene), PS (Polystyrene) types (PP, PET, PE) in different shapes such as fragments, fibers, films, microbeads, and foams. The study conducted in Australia reported higher number of MPs particles (2067-2133 particles/m^3) than China (Herath *et al.*, 2022) while a smaller number of shape of particles (fours: fragments, fibers, films, and beads) than the study reported by Hossain *et al.* (2023) from China. Polyester, PP, PVC, PP, PE, and PMMA was the dominant types of polymers reported in Australian pond water (Hossain *et al.*, 2023). However, study reported by Le *et al.* (2022) found PE, PP, PET, EVA types of polymers from Vietnam and PP, PS, EVA, HDPE, PVC, and LDPE types of polymers from Indonesia (Supriatna *et al.*, 2023).

The studies reported from India also showed various polymer types. Chaudhari *et al.* (2023) and Upadhyay and Bajpai (2024) reported six types of polymers from the different location of India while the type of polymers is differed from each site, of these Chaudhari *et al.* (2023) found PP, PET, PS, PVC, HDPE, LDPE and whereas Upadhyay and Bajpai (2024) found PP, PE, PA, PET, PS, and PVC. In case of shape, totally five type of shape that is fragments, fibers, films, foam, spheres are observed byChaudhari *et al.* (2023) and Upadhyay and Bajpai (2024). These studies also showed the color diversity in MPs particles (Table 1).

Detection and Analysis Methods

Digestion methods of Analysis

Microplastics sampling techniques begin with sample collection, which should be done by using non-plastic containers form collection and storage the samples (to avoid contamination) and proceed to microplastics extraction, which completed in two stages. First reduction stage lowers the volume of the sample; for example, using nets during collection or bulk collection samples and then pass through the 300 µm sieving and then collected the supernatant for further analysis. Second stage is digestion followed by density separation and final filtration.

Various digestion methods such as acidic, alkali, oxidative, and enzymatic are used (Table 2). Therefore, digestion methods need to be adopted as per the target samples and occurrence of organic matter in samples. However, NOAA recommended wet peroxide oxidation (WPO-using 30% H_2O_2 with Fe (II) solution in glass beaker) method for digestion of water samples. H_2O_2 (30%) proves to be more efficient in digesting organic matter compared to NaOH and HCl. This method results in minimal degradation of polymers and is more effective than other acidic, alkaline, and enzymatic digestion methods. Therefore, treatments involving H_2O_2 may offer an efficient way to eliminate organic matter while preserving the integrity of microplastics (Masura *et al.*, 2015; Karlsson *et al.*, 2017; Ziajahromi *et al.*, 2017; Prata *et al.*, 2019; Lavoy *et al.*, 2021; Zhou *et al.*, 2022).

Certain acids such as HCl and HNO_3 are commonly used for the digestion of organic matter (Catarino *et al.*, 2016; Prata *et al.*, 2019; Li *et al.*, 2020; Monteiro *et al.*, 2022). Acid digestion is commonly used for digestion of biological samples like fishes and bivalves. Other methods (known as enzymatic methos) have been also adopted in degradation of organic matter and success to achieved 75-88% digestion (Courtene-Jones *et al.*, 2017; Lusher *et al.*, 2020; Lv *et al.*, 2021). In this method certain enzymes such as collagenase trypsin, and pepsin (Table 2) are used for degradation purpose.

Microscopic analysis and characterization

Microscopic analysis is generally used for morphological description of MPs based on their size, colour, shape and identification. For these various techniques are used like Stereo-microscope, Fluorescence, Scanning Electron Microscope (SEM), Transmission Electron Microscope (TEM), Atomic Force Microscope (AFM), Confocal Laser Scanning Microscope (CLSM) (Table 3). The stereomicroscope is very simple, well-proven and straightforward technique for counting microplastics (Qui *et al.*, 2016; Pervez *et al.*, 2020; Cheng *et al.*, 2022). Another method used in microplastic

Table 2: Methods of digestion of organic matter in water samples

Digestion methods	Treatment	Rate of organic matter digestion	Reference
Acid	HNO_3(35%) 60^{0}C, 1h	100%	Catarino *et al.* (2016); Prata *et al.* (2019); Li *et al.* (2020); Monteiro *et al.* (2022)
	HCl (5-37%) 25-6^{0}C, 96h	>95%	Karami *et al.* (2017); Li *et al.* (2020); Zou *et al.* (2021); Corbacho *et al.* (2022)
Alkali	NaOH(10M) 60^{0}C,24h	-	Dehaut *et al.* (2016); Hurley *et al.* (2018); Li *et al.* (2022); Akyildiz *et al.* (2023)
	KOH (10%) 50^{0}C, 96h	-	Karami *et al.* (2017); Prata *et al.* (2019); Koh *et al.* (2022); Akyildiz *et al.* (2023);
	$K_2S_2O_8$(0.27M) & NaOH (0.24M) 65^{0}C, 24h	-	Dehaut *et al.* (2016); Nollet *et al.* (2020); Li *et al.* (2022); Li *et al.* (2024)
Oxidative	H_2O_2(30%) 60^{0}C until evaporates	-	Masura *et al.* (2015); Ziajahromi *et al.* (2017); Prata *et al.* (2019); Lavoy *et al.* (2021); *Zhou et al.* (2022)
Enzymatic	Collagenase (30M) 38-42^{0}C	76%	Courtene-Jones *et al.* (2017); Lusher *et al.* (2020); Lv *et al.* (2021)
	Trypsin(30M) 38-42^{0}C	88%	Courtene-Jones *et al.* (2017); Lusher *et al.* (2020); Zhu *et al.* (2022)
	Pepsin(30M) 38-42^{0}C	72%	Courtene-Jones *et al.* (2017); YU *et al.* (2022); Geppner *et al.* (2023); Liu *et al.* (2024)

investigations are fluorescence microscopy, which blocks light from the lateral portion of the focal point using a confocal pinhole. As a result, it permits axial and lateral resolution near the difraction limit. When hydrophobic microplastic debris is dyed with a fluorescence-active dye, such as Nile red dye, this approach is mostly utilized (Maes *et al.*, 2017; Scircle and Cizdziel, 2019; Kukkola *et al.*, 2023). Fluorescence and stereoscopic microscopy are the most frequently used in the context of MPs.

Electron microscopy is an efficient instrument for capturing morphological data, such as size, shape, surface topography, and aggregate structure, in the context of obtaining qualitative and semi-quantitative information regarding the elemental composition and crystal structure of the studied samples. Within this field of microscopy, scanning electron microscopy (SEM) and transition electron microscopy (TEM) are the two most often used methods. AFM (Atomic Force Microscopy) and CLSM (confocal laser microscopy) are two alternatives to the standard microscopic techniques used in MPs/NPs detection that are based on entirely different operating principles than standard microscopy (Kalaronis *et al.*, 2022).

Spectroscopy analysis and Polymer identification

Compared to purely visual detection, spectroscopic analytical procedures yield more accurate chemical information since they can not

Table 3: Microscopy techniques to identify microplastics particles

Microscope	Analytical information	Resolution	Merits	Demerits	Reference
Stereomicroscope	Characterization of the MPs morphology; Determination of their size	<100 µm	Simple, fast, and inexpensive technique	Not feasible identification of particles; need for coupling with other al., techniques	Qui *et al.* (2016); Pervez *et al.* (2020); Cheng *et al.* (2022)
Fluorescence	Determination of potential MPs; Identification of shape, size and colour quantification of MPs	<5 µm	Simple, fast, inexpensive technique; No need for specific pretreatment	Non-fluorescent polymers cannot be detected	Maes *et al.* (2017); Scircle and Cizdziel (2019); Kukkola *et al.* (2023)
SEM	Size, shape, number, and composition of MPs	<100 nm	Complete analysis includes number, size, shape, and composition	Time-consuming sample preparation	Wang *et al.* (2017); Tirkey *et al.* (2021); Girão *et al.* (2022)
TEM	Morphology and structure of MPs	<0.1 nm	Very high-resolution image	Long time and preparation for analysis	Nguyen *et al.* (2019); Yang *et al.* (2021); Kalaronis *et al.* (2022)
AFM	Topographic analysis of MPs' surface and morphological description	<0.3 nm	Very high resolution, Identification of polymer blends, 3D images	External contamination, Tip of cantilever can damage the sample	Shim *et al.* (2017); Mariano *et al.* (2021)
CLSM	Detection of small sized MPs and NPs	<100 nm	Detection of MPs, Identification of polymer blend and adsorbed organic compounds onto MPs	-	Chen *et al.* (2020); Melo-Agustín *et al.* (2022)

SEM (Scanning Electron Microscope), TEM (Transmission Electron Microscope), AFM (Atomic Force Microscope Microscope), CLSM (Confocal Laser Scanning Microscope)

only identify plastic particles but also determine their composition and provide unique information about the samples under study. The preceding statement is attributed to the distinct and independent signal that distinguishes between polymeric and non-polymeric materials, as indicated by the spectral signal. Raman spectroscopies and Fourier Transform Infrared (FT IR) identify plastic items through their vibrational spectrum (Table 4), which is specific to each type of polymer and can be set up in microscopic settings, enabling chemical imaging in addition to counting, colour, size, and shape determination (Xu *et al.*, 2019).

FTIR (Fourier Transform Infrared)

Determining the precise polymer composition of microplastics is essential to comprehending their origins, dispersion, and ecological consequences. Because of their great specificity and non-destructive nature, FTIR and Raman spectroscopy are commonly utilized (Löder *et al.*, 2015; Araujo *et al.*, 2018).

Impact of Microplastic on Ponds ecosystem

According to Deng *et al.* (2021) microplastics have been identified as a novel biological niche in aquatic ecosystem. They are widely accessible and have a strong inclination to interact with the ecosystem, upsetting the biogenic flora and fauna (Au *et al.*, 2017; Ivleva *et al.*, 2017). Additionally, microplastics have the ability to leach chemicals out of their environment and act as transport vectors for contaminants (Issac and Kandasubramanian, 2021). In just a few minutes to hours, a variety of microorganisms, including

Table 4: Spectroscopy techniques used for polymer identification

Spectroscopy	Identical information	Resolution	Merits	Demerits	Reference
Raman	Chemical fingerprint	up to 1 µm	Hyperspectral image, Low interference from water signal, High spatial resolution.	Low Raman signal, Potential burn of the sample.	Vašková *et al.* (2011); Lenz *et al.* (2015); Araujo *et al.* (2018); Xu *et al.* (2019);
FTIR	Chemical fingerprint	< 10 µm	Simple sample mapping; Lower detection limit	Particle thickness; Reflective errors	Bhargava *et al.* (2003); Riaz *et al.* (2014); Bell *et al.* (2019)

bacteria, fungi, diatoms, and others, may colonize the surface of MPs placed in an aquatic environment. This process results in the formation of so-called biofilm, also known as "Plastisphere" (Zettler *et al.*, 2013; Zhai *et al.*, 2023), which is a colony of microorganisms that can take part in the nitrogen (N) and phosphorus (P) cycles. The findings indicated that microplastic biofilms could quicken the oxidation of ammonia and nitrite in addition to denitrification (Connor, 2023). Alkaline phosphatase (APA) activity was momentarily elevated in the system by phosphorus. Phosphorus (P) and Nitrogen (N) were discharged into the water via the disintegration of mature biofilms (Khoironi *et al.*, 2023). According to Chen *et al.* (2022) aquatic systems' N and P cycling mechanisms can be altered by biofilms linked to microplastics. Water-based food webs depend heavily on phytoplankton groups as major energy generators; MPs have the potential to jeopardize the health of the entire plankton ecosystem. They have a profound impact on the organization of phytoplankton communities (Hitchcock *et al.*, 2022; Pan *et al.*, 2022). MPs have a variety of adverse consequences on zooplankton, including detrimental effects on eating habits, reproduction, growth, development, and lifespan (Chen *et al.*, 2021; Sarijan *et al.*, 2021). The concentration, form, size, and age of microplastics have all been found to have an impact on their bioavailability to zooplankton. Exposure to microplastics affects not just an individual but also the population as a whole and the environment (Bottrell *et al.*, 2019).

On the outside of certain plant and macrophyte species, microplastics can build up (Mateos-Cárdenas *et al.*, 2021; Mao *et al.*, 2023). Reductions in population growth, reductions in photosynthetic activity, an increase in reactive oxygen species formation, and alterations in gene expression linked to sugar biosynthesis are only some of the harmful impacts that can result from exposure to microplastics (Wu *et al.*, 2021; Colzi *et al.*, 2022). As aquatic plants are essential to preserving the equilibrium and well-being of aquatic ecosystems, this may eventually have an impact on their growth and health. and macrophytes could make it easier for plastics to enter the food chain, which would affect a variety of species, including human food sources and, consequently, food safety (Mateos-Cárdenas *et al.*, 2021).

MPs affect the intestine, liver, gills, and brain structurally while also affecting metabolic balance, behaviour, and fertility in aquatic invertebrates (Wei *et al.*, 2023). They also slow down larval growth and development, increase oxygen consumption, and stimulate the production of reactive oxygen species (Jabeen *et al.*, 2018). The degree of these detrimental effects varies on the particle sizes and doses as well as the exposure parameters (Zolotova *et al.*, 2022). Aquatic plants,

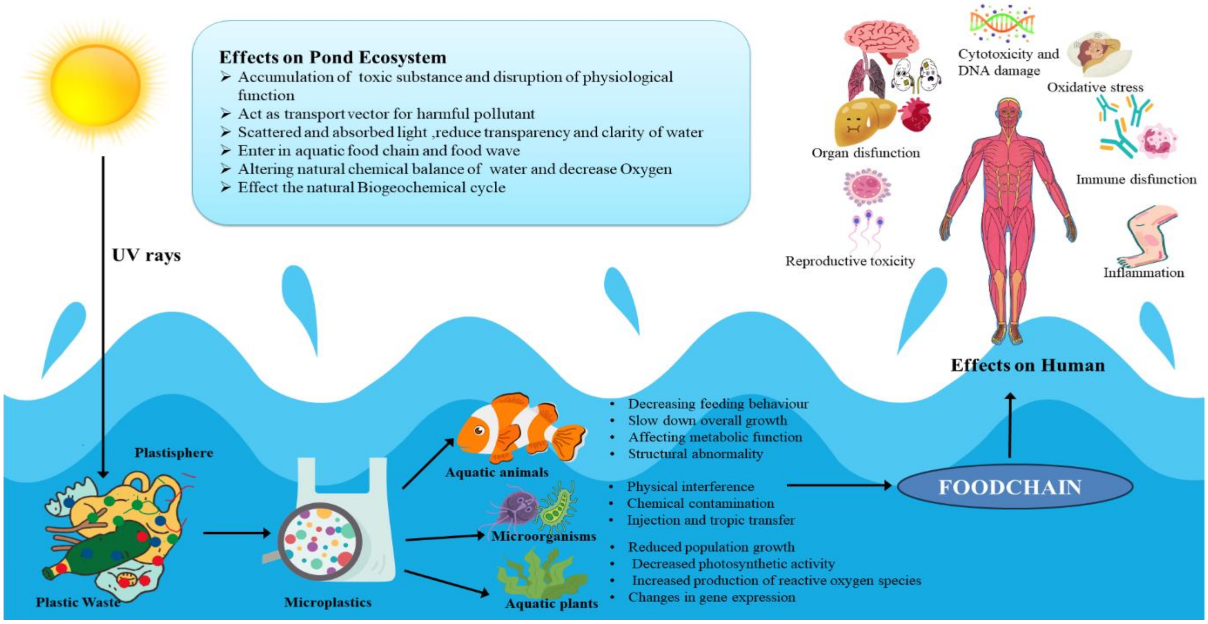

Fig. 4: Effect of microplastics in human health and aquatic ecosystem.

animals, and bacteria are vital fot preserving the ecosystem's balance and health in ponds, and their growth and health may eventually be impacted by microplastic contamination (Cole *et al.*, 1982; Zaghloul *et al.*, 2022).

Microplastics can enter the human body through the food we eat, the air we breathe, or our skin when we come into contact with these tiny particles (Fig. 4). Particle toxicity from microplastic exposure can result in enhanced absorption or translocation, oxidative stress, and inflammatory lesions. The immune system's incapacity to get rid of artificial particles may raise the risk of neoplasia and cause chronic inflammation (Prata *et al.*, 2020).

Mitigation and Management Strategies for Microplastic Contamination in Pondwater

Mitigation Strategies

For handling the plastic pollution, we have to put collective efforts for mitigation and management. First and foremost, we have to strictly follow the policy and regulation declared by United Environmental Protection Program (UNEP) on implementing bans on single-use plastics (UNEP, 2018) which will significantly reduce the plastics pollution and its intervention in aquatic ecosystem. Indeed in 2019 European union, also come forward the strengthening waste management policy to prevent plastics entering into water bodies (Plastic Europe, 2019). Gallo *et al.* (2018) suggested, enforcing strict guidelines for industrial effluents in order to reduce the emission of microplastics. Whereas, we also need to provide technological based solutions like installing advanced filtration systems, utilizing microbes capable of breaking down plastic polymers to lower the amount of microplastic in aquatic environments and advance nano-based techniques (Talvitie *et al.*, 2017; Raju *et al.*, 2018; Tiwari *et al.*, 2020).

Indeed, adopt ecosystem-based techniques like constructed wetland for filtration and degradation of microplastics via natural process (Vymazal, 2011). Also established riparian buffers along water bodies to trap, prevent the entry of runoff water, which contaminated with microplastics (Dosskey *et al.*, 2010). Highly Prominently Strategy is raising public awareness about source of MPs, and its impact on human and aquatic ecosystem through providing education, community involvement and promoting sustainable practices (Schmidt *et al.*, 2017; Hartley *et al.*, 2018; Ramasamy and Harit, 2021). To guarantee comprehensive and long-lasting solutions, microplastic pollution mitigation should be integrated into larger water management frameworks (Biswas, 2008).

Management Strategies

Several management approaches are necessary for the elimination of plastic waste in any body of water. Numerous techniques involving physical, chemical, and biological methods have been documented for the extraction of microplastics. Coagulation, flocculation, sedimentation, ultrafiltration, charcoal adsorption, UV, and ozone are among the methods utilized for the extraction of microplastics from aquatic environments. Specific types of microalgae can naturally remove microplastics. One biological method employed for microplastic removal is the activated sludge strategy, which effectively separates microplastics, showcasing a notably heightened efficiency compared to traditional methods. Additionally, implementing regular monitoring programs to examine the plastic pollution in pond water. Also developed the standards protocols for data analysis and community clean activities for to removing visible and floating plastic debris from the water bodies are good management strategies (Hidalgo-Ruz *et al.*, 2012; Lusher *et al.*, 2015; Pahl *et al.*, 2017). Promoting cooperation between the public sector, private sector, and non-governmental groups in order to fully solve the issue of microplastic contamination (Heidbreder *et al.*, 2019).

Another solution to combat the issue of plastic pollution is the increased utilization of biodegradable materials known as bioplastics. Bioplastics are manufactured from replenishable sources like starch, cellulose, lignin, and bioethanol. Currently, bioplastics amount to only about 0.5% of the approximately 335 million tons of plastic produced annually. Effective measures to address microplastic pollution should include source control achieved through legislation and awareness programs, as well as remediation and clean-up efforts to eliminate microplastics already present in water bodies, accompanied by education and awareness initiatives. (Picó and Barceló, 2019).

Conclusion

This review consolidates a substantial body of evidence indicating the pervasive presence of microplastics in pond ecosystems. Through diverse methodologies and global investigations, researchers have consistently detected micro-plastics across various pond types, highlighting the ubiquitous nature of this environmental pollutant. The documented impacts on aquatic organisms and potential implications for human health underscore the urgency for further research and proactive mitigation strategies to address this emerging environmental challenge. By synthesizing existing knowledge, this review emphasizes the imperative for continued monitoring, interdisciplinary collaboration, and policy interventions, ecosystem-based tactics legislative measures, and public involvement which are needed to address microplastic contamination in pond water and ensure the sustainability of freshwater resources in the face of microplastic contamination. Freshwater ecosystems and human health can be safeguarded by lowering the sources and effects of microplastics through the application of various mitigation and management techniques

Ethical Statement

This is a review article hence no Ethical Approval needed.

Author Contributions

Each author has contributed equally to the study's planning, analysis, writing, and editing. All authors have read and agreed to the published version of the manuscript.

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Conflict of Interest

The authors declare no conflicts of interest.

References

Akyildiz SH, Sezgin H, Yalcin B and Yalcin-Enis I. (2023) Optimization of the textile wastewater pretreatment process in terms of organics removal and microplastic detection. J Cleaner Production 384: 135637.

Araujo CF, Nolasco MM, Ribeiro AMP and Ribeiro-Claro PJA. (2018) Identification of microplastics using Raman spectroscopy: Latest developments and future prospects. Water Res. 142: 426-440.

Au SY, Lee CM, Weinstein JE, van den Hurk P and Klaine SJ. (2017) Trophic transfer of microplastics in aquatic ecosystems: identifying critical research needs. Integrated Environ Assessm Managem. 13(3): 505-509.

Barnes DK, Galgani F, Thompson RC and Barlaz M. (2009) Accumulation and fragmentation of plastic debris in global environments. Philosop Transactions Royal Soc B Biol Sci. 364(1526): 1985-1998.

Bell J, Nel P and Stuart B. (2019) Non-invasive identification of polymers in cultural heritage collections: Evaluation, optimisation and application of portable FTIR (ATR and external reflectance) spectroscopy to three-dimensional polymer-based objects. Heritage Sci. 7(1): 95.

Bhargava R, Wang SQ and Koenig JL. (2003) FTIR microspectroscopy of polymeric systems. Adv Polym Sci. 163: 137-191.

Biswas AK. (2008) Integrated water resources management: Is it working? Int J Water Resources Developm. 24(1): 5-22.

Bordós G, Urbányi B, Micsinai A, Kriszt B, Palotai Z, Szabó I, Hantosi Z and Szoboszlay S. (2019) Identification of microplastics in fish ponds and natural freshwater environments of the Carpathian basin, Europe. Chemosphere 216: 110-116.

Botterell ZL, Beaumont N, Dorrington T, Steinke M, Thompson RC and Lindeque PK. (2019) Bioavailability and effects of microplastics on marine zooplankton: A review. Environ Pollut. 245: 98-110.

Catarino AI, Thompson R, Sanderson W and Henry TB. (2017) Development and optimization of a standard method for extraction of microplastics in mussels by enzyme digestion of soft tissues. Environ Toxicol Chem. 36(4): 947-951.

Chaudhari S and Samnani P. (2023) Determination of microplastics in pond water. Materials Today Proc. 77: 91-98.

Chen G, Li Y and Wang J. (2021) Occurrence and ecological impact of microplastics in aquaculture ecosystems. Chemosphere 274: 129989.

Chen X, Chen X, Zhao Y, Zhou H, Xiong X and Wu C. (2020) Effects of microplastic biofilms on nutrient cycling in simulated freshwater systems. Sci Total Environ. 719: 137276.

Chen Y, Wen D, Pei J, Fei Y, Ouyang D, Zhang H and Luo Y. (2020) Identification and quantification of microplastics using Fourier-transform infrared spectroscopy: Current status and future prospects. Curr Opinion Environ Sci Hlth. 18: 14-19.

Cheng YL, Zhang R, Tisinger L, Cali S, Yu Z, Chen HY and Li A. (2022) Characterization of microplastics in sediment using stereomicroscopy and laser direct infrared (LDIR) spectroscopy. Gondwana Res. 108: 22-30.

Cole JJ. (1982) Interactions between bacteria and algae in aquatic ecosystems. Annual Rev Ecol Systematics 13(1): 291-314.

Cole M, Webb H, Lindeque PK, Fileman ES, Halsband C and Galloway TS. (2014) Isolation of microplastics in biota-rich seawater samples and marine organisms. Sci Rep. 4(1): 4528.

Colzi I, Renna L, Bianchi E, Castellani MB, Coppi A, Pignattelli S, Loppi S and Gonnelli C. (2022) Impact of microplastics on growth, photosynthesis and essential elements in *Cucurbita pepo* L. J Hazard Mater. 423(Pt B): 127238.

Connor, F. (2023). Investigating the effectiveness of microplastic removal and the relationship between microplastics, bacterial communities, and nitrogen cycling in the natural treatment systems ldt.edu/etdat the Arcata Wastewater Treatment Facility. Cal Poly Humboldt theses and projects. 650. https://digitalcommons.humboldt.edu/etd/650

Courtene-Jones W, Quinn B, Murphy F, Gary SF and Narayanaswamy BE. (2017) Optimisation of enzymatic digestion and validation of specimen preservation methods for the analysis of ingested microplastics. Analytical Methods, 9(9), 1437-1445.

Davis, EK and Raja S. (2020) Sources and impact of microplastic pollution in Indian aquatic ecosystem: A review. Curr World Environ. 15(Special issue 1): 1-9.

Dehaut A, Cassone AL, Frère L, Hermabessiere L, Himber C, Rinnert E, Rivière G, Lambert C, Soudant P, Huvet A, Duflos G and Paul-Pont I. (2016) Microplastics in seafood: Benchmark protocol for their extraction and characterization. Environ Pollut. 215: 223-233.

Deng H, Qianqian Fu, Dazhen Li, Yuqing Zhang, Jianxiong He, Dan Feng, Yuanyuan Zhao, Gan Du, Huamei Yu and Chengjun G. (2021) Microplastic-associated biofilm in an intensive mariculture pond: Temporal dynamics of microbial communities, extracellular polymeric substances and impacts on microplastics properties. J Clean Prod. 319: 128774.

Dosskey MG, Vidon P, Gurwick NP, Allan CJ, Duval TP and Lowrance R. (2010) The role of riparian vegetation in protecting and improving chemical water quality in streams. J American Water Resour Assoc. 46(2): 261-277.

Dris R, Gasperi J, Saad M, Mirande C and Tassin B. (2016) Synthetic fibers in atmospheric fallout: a source of microplastics in the environment?. Mar Pollut Bull. 104(1-2): 290-293.

Erdoğan Ş. (2020) Microplastic pollution in freshwater ecosystems: A case study from Turkey. Ege J Fisheries Aquat Sci. 37(3): 213-221.

Eriksen M, Mason S, Wilson S, Box C, Zellers A, Edwards W, Farley H and Amato S. (2013) Microplastic pollution in the surface waters of the Laurentian Great Lakes. Mar Pollut Bull. 77(1-2): 177-182.

Gallo F, Fossi C, Weber R, Santillo D, Sousa J, Ingram I, Nadal A and Romano D. (2018) Marine litter plastics and microplastics and their toxic chemicals components: the need for urgent preventive measures. Environ Sci Eur. 30(1): 13.

Geppner L, Karaca J, Wegner W, Rados M, Gutwald T, Werth P and Henjakovic M. (2023) Testing of different digestion solutions on tissue samples and the effects of used potassium hydroxide solution on polystyrene microspheres. Toxics 11(9): 790.

Geyer R, Jambeck JR and Law KL. (2017) Production, use, and fate of all plastics ever made. Sci Adv. 3(7): e1700782.

Girão AV. (2022) SEM/EDS and optical microscopy analysis of microplastics. In: Handbook of Microplastics in the Environment , Cham: Springer International Publishing, pp. 57-78.

González-Pleiter M, Tamayo-Belda M, Pulido-Reyes G, Amariei G, Leganés F, Rosal R and Fernández-Piñas, F. (2019) Secondary nanoplastics released from a biodegradable microplastic severely impact freshwater environments. Environ Sci Nano 6(5): 1382-1392.

Harit AK, Aiswyira VP, Babu N, Sruthi SN and Ramasamy EV. (2019) Microplastic contamination in green mussels: a favourite seafood in Kerala, India. InAdCoRe 2019, National Centre for Coastal Research, Chennai, December 17–19, 2019.

Hartley BL, Pahl S, Veiga J, Vlachogianni T, Vasconcelos L, Maes T, Doyle T, d'Arcy Metcalfe R, Öztürk AA, Di Berardo M and Thompson RC. (2018) Exploring public views on marine litter in Europe: Perceived causes, consequences and pathways to change. Mar Pollut Bull. 133: 945-955.

Heidbreder LM, Bablok I, Drews S and Menzel C. (2019) Tackling the plastic problem: A review on perceptions, behaviors, and interventions. Sci Total Environ. 668: 1077-1093.

Herath S, Hagare D, Siddiqui Z and Maheshwari B. (2022) Microplastics in urban stormwater—developing a methodology for its monitoring. Environ Monitor Assess. 194(3): 173.

Hidalgo-Ruz V, Gutow L, Thompson RC and Thiel M. (2012) Microplastics in the marine environment: A review of the methods used for identification and quantification. Environ Sci Technol. 46(6): 3060-3075.

Hitchcock JN. (2022) Microplastics can alter phytoplankton community composition. Sci Total Environ. 819: 153074.

Hopewell J, Dvorak R and Kosior E. (2009) Plastics recycling: challenges and opportunities. Philosophical Transact Royal Soc B Biol Sci. 364(1526): 2115-2126.

Hossain MB, Banik P, Nur AA, Choudhury TR, Liba SI, Albeshr MF, Yu J and Arai T. (2023) Microplastics in fish culture ponds: abundance, characterization, and contamination risk assessment. Front Environ Sci. 11: 1251158.

Hurley RR, Lusher AL, Olsen M and Nizzetto L. (2018) Validation of a method for extracting microplastics from complex, organic-rich, environmental matrices. Environ Sci Technol. 52(13): 7409-7417.

Issac MN and Kandasubramanian B. (2021) Effect of microplastics in water and aquatic systems. Environ Sci Pollut Res. 28: 19544-19562.

Ivleva NP, Wiesheu AC and Niessner R. (2017) Microplastic in aquatic ecosystems. Angew Chem Int Ed Engl. 56(7): 1720-1739.

Jabeen K, Li B, Chen Q, Su L, Wu C, Hollert H and Shi H. (2018) Effects of virgin microplastics on goldfish (*Carassius auratus*). Chemosphere 213: 323-332.

Kalaronis D, Ainali NM, Evgenidou E, Kyzas GZ, Yang X, Bikiaris, DN and Lambropoulou DA. (2022) Microscopic techniques as means for the determination of microplastics and nanoplastics in the aquatic environment: A concise review. Green Anal Chem. 3: 100036.

Karami A, Golieskardi A, Choo CK, Romano N, Ho YB and Salamatinia B. (2017) A high-performance protocol for extraction of microplastics in fish. Sci Total Environ. 578: 485-494.

Karlsson TM, Vethaak AD, Almroth BC, Ariese F, van Velzen M, Hassellöv M and Leslie HA. (2017) Screening for microplastics in sediment, water, marine invertebrates and fish: Method development and microplastic accumulation. Mar Pollut Bull. 122(1-2): 403-408.

Khoironi A, Hadiyanto H, Hartini E, Dianratri I, Joelyna FA and Pratiwi WZ. (2023) Impact of disposable mask microplastics pollution on the aquatic environment and microalgae growth. Environ Sci Pollut Res. 30(31): 77453-77468.

Koh KY, Chen Z, Lin S, Mohan KC, Luo X and Chen JP. (2022) Leaching of organic matters and formation of disinfection by-product as a result of presence of microplastics in natural freshwaters. Chemosphere 299: 134300.

Kukkola A, Krause S, Yonan Y, Kelleher L, Schneidewind U, Smith GHS, Nel H and Lynch I. (2023) Easy and accessible way to calibrate a fluorescence microscope and to create a microplastic identification key. MethodsX 10: 102053.

Lavoy M and Crossman J. (2021) A novel method for organic matter removal from samples containing microplastics. Environ Pollut. 286: 117357.

Lenz R, Enders K, Stedmon CA, Mackenzie DM and Nielsen TG. (2015) A critical assessment of visual identification of marine microplastic using Raman spectroscopy for analysis improvement. Mar Pollut Bull. 100(1): 82-91.

Le ND, Hoang TT, Duong TT, Lu X, Pham TM, Phung TX, Le TM, Duong TH, Nguyen TD and Le TP. (2022) First observation of microplastics in surface sediment of some aquaculture ponds in Hanoi city, Vietnam. J Hazard Mater Adv. 6: 100061.

Li M, Li Z, Chen F, Shi B, Li Y, Zhu Z, Wang L and Jin Y. (2024) Effects of different oxidants on the behaviour of microplastic hetero-aggregates. J Hazard Mater. 470: 134286.

Li W, Luo Y and Pan X. (2020) Identification and characterization methods for microplastics basing on spatial imaging in micro-/nanoscales. In: Microplastics in terrestrial environments: emerging contaminants and major challenges, (eds.) He D. and Luo Y., Springer, Cham., pp. 25-37.

Li X, Chen L, Ji Y, Li M, Dong B, Qian G, Zhou J and Dai X. (2020) Effects of chemical pretreatments on microplastic extraction in sewage sludge and their physicochemical characteristics. Water Res. 171: 115379.

Li X, Li M, Liu L and Huang X. (2022) Techniques for microplastics detection in urban water systems. In: Microplastics in Urban Water Management, (eds.) Bing-Jie N., Qiuxiang X. and Wei W., Wiley, pp. 1-52.

Liu F, Olesen KB, Borregaard AR and Vollertsen J. (2019) Microplastics in urban and highway stormwater retention ponds. Sci Total Environ. 671: 992-1000.

Liu G, Jiang Q, Qin L, Zeng Z, Zhang P, Feng B, Liu X, Qing Z and Qing T. (2024) The influence of digestive tract protein on cytotoxicity of polyvinyl chloride microplastics. Sci Total Environ. 945: 174023.

Löder MGJ, Kuczera M, Mintenig S, Lorenz C and Gerdts G. (2015) Focal plane array detector-based micro-Fourier-transform infrared imaging for the analysis of microplastics in environmental samples. Environ Chem. 12(5): 563-581.

Long Z, Wang W, Yu X, Lin Z and Chen J. (2021) Heterogeneity and contribution of microplastics from industrial and domestic sources in a wastewater treatment plant in Xiamen, China. Front Environ Sci. 9: 770634.

Lusher AL, Hollman PCH and Mendoza-Hill JJ. (2015) Microplastics in fisheries and aquaculture: Status of knowledge on their occurrence and implications for aquatic organisms and food safety. FAO Fish Aquacult Technical Paper No. 615.

Lusher AL, Munno K, Hermabessiere L and Carr S. (2020) Isolation and extraction of microplastics from environmental samples: an evaluation of practical approaches and recommendations for further harmonization. Appl Spectroscopy 74(9): 1049-1065.

Lv L, Yan X, Feng L, Jiang S, Lu Z, Xie H, Sun S, Chen J and Li C. (2021) Challenge for the detection of microplastics in the environment. Water Environ Res. 93(1): 5-15.

Maes T, Jessop R, Wellner N, Haupt K and Mayes AG. (2017) A rapid-screening approach to detect and quantify microplastics based on fluorescent tagging with Nile Red. Sci Rep. 7(1): 44501.

Mao H, Yang H, Xu Z, Yang Y, Zhang X, Huang F, Wei L and Li Z. (2023) Microplastics and co-pollutant with ciprofloxacin affect interactions between free-floating macrophytes. Environ Pollut. 316(Pt 1): 120546.

Masura J, Baker JE, Foster GD, Arthur C and Herring C. (2015) Laboratory methods for the analysis of microplastics in the marine environment: recommendations for quantifying synthetic particles in waters and sediments. file:///C:/Users/PC/Downloads/noaa_10296_DS1.pdf

Mateos-Cárdenas A, van Pelt FN, O'Halloran J and Jansen MA. (2021) Adsorption, uptake and toxicity of microand nanoplastics: Effects on terrestrial plants and aquatic macrophytes. Environ Pollut. 284: 117183.

Monteiro SS, Rocha-Santos T, Prata JC, Duarte AC, Girão AV, Lopes P, Cristovão T and da Costa JP. (2022) A straightforward method for microplastic extraction from organic-rich freshwater samples. Sci Total Environ. 815: 152941.

Morritt D, Stefanoudis PV, Pearce D, Crimmen OA and Clark PF. (2014) Plastic in the Thames: a river runs through it. Mar Pollut Bull. 78(1-2): 196-200.

Nguyen B, Claveau-Mallet D, Hernandez LM, Xu EG, Farner JM and Tufenkji N. (2019) Separation and analysis of microplastics and nanoplastics in complex environmental samples. Acc Chem Res. 52(4): 858-866.

Nollet LM. (2020) Sampling, isolating and digesting of microplastics. In: Analysis of Nanoplastics and Microplastics in Food, (eds.) Leo M.L.N. and Siddiqi K.S., CRC Press, pp. 103-117.

O'Brien S, Rauert C, Ribeiro F, Okoffo ED, Burrows SD, O'Brien JW, Wang X, Wright SL and Thomas KV. (2023) There's something in the air: A review of sources, prevalence and behaviour of microplastics in the atmosphere. Sci Total Environ. 874: 162193.

Olesen KB, Stephansen DA, van Alst N and Vollertsen J. (2019) Microplastics in a stormwater pond. Water 11(7): 1466.

Pahl S, Wyles KJ and Thompson RC. (2017) Channelling passion for the ocean towards plastic pollution. Nature Human Behaviour 1(10): 697-699.

Pan Y, Long Y, Hui J, Xiao W, Yin J, Li Y, Liu D, Tian Q and Chen L. (2022) Microplastics can affect the trophic cascade strength and stability of plankton ecosystems via behavior-mediated indirect interactions. J Hazard Mater. 430: 128415.

Pervez R, Wang Y, Mahmood Q and Jattak Z. (2020) Stereomicroscopic and Fourier transform infrared (FTIR) spectroscopic characterization of the abundance, distribution and composition of microplastics in the beaches of Qingdao, China. Anal Letts. 53(18): 2960-2977.

Picó Y and Barceló D. (2019) Analysis and prevention of microplastics pollution in water: current perspectives and future directions. ACS Omega 4(4): 6709-6719.

PlasticsEurope (2019) Plastics—The Facts 2019. An Analysis of European Plastics Production, Demand and Waste Data. PlasticEurope https://www.plasticseurope.org/en/resources/publications/1804-plastics-facts-2019

Pradhan C and Harit AK. (2023) Microplastics contamination in fresh water and bottle water: A mini review. In: Current strategies and initiative in environmental science and technology, pp. 1-14. ISBN: 978-81-967662-4-5.

Pradhan C and Harit AK. (2024) Microplastics: A hidden thread to human life. In: Pollution and Climate: Strategies for A Sustainable Future, Genic publication, Agra, pp. 123-139. ISBN: 978-81-980575-8-7.

Prata JC, da Costa JP, Girão AV, Lopes I, Duarte AC and Rocha-Santos T. (2019) Identifying a quick and efficient method of removing organic matter without damaging microplastic samples. Sci Total Environ. 686: 131-139.

Prata JC, da Costa JP, Lopes I, Duarte AC and Rocha-Santos T. (2020) Environmental exposure to microplastics: An overview on possible human health effects. Sci Total Environ. 702: 134455.

Qiu Q, Tan Z, Wang J, Peng J, Li M and Zhan Z. (2016) Extraction, enumeration and identification methods for monitoring microplastics in the environment. Estuarine Coastal Shelf Sci. 176: 102-109.

Ramasamy EV and Harit AK. (2023) Microplastics in Human Consumption. 1st edn., CRC Press, pp.1186.

Ramasamy EV, Sruthy S, Harit AK, Mohan M and Binish MB. (2021) Microplastic pollution in the surface sediment of Kongsfjorden, Svalbard, Arctic. Mar Pollut Bull. 173: 112986.

Ramasamy EV, Sruthy SN, Harit AK and Babu N. (2019) Microplastics in human consumption: Table salt contaminated with microplastics. Water Perspectives in Emerging Countries: Microplastics in the Water Environment. August 19-21, 2019-Island of Koh Samui, Thailand.

Riaz U and Ashraf SM. (2014) Characterization of polymer blends with FTIR spectroscopy. In: Characterization of Polymer Blends: Miscibility, Morphology and Interfaces, (eds.) . Thomas S., Grohens Y. and Jyotishkumar P., Wiley, pp. 625-678.

Sarijan S, Azman S, Said MIM and Jamal MH. (2021) Microplastics in freshwater ecosystems: a recent review of occurrence, analysis, potential impacts, and research needs. Environ Sci Pollut Res. 28: 1341-1356.

Schmidt C, Krauth T and Wagner S. (2017) Export of plastic debris by rivers into the sea. Environ Sci Technol. 51(21): 12246-12253.

Scircle A and Cizdziel JV. (2019) Detecting and quantifying microplastics in bottled water using fluorescence microscopy: A new experiment for instrumental analysis and environmental chemistry courses. J Chem Education 97(1): 234-238.

Shim WJ, Hong SH and Eo SE. (2017) Identification methods in microplastic analysis: a review. Anal Methods 9(9): 1384-1391.

Supriatna I, Risjani Y, Kurniawan A and Yona D. (2023) Microplastics contaminant in *Telescopium telescopium* (gastropods), the keystone mangrove species and their habitat at brackish water pond, East Java, Indonesia. Emerging Contaminants 9(4): 100245.

Talvitie J, Mikola A, Koistinen A and Setälä O. (2017) Solutions to microplastic pollution–Removal of microplastics from wastewater effluent with advanced wastewater treatment technologies. Water Res. 123: 401-407.

Thompson RC, Olsen Y, Mitchell RP, Davis A, Rowland SJ, John AW, McGonigle D and Russell AE. (2004) Lost at sea: where is all the plastic? Science 304(5672): 838.

Tirkey A and Upadhyay LSB. (2021) Microplastics: An overview on separation, identification and characterization of microplastics. Mar Pollut Bull. 170: 112604.

UNEP (2018). Single-use plastics: A roadmap for sustainability. https://wedocs.unep.org

Upadhyay K and Bajpai S. (2024) Urban tropical freshwater ponds as microplastics hotspots—insight on abundance and characteristics using an improved sampling technique. Environ Monitor Assess. 196(1): 73.

Vašková H. (2011) A powerful tool for material identification: Raman spectroscopy. Int J Mathematical Models Methods Appl Sci. 5(7): 1205-1212.

Vijayaraman S, Mondal P, Nandan A and Siddiqui NA. (2020) Presence of microplastic in water bodies and its impact on human health. In: Advances in Air Pollution Profiling and Control: Select Proceedings of HSFEA 2018, Springer Singapore, pp. 57-65.

Vymazal J. (2011) Constructed wetlands for wastewater treatment: Five decades of experience. Environ Sci Technol. 45(1): 61-69.

Wang J, Bucci K, Helm PA, Hoellein T, Hoffman MJ, Rooney R and Rochman CM. (2022) Runoff and discharge pathways of microplastics into freshwater ecosystems: A systematic review and meta-analysis. Facets 7. https://doi.org/10.1139/facets-2022-0140

Wang ZM, Wagner J, Ghosal S, Bedi G and Wall S. (2017) SEM/EDS and optical microscopy analyses of microplastics in ocean trawl and fish guts. Sci Total Environ., 603: 616-626.

Wei W, Yang Q, Xiang D, Chen X, Wen Z, Wang X, Xu X, Peng C, Yang L, Luo M and Xu J. (2023) Combined impacts of microplastics and cadmium on the liver function, immune response, and intestinal microbiota of crucian carp (*Carassius carassius*). Ecotoxicol Environ Saf. 261: 115104.

Weinstein JE, Crocker BK and Gray AD. (2016) From macroplastic to microplastic: Degradation of high-density polyethylene, polypropylene, and polystyrene in a salt marsh habitat. Environ Toxicol Chem. 35(7): 1632-1640.

Wu Y, Guo P, Zhang X, Zhang Y, Xie S and Deng J. (2019) Effect of microplastics exposure on the photosynthesis system of freshwater algae. J Hazard Mater., 374: 219-227.

Xiong X, Xie S, Feng K and Wang Q. (2022) Occurrence of microplastics in a pond-river-lake connection water system: How does the aquaculture process affect microplastics in natural water bodies. J Cleaner Prod. 352: 131632.

Xu JL, Thomas KV, Luo Z and Gowen AA. (2019) FTIR and Raman imaging for microplastics analysis: State of the art, challenges and prospects. Trends Anal Chem. 119: 115629.

Yang T, Luo J and Nowack B. (2021) Characterization of nanoplastics, fibrils, and microplastics released during washing and abrasion of polyester textiles. Environ Sci Technol. 55(23): 15873-15881.

Yu W, Chen J, Zhang S, Zhao Y, Fang M, Deng Y and Zhang Y. (2022) Extraction of biodegradable microplastics from tissues of aquatic organisms. Sci Total Environ. 838: 156396.

Zaghloul A, Saber M, Gadow S and Awad F. (2020) Biological indicators for pollution detection in terrestrial and aquatic ecosystems. Bull National Res Centre 44: 1-11.

Zettler ER, Mincer TJ and Amaral-Zettler LA. (2013) Life in the "plastisphere": microbial communities on plastic marine debris. Environ Sci Technol. 47(13): 7137-7146.

Zhai X, Zhang XH and Yu M. (2023) Microbial colonization and degradation of marine microplastics in the plastisphere: A review. Front Microbiol. 14: 1127308.

Zhou Q, Chen J, Zhang D and Pan X. (2022) Evaluation of organic matter removal by H_2O_2 from microplastic surface by nano-physicochemical methods. Green Anal Chem. 3: 100035.

Zhu J and Wang C. (2020) Recent advances in the analysis methodologies for microplastics in aquatic organisms: current knowledge and research challenges. Anal Methods 12(23): 2944-2957.

Ziajahromi S, Neale PA, Rintoul L and Leusch FD. (2017) Wastewater treatment plants as a pathway for microplastics: development of a new approach to sample wastewater-based microplastics. Water Res. 112: 93-99.

Zolotova N, Kosyreva A, Dzhalilova D, Fokichev N and Makarova O. (2022) Harmful effects of the microplastic pollution on animal health: a literature review. PeerJ 10: e13503.

Zou YD, Xu Q, Zhang G, Li FY and Li FM. (2021) Influence of six digestion methods on the determination of polystyrene microplastics in organisms using the fluorescence intensity. Huan Jing Ke Xue 40(1): 496.