



Original Article



An Appraisal on the Microplastics Pollution in Aruvikkara Reservoir, Kerala, India

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***Corresponding author:**Navami Surendran Sethulekshmi,
Email: navami@keralauniversity.ac.in**Abstract****Background:** Plastic and microplastic (MP) pollution are recognized as a major problem in fresh and marine water bodies. Anthropogenic activities contribute to this kind of pollution. Aruvikkara reservoir, one of the important reservoirs of Kerala, provide drinking water to the capital city, Thiruvananthapuram.**Methods:** In this study, surface water samples from Aruvikkara reservoir were collected for the assessment of MP pollution during monsoon and post monsoon seasons in 2021. The MP particles were extracted following standard procedure, then examined using stereomicroscope. The particles were analyzed using Fourier-transform infrared (FTIR) spectroscopy for identification and its composition analysis.**Results:** The MP particles were categorized into different groups namely pellet, fragment, fiber, film and foam. Polyethylene, polypropylene (PP) and polystyrene (PS) were the major classes of MP polymer types identified in the water samples by FTIR spectroscopy.**Conclusion:** The MP particles may enter into the human body through consumption leading to metabolic changes. Moreover, MPs can enter the food web through trophic transfer, potentially disrupting the normal biological balance of the ecosystem.**Keywords:** Aruvikkara reservoir, FTIR spectroscopy, Microplastics, Pollution, Water

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Introduction

The term “plastic” is derived from the ancient Greek word ‘plastikos’, which means “suitable for molding”. Today, it is commonly used to refer to a variety of materials that have become an essential part of our daily lives due to their versatility. The production of these materials has been increased immensely to meet the global demand.¹ Approximately 33% of all plastics produced annually are designated as non-reusable and are typically discarded within one year.² Plastic materials constitute 16% of all municipal waste produced globally.³ Most plastic materials are discarded after use, with only 6%–26% being recycled or landfilled. This is due to large-scale production and improper management of these materials over the past few decades.^{4,5} A substantial amount of these land-based plastic materials eventually enters aquatic ecosystems.

Any plastic particle smaller than 5 mm to 1 mm along its longest dimension is termed a microplastic (MP). Pollution with MP fragments has been recognized as a major issue in both freshwater and marine ecosystems.^{6,7} While the breakdown of larger pieces of plastic contributes to MP pollution in aquatic environments, MPs are also

intentionally manufactured and added as ingredients in cosmetics and personal care products. Common types of MPs found in many aquatic environments include fibres and microbeads.⁸ MPs exhibit high diversity in terms of shape, size, color, and density, leading to significant variability in their distribution over space and time, even within localized environmental compartments.^{9,10} Figure 1 shows the schematic representation of MP categories based on their appearance. Various types of anthropogenic particles fall within the MP size classification (<5 mm to 1 mm) and are defined as plastic particles, often referred to as plasticles.¹¹

All of the freshwater ecosystems specially rivers have been affected by plastic pollution, thereby disturbing the ecological balance.⁹ The potential sources of MPs in freshwater areas are domestic sewage, upstream input and solid wastes.¹² MPs originating from terrestrial sources are transported by freshwater systems, particularly rivers, to estuaries and subsequently to the open ocean.¹³ Pollutants discharged from adjacent pollution sources, including domestic and industrial land uses reaches urban water bodies and river systems. The major rivers across



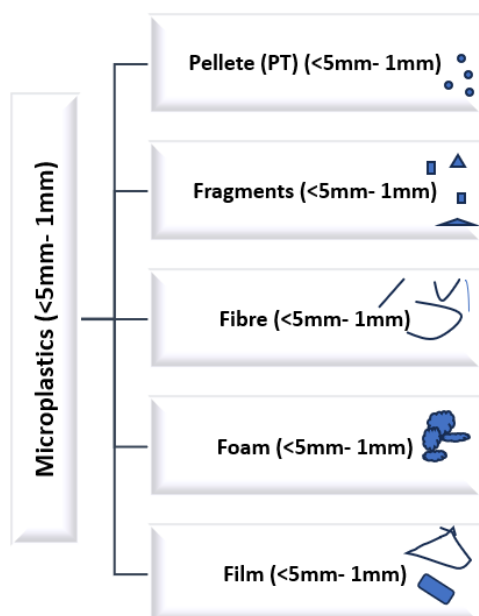


Figure 1. Schematic Representation of Microplastic Classification (<5 mm-1 mm) Based on Their Appearance

coastal cities are primary pathways between source of pollution and the open ocean. MPs in freshwater systems are serving as important transport vectors of land-based contaminants to open sea and coastal environments.¹⁴

Cheng et al¹⁵ proved that the chemical oxidation of MPs could be enhanced by light, showing a synergistic aging effect. Polymer photo-oxidation reactions generally include chain initiation, chain growth, chain formation and chain termination. Under the combined action of UV irradiation and oxygen, the aging rate of the polymer will be further accelerated. The photo-degradation of polymer is initially due to the unsaturated structure or additives in the polymer absorbing UV light, forming free radicals, which interact with oxygen to produce more free radicals, thus accelerating its aging and eventually causing the polymer chain to collapse.¹⁶ The degradation process of plastics progresses over time, ultimately resulting in the formation of nanoplastics (NPs, particle size < 1 μm).¹⁷

MPs present in water and sediment can reach aquatic organisms, potentially causing stress by releasing additives contained within the MPs.¹⁸ The water borne chemical contaminants can be picked up by MPs through food chain by aquatic organisms and can concentrate up to 1 million times greater than the surrounding water.¹⁹⁻²¹ Block of glands and gills disruption of nutrient absorption, respiratory functions and enzymatic reactions can be occurred due to the activity of nano-plastics and mini-MPs.²² It has been estimated that 1.15 to 2.41 million tons of plastic wastes enter annually into the ocean through rivers, and the top 20 rivers are typically situated in Asia.²³ Approximately 25 940 tons of plastic waste are being produced daily in India and around 43% of this manufactured plastic is used for packaging purposes which is single-use plastic. Kerala is situated in the south west coast of India, and its beaches are under stress due to

riverine debris originated from tourism, fishing and other municipal activities. The amount of municipal solid waste produced in Kerala is approximately 3.7 tons annually and 4 percent of this is plastic waste.²⁴ The state is blessed with 43 rivers which support rich biodiversity. So, the assessment of emerging pollutants including MPs in these rivers is essential. The water bodies of Kerala have been exploited for various human requirements, so that the monitoring of MPs in Kerala rivers is of special concern.

The Karamana River, one of the 44 rivers in Kerala, originates from the Western Ghats and flows 66 km westward before merging with the Arabian Sea. Rapid urbanization has posed a significant threat to this tropical river. The Aruvikkara reservoir, a crucial water source for Kerala, provides drinking water to the capital city, Thiruvananthapuram. However, the reservoir is currently facing severe threats due to improper management and the dumping of municipal solid waste. In this context, the present study focuses on the identification of MPs and the assessment of MP pollution in the Aruvikkara reservoir.

Materials and Methods

Study Area

Aruvikkara reservoir is situated in the banks of Karamana River basin, Kerala, South India between the coordinates 80 56'77" N and 77 021' 88" E. The dam was constructed in 1931 to facilitate the supply of piped drinking water to Thiruvananthapuram, the capital city of Kerala. For this study, a detailed survey was carried out to identify and select the sampling locations. Ten sampling stations are shown in Figure 2. The surface water samples were collected during the monsoon and post-monsoon seasons in 2021. A portrait of sampling stations is given in Table 1.

The sampling and analysis of MPs were carried out by the standard procedures of NOAA guidelines²⁵ of MP sampling. The collected water samples were treated with hydrogen peroxide (30%) by wet peroxidation method. After wet peroxidation, the samples were filtered through a Millipore membrane filter (0.45 μm , 47 mm) apparatus using Whatman GF/A filter paper (25 mm). Then, the filter papers were transferred into clean glass petri dishes. During the extraction process, all the glass wares were rinsed with double distilled water and carried out the procedures under fume hood chamber to prevent contamination. The filter papers with extracted MPs were dried and examined using camera attached Stereo microscope (Magnus, MSZ-TR LED) for identifying potential MP particles in water samples. Photographs were taken and visual sorting of particles were carried out based on their size, shape and color, and recorded the observations. The plastic particles (plasticles) identified were classified into pellete (PT), fragment (FR), fibre (FB), film (FI) and foam (FM) as per the standardized size and color sorting system.²⁶ Using Fourier-transform infrared (FTIR) Spectrophotometer (Thermo scientific, Nicolet iS50 FT-IR), the chemical composition of the MP particles were identified.

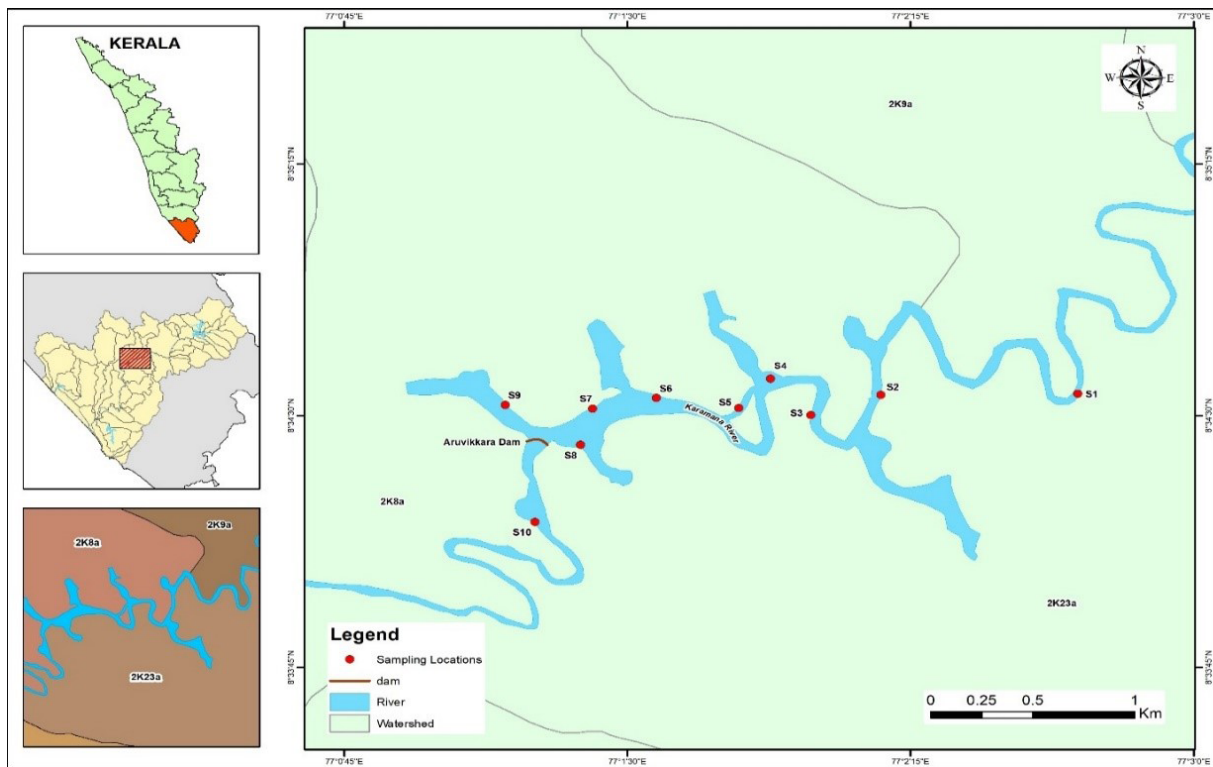


Figure 2. Geographical Location of the Study Sampling Stations

Table 1. Portrait of Sampling Stations

Station No.	Latitude	Longitude	Sampling Station
S1	8.57442	77.04621	Kulakkode
S2	8.5742	77.03725	Koovakkudi Bridge
S3	8.57391	77.03432	Kattaikkal
S4	8.57667	77.03161	Mundela
S5	8.57448	77.03126	Kaliyamoozhi
S6	8.57521	77.02602	Kanjikkavila
S7	8.57332	77.02364	Dam Opposite
S8	8.57156	77.02408	Vembannoor
S9	8.57549	77.01884	Mylamoodu
S10	8.56793	77.02193	Balikkadavu

Results and Discussion

Physio-chemical properties of Microplastics

The appearance, picture of the identified MP particle and the MP polymer identified in the water samples during the two seasons (monsoon and post-monsoon) from different stations are given in Tables 2 and 3. The size of MPs varied from 1mm to 4 mm. Color of particles was also different between particles. Even though differently colored particles were identified, most of them were in white or transparent in nature. Scherer et al²⁷ mostly identified transparent MP particles in their studies. Plastic products with long shelf life are manufactured with colored plastic materials.²⁸

The five major categories of MP particles based on their appearance such as pellet, fragment, fibre, film and foam were identified. Figures 3 and 4 show the abundance of different categories of MPs based on their appearance

in the water samples during the two seasons. During the monsoon season and post-monsoon season a total of 35 and 36 MP particles were collected and identified respectively. During monsoon season, the highest number of particles were from fragment category (34%) and least were pellets (3%) in the water samples. During the post-monsoon season, the highest proportion of MPs identified were fragments and films (28%), while the lowest were pellets (3%). The prevalence of fragments and films can be attributed to changes in the horizontal movement of particles within the water column. Variations in flow patterns and water residence time may influence the occurrence and distribution of plastic particles in aquatic environments.²⁹

The identification of MP polymers was carried out using FTIR spectroscopy. The FTIR spectrum of the identified polymers are given in Table 4. Figure 5 shows the abundance of MP categories based on their chemical composition. Through the IR Spectroscopy, the infrared radiation excites molecular vibrations when interacting with an object. Excitable vibrations are wavelength-specific and depend on the composition and molecular structure of a substance. Infrared (IR) radiation is absorbed to varying degrees, facilitating the measurement of individual IR spectra. Plastic polymers exhibit highly specific IR spectra characterized by unique band patterns. This characteristic property of plastic polymers makes IR spectroscopy an ideal technique for the identification of MPs.³⁰ This technique can provide information about the specific chemical bonds of particles and therefore the polymer can be easily identified.

High density polyethylene (HDPE), low density

Table 2. Characteristics of Microplastics Identified in the Water During Monsoon Season

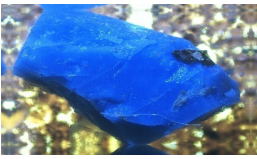
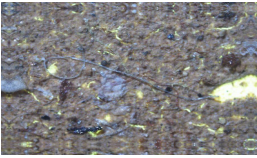

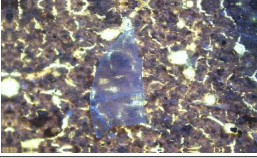






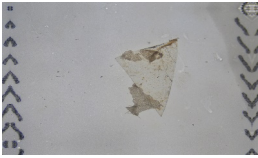
Station	Sample ID	Appearance	Picture	Polymer
1	MP1 A	Blue fragment		HDPE
	MP1 B	White fibre		PP
	MP1 C	White fragment		LDPE
	MP1 D	Transparent fragment		PET
2	MP2 A	White fibre		PP
	MP2 B	Transparent fragment		PET
	MP2 C	White fragment		LDPE
	MP2 D	Red fibre		PET
3	MP3 A	Blue fragment		LDPE
	MP3 B	Black film		LDPE
	MP3 C	Transparent fragment		PET

Table 2. Continued.


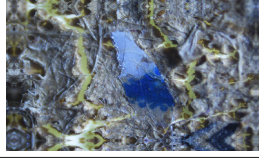

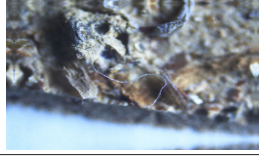

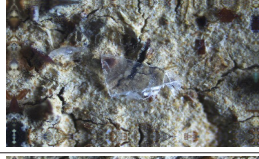

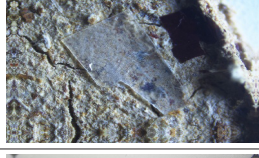
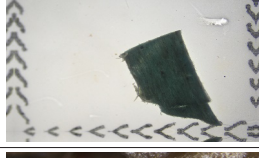


Station	Sample ID	Appearance	Picture	Polymer
4	MP4 A	White film		PP
	MP4 B	Blue film		PP
	MP5 A	White pellet		PP
5	MP5 B	White fibre		PP
	MP5 C	Blue fibre		PP
	MP5 D	Transparent film		HDPE
	MP5 E	Purple fibre		Fibre polyester PET
	MP5 F	Transparent fragment		PET
	MP6 A	Green film		PP
6	MP6 B	Styrofoam (Thermocol)		PS foams (expanded)
	MP6 C	Red film		PP

Table 2. Continued.


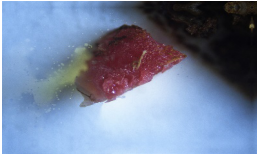
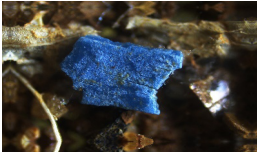

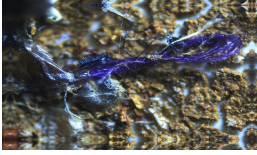

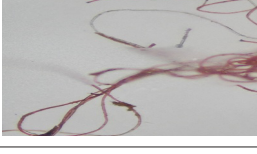

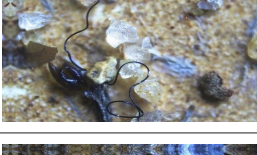
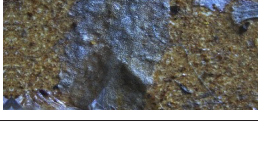



Station	Sample ID	Appearance	Picture	Polymer
7	MP7 A	Blue-white film		PVC
	MP7 B	Red fragment		Cellulose
	MP7 C	Blue fragment		LDPE
	MP7 D	Red fibre		Fibre polyester PET
8	MP8 B	Purple fibre		PP
	MP8 C	Styrofoam		PS
	MP8 A	Brown fibre		Fibre polyester PET
9	MP9 A	White fragment		LDPE
	MP9 B	Black fibre		Fibre polyester PET
	MP9 C	Styrofoam		PS

Table 2. Continued.

Station	Sample ID	Appearance	Picture	Polymer
10	MP10 A	Transparent film		Fibre polyester PET
	MP10 B	White fragment		LDPE
	MP10 C	Styrofoam (Thermocol)		PS expanded

Abbreviations: HDPE, High density polyethylene; LDPE, low density polyethylene; PP, polypropylene; PS, polystyrene; PET, polyethylene terephthalate; PVC, polyvinyl chloride.

polyethylene (LDPE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET), polyvinyl chloride (PVC) and cellulose polymers were identified in the water samples from the reservoir. In this study, typical polymer bands were obtained against wavenumber and transmittance which are specific to each above-mentioned polymers identified. PET and PP (10 Nos) were the most abundant in samples collected during the monsoon season. During the post monsoon season, the PET was the highest (9 Nos). The abundance of PE, PP and PS in the water samples of current study is in agreement with the findings of Matjasic et al.³¹ The abundance of the above-mentioned polymers may be due to the fact that the global demand for the largest groups in total non-fiber plastics production is PE (36 %), PP (21 %), and PVC (12 %), followed by PS and others (< 10 % each).³²

Due to the attachment of microorganisms to the plastic particles, MPs require more settling velocity.³³ Particle properties such as shape, density, type of material and microbial growth and flow conditions of the water body greatly influence the transportation and occurrence of plastic particles in the water column.³⁴ When introduced into the water, particle may sink or float based on their density.³⁵ Among the different types of plastic particles extracted and examined, fragments have the shortest transport length in streams due to surface to volume ratio.³⁶ Hydrology, climate, topography and land-use can amend the MP mass balance within a catchment area.³⁷ Heavy rainfall increases the flux of MP particles into river systems through atmospheric fallout.³⁸ The present study is also in agreement with the presence of MP particles in Aruvikkara Reservoir water during monsoon season.

Zhang et al³⁹ reported that tributaries impacted by reservoirs can serve as hotspots for MP pollution. In the backwater areas of reservoir tributaries, unique

Table 3. Characteristics of Microplastics Identified in the Water During Post-monsoon Season


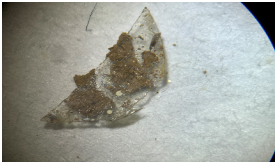









Station	Sample ID	Appearance	Picture	Polymer
1	MP1 A	White film		HDPE
	MP1 B	Transparent fragment		PET
	MP1 C	White film		HDPE
2	MP2 A	Transparent film		PP
	MP2 B	White film		PET
	MP2 C	Transparent fragment		PET
	MP2 D	White film		HDPE
3	MP3 A	Styrofoam (Thermocol)		PS expanded
	MP3 B	Black fibre		PP
	MP3 C	Transparent film		PP
	MP3 D	White fragment		LDPE

Table 3. Continued.



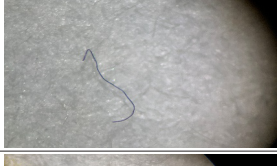
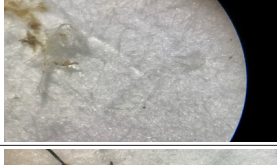



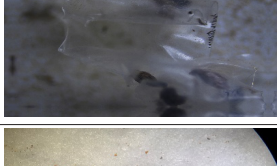


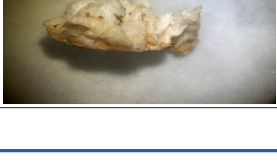
Station	Sample ID	Appearance	Picture	Polymer
4	MP4 A	White fragment		PET
	MP4 B	Green film		Cellulose
	MP4 C	Blue fibre		PP
5	MP4 D	White fibre		Fibre polyester PET
	MP5 A	Black fibre		PP
	MP5 B	Transparent fibre		PET
6	MP5 C	Styrofoam (Thermocol)		PS expanded
	MP5 D	Transparent film		HDPE
	MP6 A	Transparent film		Cellulose
6	MP6 B	Pink fibre		PET
	MP6 C	Styrofoam (Thermocol)		PS expanded

Table 3. Continued.






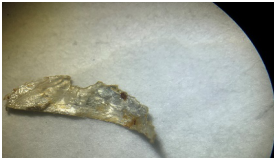





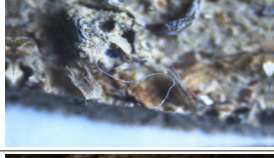


Station	Sample ID	Appearance	Picture	Polymer
	MP7 A	Styrofoam (Thermocol)		PS expanded
7	MP7 B	White pellet		HDPE
	MP7 C	Transparent fragment		PET
	MP8 A	Silver film		PP
	MP8 B	White fragment		LDPE
8	MP8 C	Silver fragment		PP
	MP8 D	Styrofoam (Thermocol)		PS expanded

Table 3. Continued.

Station	Sample ID	Appearance	Picture	Polymer
	MP9 A	White fibre		PET fibre polyester
	MP9 B	Yellow fragment		HDPE
9	MP9 C	White fragment		LDPE
	MP9 D	Silver fragment		HDPE
	MP10 A	White fibre		HDPE
10	MP10 B	Styrofoam (Thermocol)		PS
	MP10 C	Blue fibre		PP

Abbreviations: HDPE, High density polyethylene; LDPE, low density polyethylene; PP, polypropylene; PS, polystyrene; PET, polyethylene terephthalate.

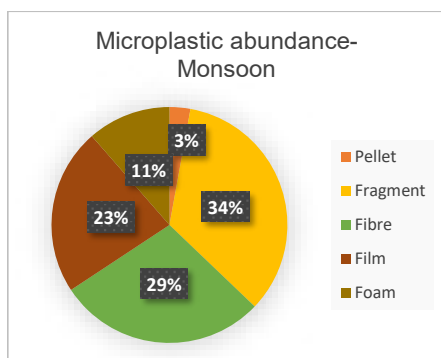


Figure 3. Microplastic Abundance in the Water Samples Collected During Monsoon

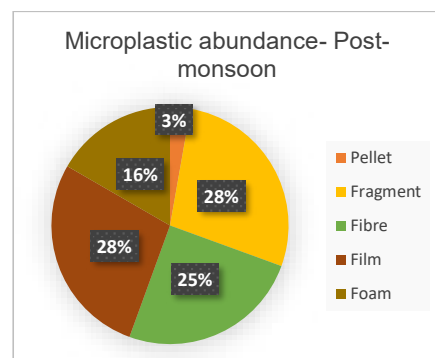


Figure 4. Microplastic Abundance in the Water Samples Collected During Post-monsoon

hydrodynamic characteristics contribute to the accumulation and distribution of MPs. As the concentration of MPs in water bodies rises, human exposure may occur

through inhalation, ingestion, and skin contact. Such exposure to these particles can lead to cytotoxicity, oxidative stress, neurotoxicity, disruption of the immune system, and

Table 4. FTIR Spectrum of Identified Polymers

Sl. No.	FTIR Spectrum	Polymer
1		PP
2		LDPE
3		HDPE
4		PET

Table 4. Continued.

Sl. No.	FTIR Spectrum	Polymer
5		PS
6		PVC
7		Cellulose

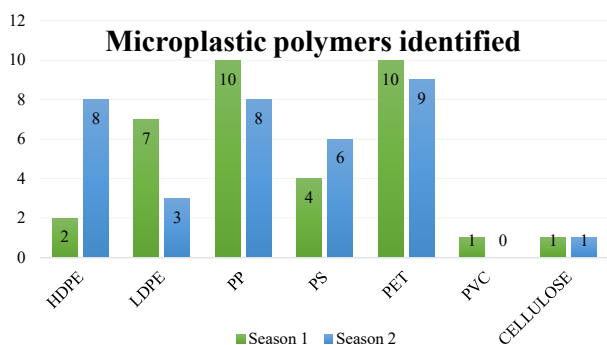


Figure 5. Abundance of Microplastic Polymers Identified Using FTIR Spectroscopy in Two Seasons. Abbreviations: HDPE, High density polyethylene; LDPE, low density polyethylene; PP, polypropylene; PS, polystyrene; PET, polyethylene terephthalate; PVC, polyvinyl chloride

the potential transfer of these particles to other tissues.⁴⁰

Conclusion

The current study focused on the MP analysis of water from ten stations of Aruvikkara reservoir during monsoon and post-monsoon seasons. The MP particles were extracted and examined microscopically. Five major types of MPs namely pellet, fragment, fiber, film and foam were identified. Fragments were the most abundant type of MP observed in the water collected during both seasons studied. The particles were analyzed by FTIR spectroscopy which identified the polymer composition. During the study, 35 and 36 particles were identified during the monsoon and post-monsoon seasons,

respectively. Among these, PET and PP were the most abundant types observed in samples collected during the monsoon season. Conversely, the highest number of PET particles was recorded during the post-monsoon season. Anthropogenic activities were identified as the primary contributors to the elevated levels of MPs found in the reservoir water. The continuous exposure of MPs in drinking water may cause biological damages in flora and fauna of the reservoir due to the disruption in metabolism. Since the reservoir water is used for municipal supply, it is highly used to control the emerging pollutants especially MP pollution in the reservoir. Better understanding of mechanism of the transportation and influencing factors of MP degradation and strategy is needed to design the control of MP pollution in waterbodies.

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Authors' Contribution

Conceptualization: Navami Surendran Sethulekshmi, Jaya Divakaran Sarasamma.

Data curation: Navami Surendran Sethulekshmi, Jaya Divakaran Sarasamma.

Formal analysis: Navami Surendran Sethulekshmi.

Investigation: Navami Surendran Sethulekshmi, Jaya Divakaran Sarasamma.

Methodology: Navami Surendran Sethulekshmi, Jaya Divakaran Sarasamma .

Project administration: Jaya Divakaran Sarasamma.

Resources: Navami Surendran Sethulekshmi, Jaya Divakaran Sarasamma.

Software: Navami Surendran Sethulekshmi.

Supervision: Jaya Divakaran Sarasamma.

Validation: Navami Surendran Sethulekshmi, Jaya Divakaran Sarasamma.

Visualization: Navami Surendran Sethulekshmi.

Writing—original draft: Navami Surendran Sethulekshmi, Jaya Divakaran Sarasamma.

Writing—review & editing: Navami Surendran Sethulekshmi, Jaya Divakaran Sarasamma.

Competing Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval

There were no ethical considerations to be considered in this research.

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