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Identification and Characterization of Microplastics in Cauvery River Sediments, India

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ABSTRACT

Microplastics (MPs) have received extensive attention as an emerging environmental pollutant. They are ubiquitous in the freshwater system and have triggered a global environmental concern. The MPs content in the Cauvery River sediments are inadequately understood due to a lack of quantification of sources, stores, and intermediates. In sediment samples concentration of MPs ranged from 40 ± 22 items kg^{-1} and 150 ± 56 items kg^{-1} in the upstream and downstream of KRS dam respectively, microplastics are found in various shapes, colours, and compositions, with red, dark brown, white, transparent. FTIR Spectroscopy analytical technique identified and analysed MP components (PP, PET, PE, and Nylon). The study emphasizes the importance of identifying and addressing microplastics in freshwater environments to mitigate their impact on aquatic ecosystems and to take appropriate action.

Key words: Freshwater Environment, FTIR Analysis, Microplastics, Sediment, Stereomicroscope

INTRODUCTION

Plastic is a synthetic or semi-synthetic material made from polymers, which are long chains of molecules called monomers (Eerkes-Medrano et al. 2015). These monomers are derived from petrochemicals, primarily crude oil and natural gas, but they can be sourced from renewable materials like plant-based starches (Esterhuizen and Kim 2021, Sruthy and Ramasamy 2016). The versatility of plastics makes them suitable for a wide range of applications due to their low cost, durability, lightweight nature, and ease of manufacturing (Amrutha et al. 2022).

The plastic industry has grown exponentially, with various applications in packaging, automotive, electronics, construction, and consumer goods (Gallitelli et al. 2022). However, the environmental challenges posed by plastic waste and microplastics have led to an increased focus on recycling, biodegradable plastics, and reducing single-use plastics in the 21st century (Ali et al. 2021). Plastic waste is recognized as hazardous, with the risk increasing as the polymers break down in nature to secondary microplastics or even nanoplastics (Blair et al. 2019). The number of studies reported on the prevalence of microplastics in every perceivable niche and bioavailable to biota is 10 times dramatically increasing (Zhao et al. 2022). Knowledge of the ecotoxicology of microplastic is advancing as well; however, information regarding plants, specifically aquatic macrophytes, is still lacking (Fältström and Anderberg 2020).

Microplastics (MPs) are considered significant components of plastic pollution worldwide (Zhao et al. 2022). They are tiny plastic particles, usually smaller than 5 mm in size, that result from the breakdown of larger plastic items, the weathering of plastic debris, and the shedding of microbeads from personal care products (Kallenbach et al. 2022, Karlsson et al. 2019, Ryan et al. 2019,). MPs can also be intentionally manufactured for specific purposes, such as microbeads in exfoliating scrubs (Kolenda et al. 2020).

Globally, researches strived to assess MPs in the different ecosystems like rivers (Fiore et al. 2022, Blair et al. 2019, Eerkes-Medrano et al. 2015), beach sediment (Schröder et al. 2021, Imhof et al. 2013), amphibians (Kolenda et al. 2020), mangrove sediment (Li et al. 2019) and lakes (Kallenbach et al. 2022) however despite the efforts of tracing the dilemma of plastics pollution, research in freshwater ecosystems is not up to the level of others ecosystems like costal or marine. Yet several studies have tried to identify and characterize MPs in freshwater system in India using sediment samples in western India. Ram and Kumar (2020), and Patel et al. (2020) investigated the correlation of antibiotic resistance with faecal, metal and MP contamination in Sabarmati. While their study addressed vulnerability of the aquatic system to MPs, they did not examine the polymer composition.

Singh et al. (2021) studied the identification and characterization of MPs in the Ganga River and found many polymers. Their stereomicroscope (Leica) and ATR-FTIR results revealed 17 to 36 items per kg^{-1} dry-weight sediments. However, in the Alaknanda River, Chauhan et al. (2021), using similar techniques, did not find any polymers. Thus, freshwater ecosystems need more studies (Sruthy and Ramasamy 2016) to explore this global problem of MPs.

Most of the research on MPs during pre-COVID-19 times was conducted for the purpose of plastic availability on beaches or marine ecosystems (Chauhan et al. 2021). There is a gap in MPs occurrences in the Cauvery River. Identifying the sources is highly challenging in MP pollution owing to the vast spectrum of applications for a single polymer type (Kallenbach et al. 2022, Dalu et al. 2021). The numerous property-tailoring options for each polymer type aggravate the problem (Fältström and Anderberg 2020). Therefore, systematic data collection followed by careful analysis in environmental forensic investigations is necessary to identify the source of MP and make the polluters accountable (Schütze et al. 2022).

MATERIALS AND METHODS

Study area

Cauvery River originates in the State of Karnataka and flows generally south and east through Karnataka. It has many tributaries before the dam, there was a confluence of three main rivers: Cauvery, Hemavathi, and Laxmanatheertha The study area is

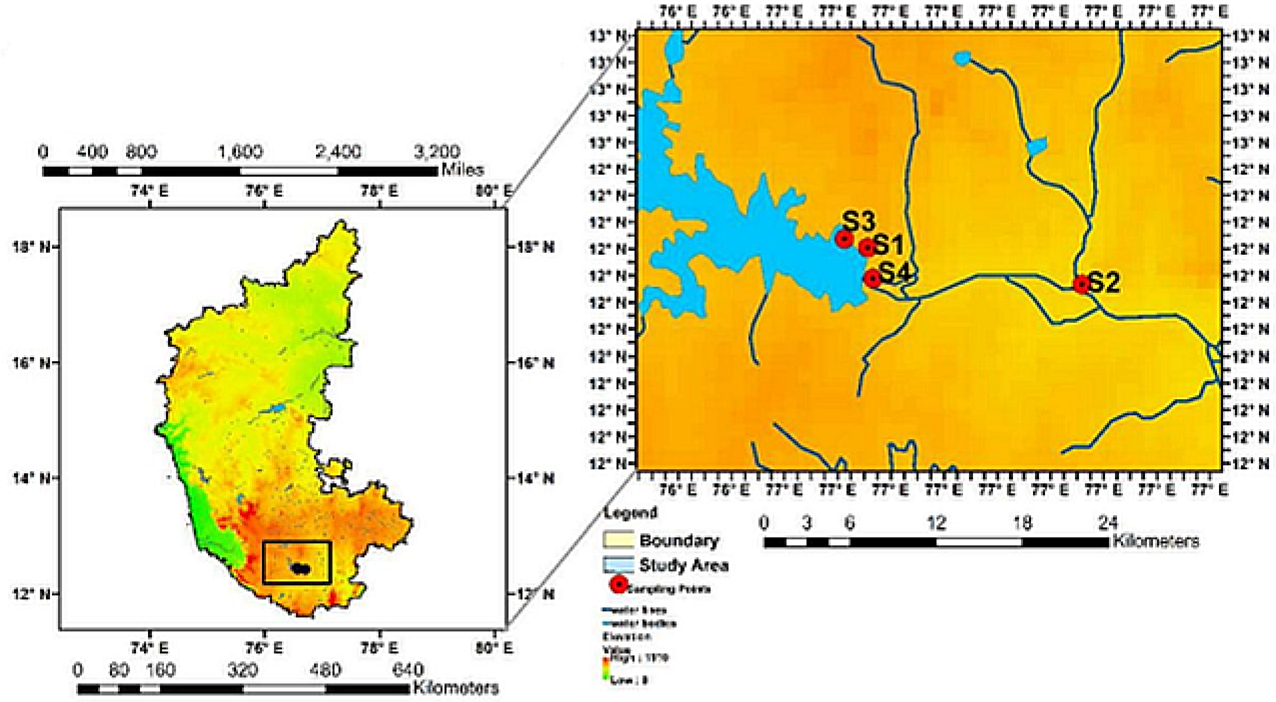


Figure 1. Study area and sampling sites (**S1, S2, S3,** and **S4**)

about 600 m amsl and lies between latitude 12°25' 30" N and longitudes 76°34' 34" E. It is a major domestic, irrigation, and industrial water supply source. It has a KRS dam and reservoir, The Krishna Raja Sagara (KRS) Dam, which was constructed on the river near the Mysore and Mandya districts. It is 15 km northwest of Mysore in Karnataka, India (Fig. 1).

Methodology

The study adopted the method of (Möller et al. 2020) with some modifications in the samples as we collected sediment which is different that mentioned in the method adopted, in addition to, the step of drying the sample with natural air for few days was a modification to suit study objective. As no standard methodology was available for MPs extraction, the steps involved in separating MPs from sediments is shown in Figure 2. Pre-collection field visit for site selection of sampling conducted. Sediment samples were collected in the bottom side of river bank sediment; they were collected from four study sites located in different zones upstream as well as downstream of the Krishna Raja Sagara (KRS) dam area of the Cauvery River.

Samples were collected in pre-monsoon season (from April to August) when the river level was characteristically low. GPS Coordinate points of each sampling site were recorded, and a steel shovel was used to dig in the bank of the river for about 10-20 cm. The samples of sediment were packed in aluminium carry bags to avoid contamination. Samples were sieved using sieves of 3-5 mm and then weighted and transferred to a beaker of 100 ml for density separation using sodium chloride (NaCl) solution. Filtered supernatant collected for chemical digestion of the organic matter using Hydrogen peroxide (H_2O_2). 30 ml of 30% solution, in addition to 0.29 g of $FeSO_4.2H_2O$ were added to purify the MPs in the sample (Ivleva 2021). In the next step, collected particles were placed in petri dishes and heated in a hot air oven at 60°C for 24 to 48 hrs. After which, the dried samples were filtered using (Whatman filter paper), and again dried in the oven at 60°C for 24 hrs. Then the collected particles were examined under a stereomicroscope for visual identification of the shapes and colour. MPs were extracted from samples and estimated their concentration within the known weight of the sample taken. For characterization and polymer compositions, FTIR analysis and SEM imaging were

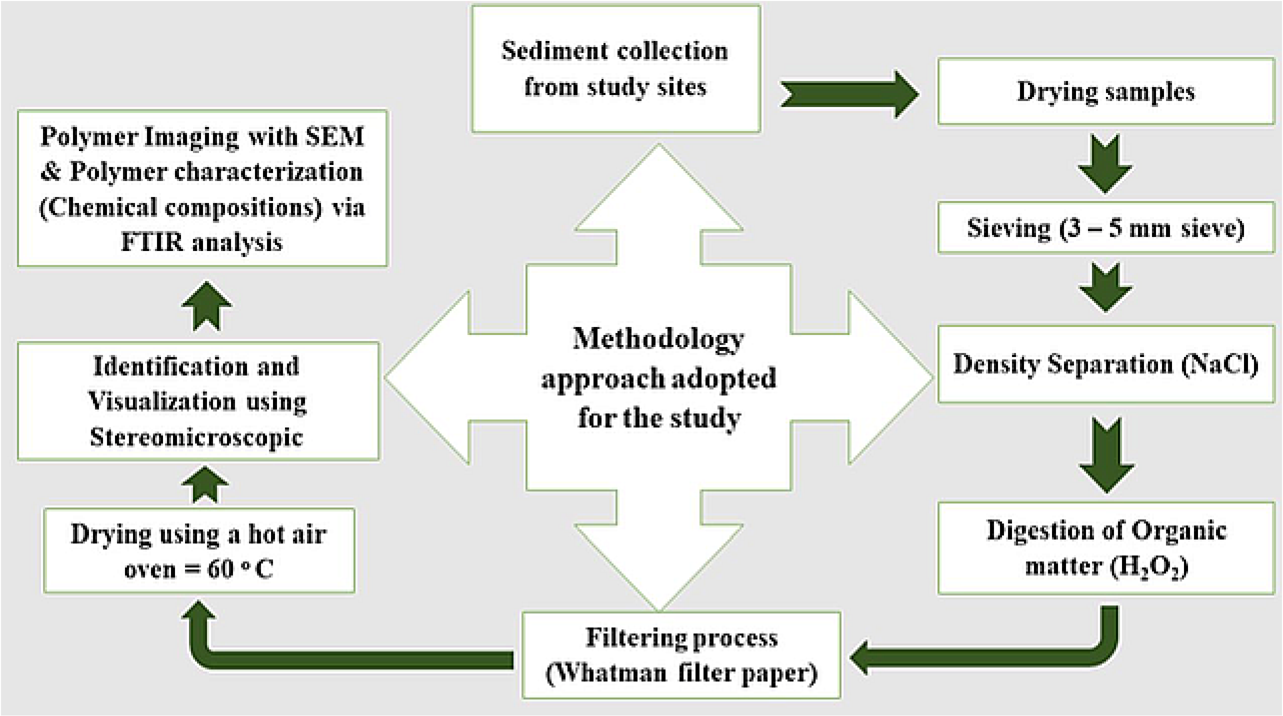


Figure 2. Methodology adopted in this study

used (Chen et al. 2020). This approach improves the accuracy and reliability of MPs identification and characterization, enabling a better understanding of the potential sources of MP pollution.

FTIR

In the characterization of microplastics or polymer identification, Infrared (IR) spectroscopy is one of the best technologies in recent years (Andrade et al. 2020). With the help of absorption lights, IR spectrum devices occur due to excitement within material molecules, which creates vibrations explained through spectrum bands that ensure the presence or absence of specific functional groups in molecules (Chen et al. 2020). The essential parts of FTIR are the source of light, sample compartment, interferometer, detector, computer, and accessories; as a whole, the spectrum constitutes a “Fingerprint” that can be used to determine the identity of the sample (Anonymous 2012). Andrade et al. (2020), in their work about standardization of reporting in minimum experimental conditions required for replicating IR studies on microplastics to ensure accurate identification, recommended that the Minimum Information for Publication of Infrared (MIPIR-IR) data in microplastics studies be demanded to enhance scientific validity and credibility Hence; in this study, FTIR was significant to be included in the methodology to confirm the presence of microplastics and their chemical characteristics.

Quality assurance and control measures

Precautionary measures were followed to prevent contamination of samples during the sampling process (Li et al. 2019, Sruthy and Ramasamy 2016, Anonymous 2012). MPs extraction from samples was done thoroughly in a hygienic atmosphere whereby no invalid results could affect the study, and the samples were properly covered to prevent contamination.

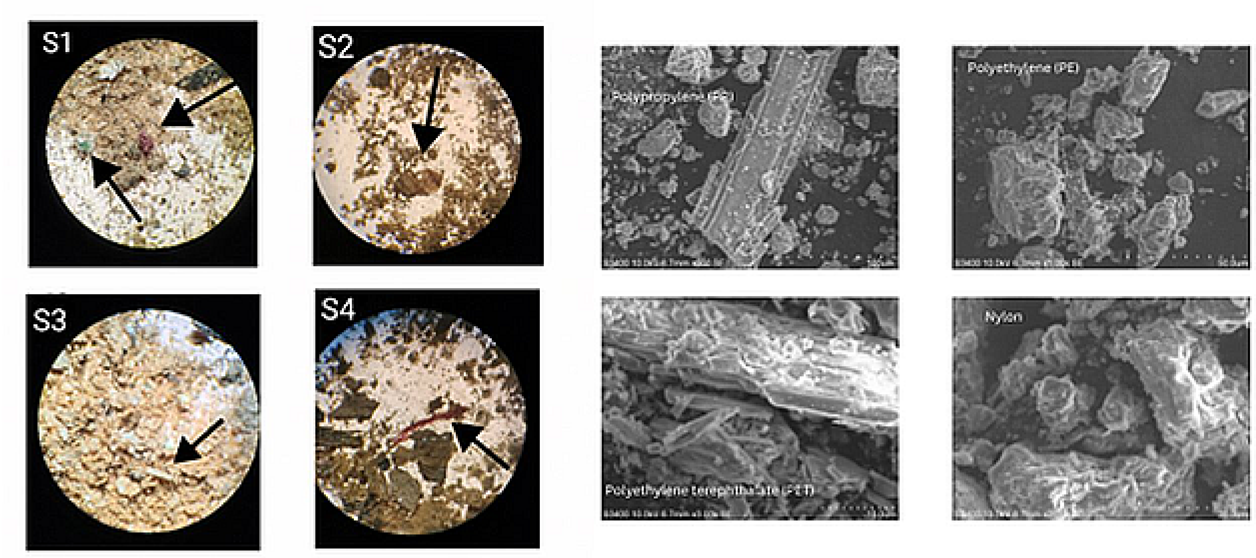
RESULTS AND DISCUSSION

The study revealed the presence of MP particles in the sediment at all sampling sites. Four types of MPs were identified, namely, Polyethylene (PE), Polypropylene (PP), Polyethylene terephthalate (PET), and Nylon (Table 1). Concentration of MPs in river sediment samples ranged from 40 ± 22 items kg^{-1} in the upstream of points and 150 ± 56 items kg^{-1} in the downstream of the KRS dam. The polymers identified morphologically are categorized into fragment, pellet, filament, and film (irregular shape, filamentous, nurdles, and polystyrene, respectively), which were also reported by Singh et al. (2021). These were visualized in different colour such as red, transparent, white, and dark brown (Fig. 3). The potential sources of these MPs are solid wastes dumped in the river banks (Fig. 4) and improper wastewater treatment (Kärkkäinen and Sillanpää 2021, Ali et al. 2021 Chauhan et al. 2021, Fältström and Anderberg 2020). In several studies in rivers of India (Singh et al. 2021, Chauhan et al. 2021, Ram and Kumar 2020, Patel et al. 2020) the most abundant polymers reported are PP, PET, and PVC. However, more research is needed to unify the standardized methods for microplastic identification and characterization (Table 2).

Scanning Electron Microscopy (SEM) and Fourier Transform Infrared Spectroscopy (FTIR) results from sediment samples confirm the polymer in the sample. The Scanning Electron Microscopy (SEM) images for visualization showed the surface morphology of plastic particles. Despite detection of some minerals within samples, their effect is negligible. However, presence of minerals could be potential source of hazard to the ecosystem and humans (Chauhan et al. 2021, Patel et al. 2020). These outputs reassure the significance of assessing

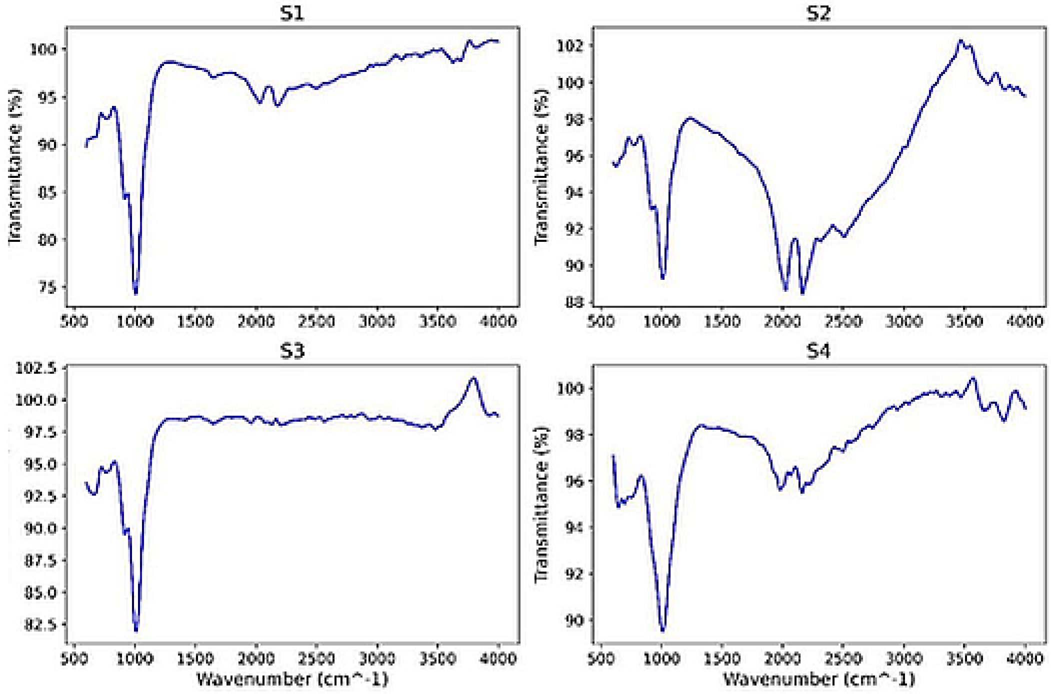
Table 1. FTIR analysis of MPs from sediments

Sample	Characteristics of the FTIR analysis	Polymer/functional group of microplastics
S1	Stretching vibrations of aliphatic C-H bonds	Polypropylene (PP)
S2	Stretching vibrations of aliphatic C-H bonds	Polyethylene (PE)
S3	Stretching vibrations C-O bonds	Polyethylene terephthalate (PET)
S4	Stretching vibrations C-N bonds	Nylon



Visual Identification Stereomicroscope

Scanning Electric Microscopy (images)



FTIR spectra of samples

Figure 3. Visual identification of microplastics, SEM imaging, and FTIR analysis

MP contamination by characterization via samples from different ecosystems to prevent such harmful pollutants from causing effects on human health. Hence, understanding the environmental consequences of MPs is urgently needed to address the issue.

Moreover, through this study, a few potential sources of MP contamination in the Cauvery River were observed, such as synthetic fiber shedding, litter from improper solid waste dumping near the river, and the washing and cleaning of cars, as well as clothes in the river banks, hence, potentially of the degradation and fragmentation of these plastics' materials and synthetic fiber in the long run of time

Table 2. Summary of the existing research work on MPs from riverine sediments in India

Name of the river	Number of samples	Sampling tools	Salt solution used for density separation	MP size	MP Categories	Instrumentation	Polymer composition	References
Sabarmati	04	Stainless steel scoop	Sodium Chloride	76-212µm and 212 µm–4 mm	Not studied	Not studied	Not studied	(Ram and Kumar 2020)
Sabarmati	04	Stainless steel scoop	Sodium Chloride	76 - 212µm and 212 µm–4 mm	Plastic debris, fibres	SEM-EDS	Not studied	(Patel et al. 2020)
Ganga	05	Stainless steel scoop	Sodium Chloride	1 mm, 1–2.5 mm, 2.5–5 mm, > 5 mm	Fragment, Foam, Filament, Film	Stereomicroscope (Leica) and ATR-FTIR	PES, PVC, PBAN, PVC/PE, PVT/B, PE-PP, PAI/PTM, PP, CL, PS, PE	(Singh et al. 2021)
Alaknanda	04	Grab samples	Sodium Chloride	< 1 mm, 1–2, 2–3, 3–4, 4–5 mm	Fragment, fibres, Pellet, Film	Stereo-microscope, SEM-EDS	Not studied	(Chauhan et al. 2021)

with UV lights, and other abiotic factors which results in microplastic generations (Tamminga et al. 2021).

CONCLUSIONS

The present work determined and verified the presence and chemical compositions of microplastics (MPs) in the Cauvery River sediments. It describes the distribution of MPs by amount, colour, shape, size, and composition in the surface sediments of Cauvery River, which is important for analytical progress in the identification, characterization, and quantification of MPs The improved MP extraction method in this study is expected to be further improved and beneficial compared to other studies The MP concentration in river sediment samples ranged from 40 ± 22 items kg^{-1} in the upstream of points, and 150 ± 56 items kg^{-1} in the downstream of KRS dam, and the primary type of MPs being red, dark brown, transparent and white fragments MPs recorded in this study area were fragment, fibres, Pellet, Filament. They are Polypropylene (PP), Polyethylene (PE), Polyethylene terephthalate (PET), and Nylon. The results of this study indicate significant amounts of MPs in Cauvery River sediments, supporting the concept that river sediments act as a sink for plastic accumulation. Moreover, the knowledge of the consequences of MPs on aquatic sediment quality is still largely unknown and requires further investigation. Hence, it recommends more focus on MP pathways and risk assessment in freshwater ecosystems to mitigate its impact on aquatic ecosystems and address global environmental concerns. This work will pave the way for future studies on solid waste management policies to minimize the emission of plastic waste into the freshwater ecosystem.

Authors' contributions: All authors contributed equally.

Conflict of interest: Authors declare no conflict of interest.

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