Occurrence, Abundance, and Distribution of Microplastics in the basins of Kabani River, Wayanad, Western Ghats, India: A Baseline Assessment

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Abstract. The large-scale production of plastics and their subsequent dispersal into water bodies have harmful impacts on aquatic environments. Despite being major manufacturers of plastic waste, developing countries have inadequate research on microplastics in freshwater ecosystems. This study examines the occurrence, abundance, and distribution of microplastic particles in the basins of the Kabani River, a region of the Western Ghats in Wayanad. The sampling was conducted at eight study stations across the Kabani River basin and analysed for microplastics using a density separation method. Identification of the microplastic particles was made using Fourier Transform Infrared spectroscopy (FTIR) with Attenuated Total Reflectance (ATR). The average abundance of microplastics collected from the major tributaries of the Kabani River was 0.103 ± 0.18 particles/L (median 0.0135 particles/L) during the study. Ethylene Vinyl Acetate (EVA) was the prevalent polymer collected in the samples. As Wayanad's first report on microplastic particles in the Kabani River, this study catalyzes additional investigation into the distribution and effects of this new contaminant on the biota of several aquatic systems throughout Kerala and India.

Keywords: Kabani, Microplastics, River, Wayanad, Western Ghats

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1. INTRODUCTION

Plastics are a subset of polymers, first produced in large quantities in the 1950s[1], playing a crucial role in present-day society worldwide[2, 3]. The application of plastics in recent years has increased rapidly, from domestic units to industry, owing to their low production cost, resistance, durability, flexibility, and wide range of uses[4]. The synthetic polymers such as high density polyethylene (HDPE), low density polyethylene (LDPE), nylons, poly-propylene (PP), polyethylene terephthalate (PET), polyvinyl chloride (PVC), polybutylene terephthalate (PBT), polystyrene (PS) and polyurethane (PUR) are get fragmented due to mechanical treatments and photochemical transformations triggering the development of microplastics (< 5 mm) or nanoplastics (< 1 μm)[5, 6].

Current lifestyles have necessitated the excessive use of plastics. It's delayed biological decomposition and increased persistence improves people's lives, but if not disposed properly, they accumulate in the environment and cause long-term ecological imbalances[7]. Freshwater systems act as reservoirs where microplastics can accumulate, affecting aquatic organisms through ingestion, entanglement, and habitat disruption[8]. Freshwater habitats have generally received less scientific scrutiny than marine systems regarding microplastic pollution[9, 10]. However, recent research has highlighted the fact that freshwater systems, most notably rivers, act as critical pathways for transporting microplastics from onshore sources into the ocean[11].

Rivers and streams are the source of nearly two-thirds of the world's drinking water and are becoming polluted by microplastics[12]. The ingestion of microplastics by aquatic animals increases both chemical and physical risks, potentially leading to adverse health effects[13]. Microplastics can act as carriers for toxic compounds, facilitating the transport of hazardous substances through the aquatic food web, which in turn promotes bioaccumulation and biomagnification[14]. Additionally, microplastics can act as potential surfaces for microbial colonisation, further strengthening ecological and health risks[15].

Wayanad district, a part of the Western Ghats, is situated on the southern tip of the Deccan plateau and is drained by the Kabani River and its tributaries[16]. The Kabani River is a vital water source for both ecological and human needs. The study report by the Kerala State Council for Science (2009), Technology and Environment and the Centre for Water Resources Development and Management[17] indicated that the Kabani River was the least polluted in Kerala, a finding subsequently corroborated by the Pollution Control Board of Karnataka and the Central Pollution Control Board (2017)[18]. However, later in 2021, according to studies by the Karnataka State Pollution Control Board, the river was found to be polluted due to the relentless discharge of sewage, industrial waste, and other effluents, rendering it unfit for drinking[19]. Conservation concerns, including pollution, deforestation, and unregulated human practices, pose threats to the Kabani River's water quality, aquatic biodiversity, and overall ecosystem health. Recent observations have revealed that the illegal dumping of solid waste, combined with algal blooms in many parts of the Kabani River, poses a serious threat to the aquatic ecosystem of the water body[20]. The drastic change from the least polluted to the most polluted condition of the Kabani River basin is a serious concern to the researchers.

Identifying and quantifying microplastics in river systems is essential for understanding their sources, transport dynamics, and fate within freshwater environments[21]. Among the several anthropogenic stresses on aquatic ecosystems, the accumulation of plastic trash is one of the most conspicuous yet least studied. Microplastic research is still in its early stages, and there is a significant lack of data on the occurrence, abundance, and distribution of microplastics in

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freshwater riverine ecosystems[22]. The current study designed to examine the distribution pattern of microplastics in Kabani River to monitor the condition and health status of the river basins. Since Kabani River is the primary water source for people and animals in the Wayanad district, a thorough assessment of microplastic contamination in the river is crucial for improving and developing plastic cycle models and for formulating efficient mitigation strategies.

Materials and Methods

1.1. Study area

Wayanad district of the Western Ghats (latitude 11^0 27' and 15^0 47' North and 70^0 27' East longitude), is a hill station, covers an area of 2130 sq. km with an altitude that varies from 700 to 2100 m above mean sea level. It is located in the North-Eastern region of Kerala, India[23]. The Kabani River is one of the significant water bodies in Wayanad and one of the eastward-flowing rivers in Kerala, with a total basin area of 7,060.362 km² that spans across the southern Indian states of Kerala, Karnataka, and Tamil Nadu[24]. The study concentrated on eight sampling stations along the Kabani River basin (**Table 1**, **Fig. 1**), each station was strategically selected based on a variety of ecological and environmental conditions to ensure systematic coverage of microplastic polluted areas.

Table 1 Study stations

Stations	Location Description	Latitude	Longitude
Koodalkadavu (KO)	Anthropogenic activities such as washing, bathing, and providing drinking water for domestic animals take place, Agricultural area	11.7986	76.0747
Panamaram (PA)	Near KWA Pump House, used for irrigation, agricultural land nearby	11.8018	76.0142
Mananthavady (MN)	Near KWA pump house	11.8029	76.0039
Thirunnelli (TH)	Temple-pilgrimage activities	11.9081	75.9971
Begoor Bridge (BE)	Near forest area	11.8476	76.0853

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Kuruva Island (KU)	Tourist area, forest area, effluent discharge from outside sources. Urban runoff sink	11.8283	76.0897
Valliyurkavu (VA)	Temple accompanied by Oottupura and a marriage hall nearby	11.8040	76.0290
Choottakadavu (CH)	Downstream of Mananthavady Puzha, Housing board	11.8014	75.9910

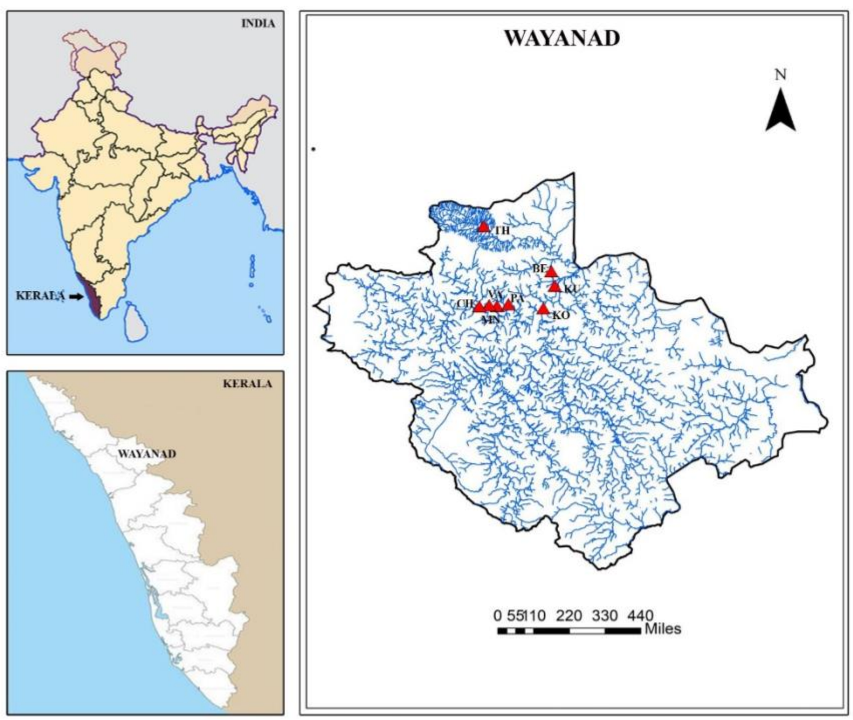

Fig.1 Sampling stations in Kabani River basins

1.2. Sampling

The samples were collected from each study station between the tail end of winter and the onset of summer 2024, during which period the amount of rainfall was largely deficient in Kerala state[25]. Sampling was conducted in the stations Thirunnelli and Begoor Bridge during the late winter period (last week of January), and the remaining stations were covered during the last week of February and the first week of March (summer period). Plankton net with a mesh size of 60 micrometres, having a mouth area of 0.126 m^2, used for sampling. River flow velocity was determined using the float method[26, 27]. Samples were collected by anchoring the plankton net in the middle of the river channel, with the net mouth positioned half dipped (effective mouth area = 0.063m^2) for a duration of 5 minutes. The average river flow during the sampling period was 0.053±0.025 m/s. The volume of water filtered was calculated based on the effective mouth area and river flow velocity.

2.3 Sample analysis

Collected samples are passed through the different mesh size sieves or filters to separate microplastics by size. To prevent contamination, all parts of the net were thoroughly rinsed with fresh water before use. The collected samples were transferred into a beaker containing a significant amount of organic matter that needs to be separated from microplastics. Thoroughly rinse the container with a wash bottle to make sure that all of its contents are collected. Organic contents in the collected samples were digested by using 10% of potassium hydroxide (KOH) solution. To avoid contamination, cover the beaker with aluminium foil and kept it for 24 hours to complete digestion process. The aliquots of the sample were placed in petri dishes for further analysis after digestion. The identified microplastics were classified according to their size, colour, and morphotypes (line/fibre, fragment, foam, or film), following the criteria defined by Free et al[28]. Microplastics were carefully collected and transferred into glass containers using stainless steel needles and laboratory forceps.

At most care was taken during each step of the sample collection and analysis to prevent any external contaminations. The entire field and laboratory work was carried out according to the contamination protocol[29, 30, 31]. Aluminium foils and steel containers were used throughout the sample collection and storage and whenever not in use the samples were covered with aluminium foil. To avoid particulate pollutants, all chemical solutions and distilled water were filtered through 0.45um pore-size filter paper. All the activities and analysis, including sample collection, processing and microplastic isolation, were performed wearing cotton lab coats and nitrile gloves to avoid airborne contamination and synthetic fibre from clothing. The working area and stereo zoom microscope were cleaned before any analysis using alcohol. Field and

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laboratory blanks were included during the collection time and microplastic isolation in the laboratory. Both blanks showed negative results.

The chemical composition of isolated microplastics was analyzed using PERKIN ELMER Spectrum 100 Fourier Transform INFRARED spectroscopy (FTIR) with Attenuated Total Reflectance (ATR). All samples of enough size were exposed to 30 scans, using a resolution of 4 cm^{-1} within a wavelength range of 4000–650 cm^{-1}. Polymer identification was carried out by comparing the obtained spectra with those in the spectral database of common synthetic polymers, previously published data, and open-access databases.

Standard Deviation, Median and range, were used to describe spatial patterns in microplastic concentration. Formal Hypothesis testing (eg. Kruskal – Wallis) was not performed due to the absence of replicate samples per station. Stations classified as Rural/Urban (KO, PA, MA, VA, CH: near settlements/bridges) vs Forest (KU, BE, TH: forested catchment reaches) based on field observations and land-use characteristics.

Microplastic impacts are evaluated using the Coefficient of Microplastic Impact (CMPI). The CMPI evaluates the impact of microplastic shapes and is calculated using the formula: CMPI = (Number of a specific microplastic shape)/(Total number of microplastics) Based on the CMPI value, impact levels are classified as follows:

- 0.0001–0.1 (minimum)
- 0.11–0.5 (average)
- 0.51–0.8 (maximum)
- 0.81–1 (extreme).

2. Results

2.1. Abundance of Microplastics

Microplastics obtained from the Kabani River ecosystems were categorized according to size, colour, and morphotype. The size of microplastics found in the riverine samples varied from 0.06 mm to 5 mm, with the most abundant sizes found in the range of 0.063 mm to 0.25 mm. A 63 µm sieve was used during filtration to capture particles within this microplastic size

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range. Fibres were the most predominant morphotype of all recognized microplastics. The majority of the microplastics were filamentous and long, existing in bundles, with the prevalence of fibres among the observed microplastic morphotypes stemming from their multiple origins and physical characteristics. A total of 237 microplastics recorded during the study period, all of which were filamentous fibres, giving a CMPI vale of one. This corresponds to an extreme dominance of fibres over other morphotypes.

Table 2. Descriptive statistics of microplastic concentration across eight stations (n=8). Values derived from single plankton net tows. (1000 L filtered /station).

Statistics	Values (Particles/L)
Mean	0.103
Sample SD	0.18
Median	0.0135
Minimum	0.002
Maximum	0.47
Urban median (n=5)	0.19
Forest median (n=3)	0.002

The presence of microplastics was recorded at all study stations, although concentrations varied. The mean concentration of microplastics gathered from the principal tributaries of the Kabani River was 0.103 ± 0.18 particles/L (median 0.0135; range 0.002-0.47). (**Table 2**) The highest concentration occurred at KO (0.47 particles/L), the Koodalkadavu confluence where PA (0.3 particles/L) and MA (0.019 particles/L) rivers merge, combining their microplastic loads (Figure 2). Among forest stations, KU Island showed elevated values (0.02 particles/L) compared to TH/BE (0.002 particles/L), reflecting downstream transport from the KO confluence. This created a clear longitudinal gradient: confluence peak → depositional island → low headwater forest. The population, geographical terrain, hydrological factors, and river velocity are the significant environmental and anthropogenic drivers of microplastic distribution in these areas. Rural/urban-proximate stations showed substantially higher median concentrations (0.19 particles/L) than forest sites (0.002 particles/L), a ~95-fold difference

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driven by KO (0.47 particles/L) and PA (0.3 particles/L) (Table 2). This pattern aligns with land-use pollution gradients reported across Indian rivers[32, 33, 34].

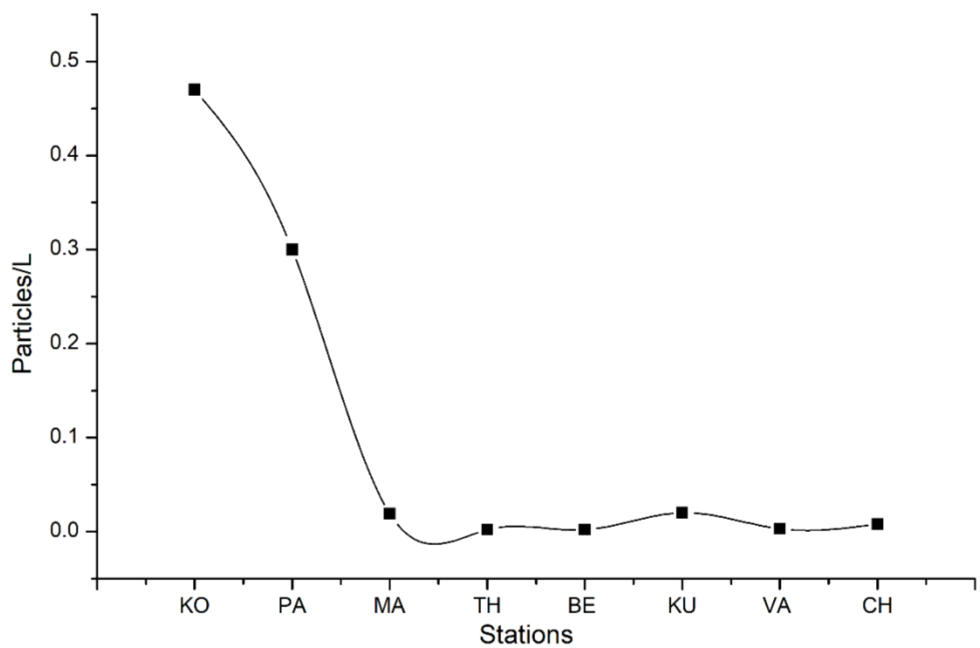

Fig. 2. Abundance of microplastics in different stations

Four prominent colours of microplastics found in our study: red, blue, green, and transparent. Red-coloured microplastics were commonly seen, while blue, green, and transparent microplastics were less common. Red fibres were dominant, particularly at Kuruva Island (57%) and Panamaram (47%). Green fibres were most common at Valliyurkavu (44%), reflecting a site-specific difference. Other colours, such as blue and transparent, occurred in lower and more variable percentages at all stations (**Fig. 3**). This reflects spatial differences in microplastic sources and inputs within the Kabani river system.

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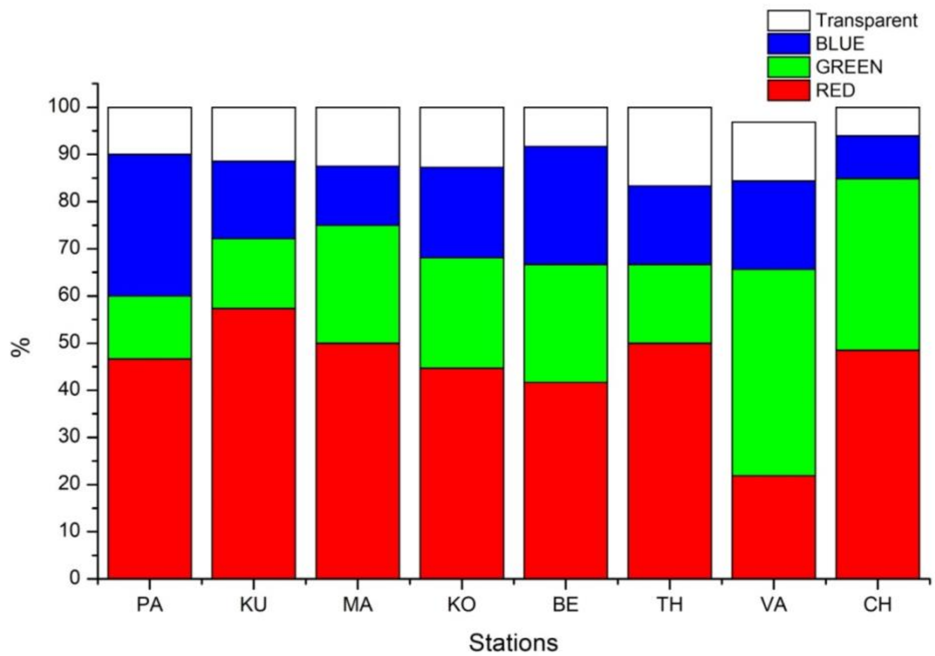

Fig. 3 Percentage composition of microplastics based on colour

2.2. Polymer identification using FTIR

Fourier Transform Infrared Spectroscopy (FT-IR) was carried out to determine the polymer composition of the collected microplastics. The FT-IR analysis indicated that Ethylene Vinyl Acetate (EVA) was the prevalent polymer in the samples. The FT-IR spectra, as shown in **Fig. 4**, confirm the occurrence of characteristic absorption bands for EVA, such as peaks of C–H stretching, C=O stretching, and C–O bending vibrations.

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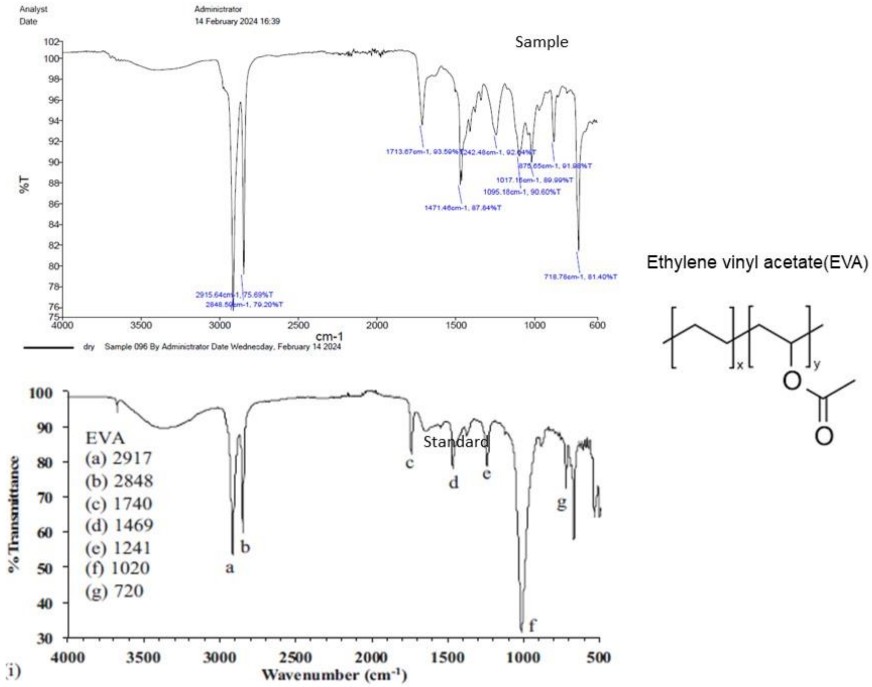

Fig. 4 FT-IR spectra analysis of microfibres with standards.

The identification of EVA in the collected microplastic samples suggests that industrial products, such as footwear and packaging materials, may be potential sources of microplastic pollution in the study area. Microscopic examination (**Fig. 5)** revealed the association of microplastics with algal material, providing insight into the potential interaction between synthetic particles and aquatic biota (**Fig. 5d**).

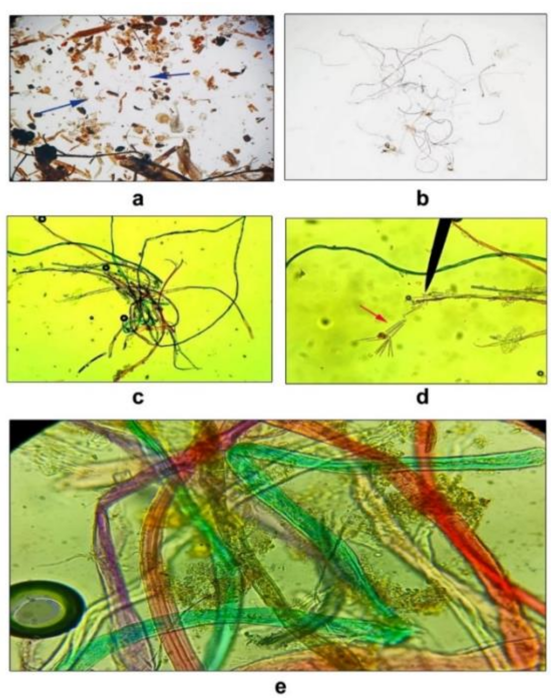

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Fig. 5 Microscopic image of microplastics

a) a – Assorted microplastics (0.75x magnification) from the sample
b) b, c, d (arrow mark indicated algal association) and e - Sorted microplastic particles (2x, 4x and 100x magnification).

Discussion

Urbanization and anthropogenic activities have introduced numerous harmful substances into the ecosystems, particularly plastics[35]. India is one of the leading plastic consumers globally, utilizing plastics in day-to-day human life as the most flexible artificial product[36]. Microplastics were first identified in 2004[37] and are now documented as prevalent contaminants in both aquatic and terrestrial ecosystems[38, 39].

Fibres were the principal morphotype of microplastics recorded in our study among the 237 microplastics. Many scientific studies recorded similar observations in which fibres to be the most abundant type of microplastics, particularly in water bodies, sediments, and organisms. Higher fibre dominance (>90%) were recorded on beach sediments of USA with ~93% of microplastics being fibres, well above fragments and other forms[40]. McNeish et al.[41] studied on fish samples and riverine water from the Gulf of Maine, microfibres accounted for 97-100% of microplastics. Densely populated areas such as Koodalkadavu, Kuruva Island, and Panamaram have shown a high concentration of fibres in our study. Effluents from laundering synthetic textiles, improper waste management, agricultural runoff, and fishing gear and sanitization products have contributed the high fibre load in these regions. A study report of Anagha et al.[42] in the Vembanad Lake, one of the Ramsar sites in Kerala, fibres dominated over 50% of entire

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microplastics collected in subsurface and bottom waters with polyamide and polypropylene polymers, which are suspected to have been released through fishing and laundry wastewater, further supporting the abundance of fibres in the aquatic system.

Begum et al.[43] reported that 79.4% of microplastics in water samples and 89.8% in sediment samples were constituted by fibres in the Palar River Estuary, Southeast Coast of India. Similarly, an investigation into the Periyar River revealed that fibres were the predominant form of microplastics, with a higher concentration observed during the monsoon season[44]. These results suggest that the fibres and fragments were the most prevalent morphotypes recorded in both northern and southern India[45]. The exclusive presence of fibres suggests substantial influence from textile, fishing lines or ropes and other fibrous materials transported via domestic wastewater and surface runoff, a pattern commonly reported in riverine microplastic studies[46, 47].

The mean concentration of microplastics obtained from the major tributaries of the Kabani River was 0.103 ± 0.18 particles/L (median 0.0135; range 0.002-0.47) which is relatively lower compared to the other major rivers in Kerala. A related microplastic abundance of 15.13 ± 4.13 – 170 ± 17.75 particles/L were observed from the eight sampling stations along the Chalakudy River of Kerala by Kumar et al[48]. These differences might be owing to changes in population density and minimal industrial activity in the Kabani River basin. The 95-fold urban-forest gradient (0.002–0.19 particles/L medians) reflects direct settlement inputs at KO/PA versus dilution/transport at forested reaches. KU (0.02 particles/L) shows intermediate pollution from upstream PA/MA runoff accumulation, consistent with riverine microplastic transport dynamics. Kabani maintains low overall abundance compared to urban Indian rivers (0.3–4 particles/L).

A comparatively low microplastic abundance recorded in the Kabani River with other urban Indian rivers can be attributed to reduced human pressure within riverine basin. Major urban rivers in South India including Adyar, Cooum, and Kosasthalaiyar rivers, for instance, have already been known for the presence of significant amount of microplastic discharged from domestic sewage and effluents from industries[49, 50, 51]. However, Kabani River drains mainly from rural and forested Western Ghats is under lesser population density and fewer industries, thereby restraining constant microplastic inputs[52]. Similar studies have also been recorded in riverine basins of South India, where lower microplastic densities noted in rural river systems

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emphasizing that land-use characteristics, along with population density, affect microplastic levels[53].

The pronounced microplastic gradient reflects river confluences and depositional geomorphology characteristic of Kabani River. Koodalkadavu (KO: 0.47 particles/L) represents a confluence hotspot where PA and MA tributaries deliver cumulative urban runoff from settlements and bridges, consistent with tributary merging as microplastic concentration maxima in river networks. Downstream Kuruva Island (KU: 0.02 particles/L) functions as a secondary depositional sink, where low-velocity eddy systems trap fibres transported from KO during summer baseflow conditions (0.053±0.025 m/s). Headwater forest stations TH/BE maintain baseline levels (0.002 particles/L) distant from settlement influences. The spatial distribution pattern of microplastics along the study stations highlights a strong longitudinal and land use related aspects with the highest concentration at the KO confluence and a progressive decrease towards the forested areas. This higher microplastic concentration at KO can be recognized by the hydrological merging of PA and MA rivers, that outcomes convergence point getting total input sources from the upstream areas, agricultural effluents and waste water discharge. The confluences are known areas for microplastic accumulation and thereby noticing decrease in the velocity of the flowing waters, increased sedimentation rates and the highest pollutant load in the tributaries[54].

The observed association between algae and microplastics strongly indicate the biofilm formation, which is likely to alter microplastic resistance, degradation, and increase the ingestion rate by aquatic animals[55]. This association may facilitate trophic transfer and warrants a more thorough ecological risk assessment.

The red, blue, green, and transparent colours of microplastics obtained in our study, in which red coloured fibres were commonly observed, and transparent fibres were less common. Meanwhile, seven colours, including brown, red, orange, green, blue, violet, and grey, have been separated from the Pasig River in the Philippines[56] and eight different colour groups of plastics were examined in the Chalakudy River[48]. Coloured microplastics can be easily ingested by aquatic invertebrates and vertebrates, which may negatively impact trophic interactions and ecosystem functioning[57, 58]. Singh et al.[59] examined the occurrence and dynamics of microplastics in the Ganga River basins surrounding the city of Varanasi, recorded different sources and

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compositions of microplastics with the predominant colours found to be blue, brown, white, and some other shades, displaying site-specific patterns. In a similar work relating microplastic contamination of Mandovi-Zuari system of Goa, an estuarine environment situated on the west coast of India, Gupta et al.[60] found that the blue and green-tinted microplastics were predominant in surface and sediment water samples. The presence of coloured microplastics within the freshwater environments indicates the continued exposure of water sources and anthropogenic activities.

The detection of ethylene–vinyl acetate (EVA) among the recovered microplastic polymers suggests inputs from industrial products, mainly parts of footwear, sports goods and packaging foams. EVA has been broadly accepted and used in industries owing to its light, flexible, and shock-absorbing nature, and its natural occurrence has gradually been integrated into the abrasion and fragmentation of footwear, mats, and packing wastes in urban and natural environments[61]. In riverine environments, EVA particles can be introduced either through the surface runoff, inadequate dumping of solid waste, or from the market places with frequent human activities. Despite the absence of huge industrial infrastructure in the Kabani River basin, the presence of EVA indicates it's diffused, non-point sources related to human activities. Such observations were likewise found in other Indian and worldwide freshwater resources, wherein EVA and other copolymers were traced to footwear deterioration, recreational use, and semi-urban community discharges[50, 51].

3. Conclusion

This research is the first investigation to undertake a comprehensive assessment of microplastic contamination in the Kabani River, which is an important freshwater ecosystem in the Western Ghats region of Wayanad district, Kerala. The confirmation of the microplastic across all the study stations reveals the prevalent nature with an average abundance of 0.103 ± 0.18 particles/L. Remarkably, higher concentrations of microplastics were recorded in overpopulated and tourist-frequented areas such as Kuruva Island, Koodalkadavu, and Panamaram, suggesting that anthropogenic influence is a key contributor. The fibres emerged as the major microplastic morphotype and coloured (red, blue, and green) and transparent particles were significantly prevalent. The FT-IR spectroscopy (PERKIN ELMER Spectrum 100)

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identified Ethylene Vinyl Acetate (EVA) as the predominant polymer in the study stations, pointing to its widespread usage and environmental persistence. These findings emphasize the immediate need for more stringent regulatory measures, public awareness campaigns, and source-specific waste management practices to mitigate microplastic pollution in ecologically sensitive riverine ecosystems. To protect, biodiversity and water quality of Kabani River, future research should emphasize on long-term monitoring, source identification and ecological and environmental impact assessments.

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