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Quantitative Assessment of Microplastic Contamination in Aquatic Ecosystems within the Buffer Zone of the Western Ghats: A Case Study Approach

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Abstract: Microplastics (MPs) are now commonly found in various water bodies and can have severe negative impacts on ecosystems. In the buffer zone of the Western Ghats, wild animals rely on ponds and check dams for drinking water. Evidence such as footprints indicates the presence of elephants, rabbits, deer, peacocks, and domestic animals using these water sources. Following the post-monsoon season, six litter samples were collected from two locations: Bharathiar University and the Marudhamalai foothills. These sites also provided water samples for analysis. Both microplastics and physicochemical parameters (temperature, pH, electrical conductivity, and total dissolved solids) were examined. The samples underwent a digestion process using Fenton's reagent, followed by the separation of organic and inorganic matter using NaCl. The digested water samples were then analyzed both qualitatively and quantitatively to determine the presence of MPs. Microplastics of various shapes and colors were observed under a trinocular microscope. In total, 892 microplastic particles were recorded. The highest concentration was found in the Bharathiar University samples (642 MPs), while the lowest was in the Marudhamalai foothills samples (250 MPs). These findings highlight how plastic pollution contaminates water sources, allowing MPs to enter lake sediments and disrupt aquatic ecosystems. Furthermore, animals drinking from these polluted sources may ingest microplastics, leading to their accumulation in the body and posing serious ecological and health risks. This study enhances our understanding of pollution sources and their ecological consequences, offering valuable insights for future research and contributing to the development of strategies to mitigate plastic pollution in the region.

1. Introduction

According to research by the United Nations Environment Programme (UNEP), packaging has become the most prevalent form of single-use plastic (SUP), with durable polymers constituting the majority of modern plastic production. The increasing demand for SUPs has significantly driven global plastic manufacturing, which surpassed 360 million metric tonnes in 2018—half of which was attributed to SUP products. Since the 1950s, plastic production has grown at an average annual rate of 9%, rising from 1.7 million metric tonnes in 1950 to over 360 million in 2018. Forecasts from the MacArthur Foundation predict continued growth in plastic production over the next two decades (Chen *et al.* (2021).

Plastics used in everyday life can have harmful effects throughout their entire life cycle. Their toxicity may stem from the polymer matrix itself, additives, degradation byproducts, and/or absorbed environmental contaminants. Polymerization processes are often incomplete, resulting in residual monomers, oligomers, low molecular weight fragments, catalysts, and solvents remaining within the final polymer structure. Many of these residuals can exert chronic toxic effects on both the environment and human health. Additionally, plastics often contain chemical additives such as bisphenol A (BPA), phthalates, polybrominated biphenyl ethers (PBDEs), and antioxidants, which are incorporated during production. Due to their weak bonds with the polymer chains, these additives can leach into the surrounding environment including air, water, sediment, food, or biological tissues after ingestion impacting a wide range of species (Rodrigues *et al*. (2019).

Microplastics (MPs), as pervasive anthropogenic pollutants, pose a significant threat to living organisms. Research has revealed suspected MPs in the internal tissues of domestic animals like dogs and cats. MPs have also been found in the digestive tracts and internal organs of fish, mussels, birds, and marine mammals. Studies have even detected polyethylene terephthalate (PET) and polycarbonate (PC) particles in pet food and in the feces of domestic animals. While factors such as inflammation may increase intestinal permeability and facilitate MP internalization, and age may influence bioaccumulation, no clear relationship was observed between suspected MP concentration and the cause of death in these animals (Prata *et al. (*2022).

2. Methodology

2.1 Study area

Coimbatore district is located at approximately 11.0168°N latitude and 76.9558°E longitude, with an average elevation of around 420 meters above sea level. It lies within the upland plateau region of Tamil Nadu and is characterized by diverse topography, including numerous hill ranges, hillocks, and gently sloping terrain that descends eastward from the hilly regions in the west. The district experiences a tropical wet and dry climate, with three distinct seasons: the pre-monsoon (March to May), the monsoon (June to November), and the post-monsoon (December to February). The mean maximum temperature ranges from 29.2°C to 35.9°C, while the mean minimum temperature varies between 19.8°C and 24.5°C. Sample collection for the study was conducted during the post-monsoon season.

2.1.1 Maruthamalai Foothill

Maruthamalai is a suburb of Coimbatore, Tamil Nadu, India, located at approximately 11°03'86" N latitude and 76°86'78" E longitude. Positioned along the Western Ghats and around 15 km from the city, it falls under the 17th ward of Coimbatore Corporation. Due to its location in a biodiversity-rich region, the area is home to various wild animals, such as elephants, leopards, deer, rabbits, gaurs, and wild boars. These animals often roam the foothills and occasionally venture into residential zones. Recently, wild boars, which were once nocturnal, have been increasingly active during the daytime in search of food and water. As they forage in human-occupied areas, they risk ingesting microplastics through contaminated resources, leading to bioaccumulation and potential biomagnification, posing ecological and health threats to both wildlife and humans.

2.1.2 Bharathiar University

Bharathiar University, a state university in Coimbatore, Tamil Nadu, India, is located at 11°2'14" N latitude and 76°52'37" E longitude. Established in February 1982 under the Bharathiar University Act, 1981, and recognized by the UGC in 1985, the university sits on a 1,000-acre campus within the Western Ghats, with the Maruthamalai Hills forming its scenic backdrop. Owing to its proximity to this ecologically rich region, the campus frequently sees wild animals such as elephants, deer, gaurs, wild boars, leopards, peacocks, and rabbits. These animals often enter the university area in search of food and water, drawn to the natural surroundings and available water sources like tanks and pools, making the campus an important interface between human activity and wildlife.

2.2 Survey

This research examines microplastic pollution in Maruthamalai foothills and Bharathiar University, Coimbatore, focusing on wildlife exposure to microplastics in water, with implications for ecosystem health.

2.3 Sampling

Water samples were collected from the study areas of Maruthamalai foothills and Bharathiar University. For microplastic examination, 6 liters of water from each location were filtered using stacked stainless-steel sieves (5 mm) in the field (Singh *et al*. (2024). The sieves, wrapped in aluminum foil to prevent contamination, were transported to the lab, cleaned with distilled water, and the residues were collected in glass bottles for further analysis.

Figure 1. Water Sampling

Figure 1. **A: Bharathiar University** **B: Maruthamalai foothills**

2.4 Analysis of Samples

The National Oceanic and Atmospheric Administration (NOAA) method was used to identify microplastics (MPs) in the water samples (Masura *et al*. (2015). If organic materials were present, the filtrate from the 5mm sieve was carefully collected and subjected to wet peroxide oxidation. A 12.5ml Fenton's reagent was added to the sample, which was then treated in an ultrasonic bath for 20 minutes. After 30 minutes, 20ml of NaCl was added, and the sample was allowed to settle for 5 hours before filtration. For filtration, the solution was diluted with distilled water and passed through cellulose nitrate (CN) filter paper (47mm diameter, 1µm pore size). The residue was then filtered using a vacuum filtration unit.

2.5 Microscopic Examination

Microplastic particles extracted from the samples were examined using a Trinocular microscope with a camera at 4X magnification. The size and color of each particle were recorded, and images were taken for further analysis.

2.6 Polymer Identification

The particles collected on the CN filters were analyzed using Fourier-transform infrared spectroscopy (FT-IR). The FT-IR results were used to identify and characterize the polymer types of the MPs in the samples.

3. Results and Discussion

3.1 Physicochemical Parameters

The physicochemical parameters of water samples collected from Bharathiar University and the Marudhamalai foothills were analyzed. According to the World Health Organization (WHO), the temperature readings between the two locations, ranging from Figure 2 26.3°C to 28.4°C, fall within an acceptable range. The WHO recommends that water pH l Figure 3 should be between 6.5 and 8.5 (Kumar *et a*l. (2012). The pH of the water samples from the buffer zone of Marudhamalai ranged from 8.3 to 8.4, indicating an alkaline nature due to the presence of dissolved carbonates and bicarbonates (Jain *et al.* (2021). The conductivity range Figure 5 from 131 to 132 mS/cm, which is within the allowable range of 78 to 489 mS/cm for drinking water (Aryal *et al.* (2012). The salinity Figure 4 varied from 68.1 to 664 parts per million, which is well below the standard limit of 1000 parts per million. The Total Dissolved Solids (TDS) ranged Figure 6 from 94.4 to 932 mg/L, which is considered acceptable by the WHO, as levels exceeding 1000 mg/L are deemed problematic (Islam *et a*l. (2017). The concentration of TDS can also increase due to organic matter, such as decaying plant and animal bodies (Muhammad Asif *et a*l. (2022).

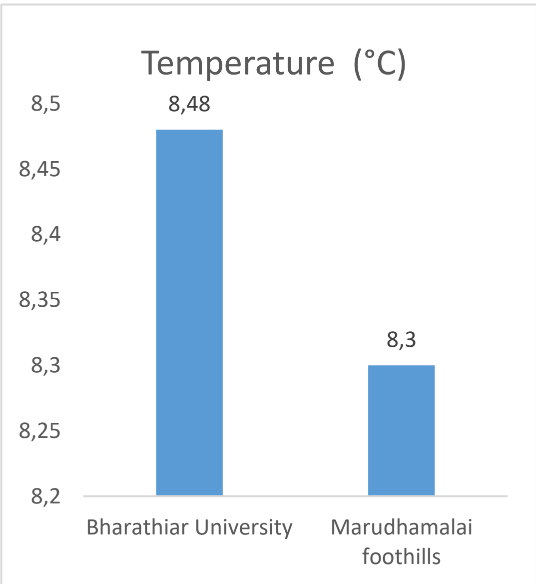

Figure 2. Temperature

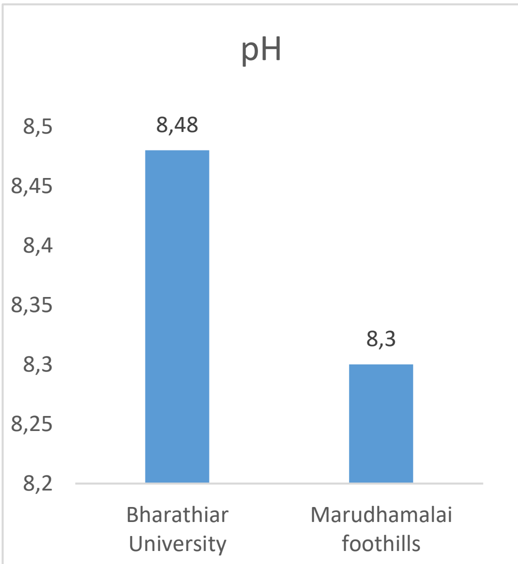

Figure 3. pH

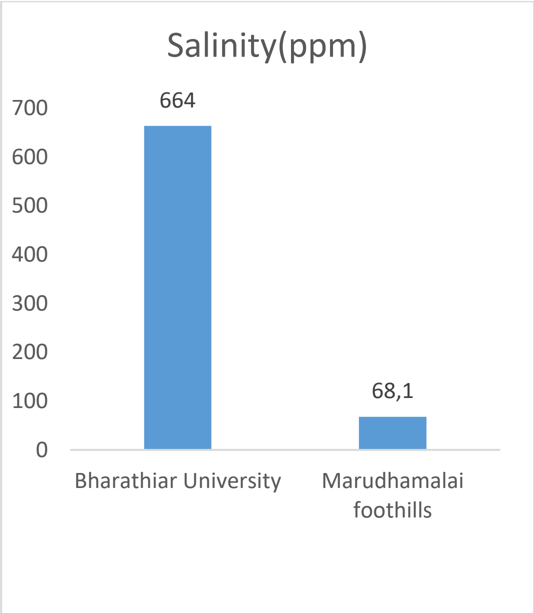

Figure 4 . Salinity

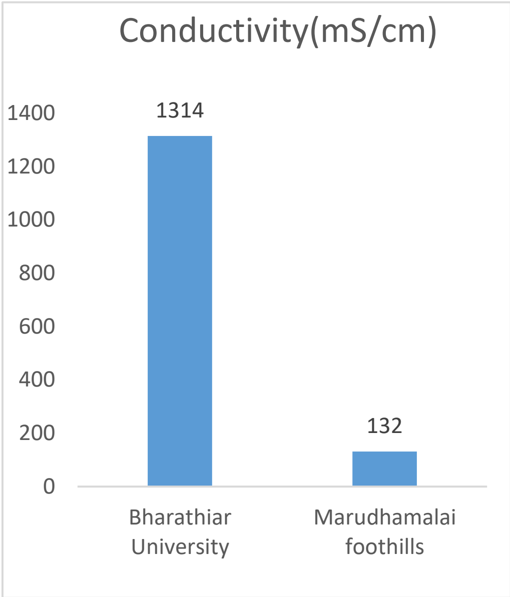

Figure 5. Conductivity

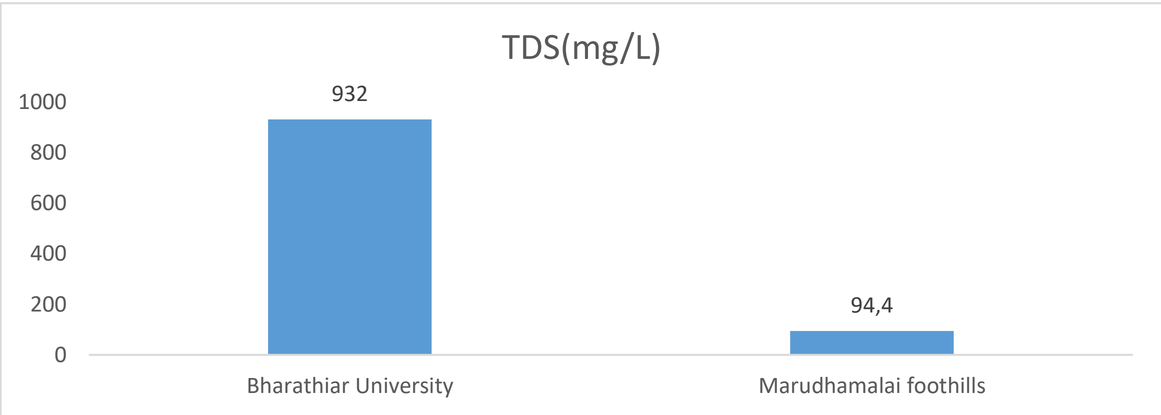

Figure 6. Total dissolve solid

3.2 Microplastics Analysis

In this study MPs were analyzed in water samples collected from Bharathiar University and the Marudhamalai foothills. The collected samples underwent digestion before being sent for both qualitative and quantitative analysis to detect the presence of MPs. MPs of various shapes and colors were observed in both sample sets. **Figure 8,** A total of 892 MPs were identified across the two water samples. The highest number of MPs was recorded at Bharathiar University, while the least number was observed at Marudhamalai foothills. A similar study by (Napper *et al.*, 2021), conducted in the Ganga River identified 140 MPs. In comparison to the buffer zone of Marudhamalai, the area surrounding Bharathiar University showed a higher concentration of MPs, likely due to the degradation of larger plastic debris over time and runoff from land sources, including wastewater, rain, and wind, which carry plastic particles into the

3.2.1 Quantitative and Qualitative Analysis of the Samples

A Trinocular microscope **Figure 7** was employed for both quantitative and qualitative analysis of the water samples in order to count and identify the MPs present. The results showed **Figure 8**that the water sample from Marudhamalai contained 250 MPs, while the sample from Bharathiar University had 642 MPs.

The observed MPs exhibited a variety of colors and shapes water

Figure 7. Trinocular microscopy image

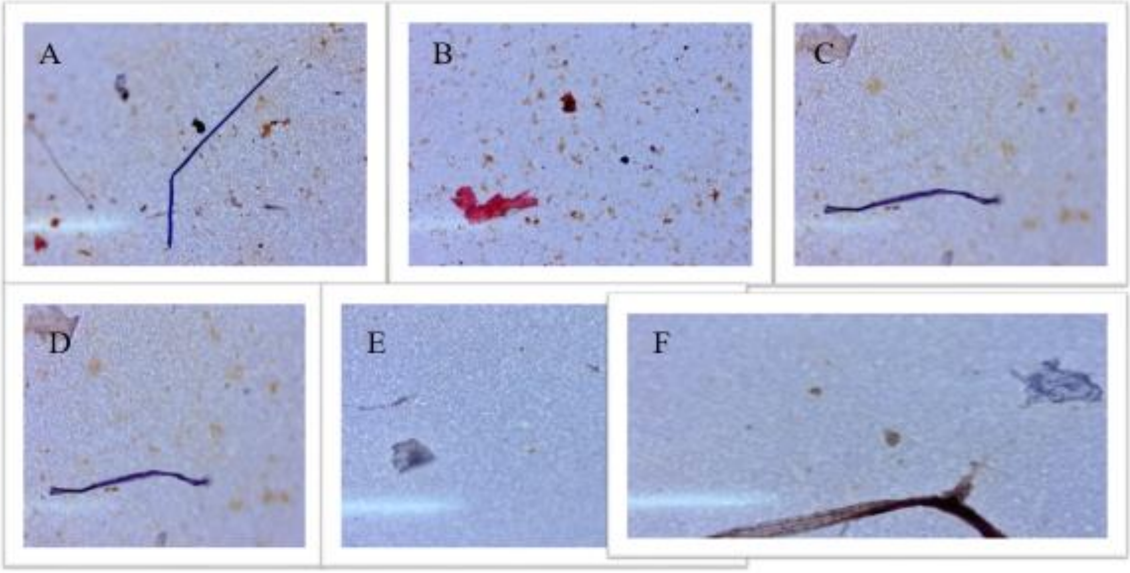

Figure 7. A.Blue fibre, B.Red film C. Black line, D. Black line, E. Black fragment, F. Black Sheet.

3.2.2 Total number of microplastics identified in collected water samples

Figure 8. Total number of microplastics

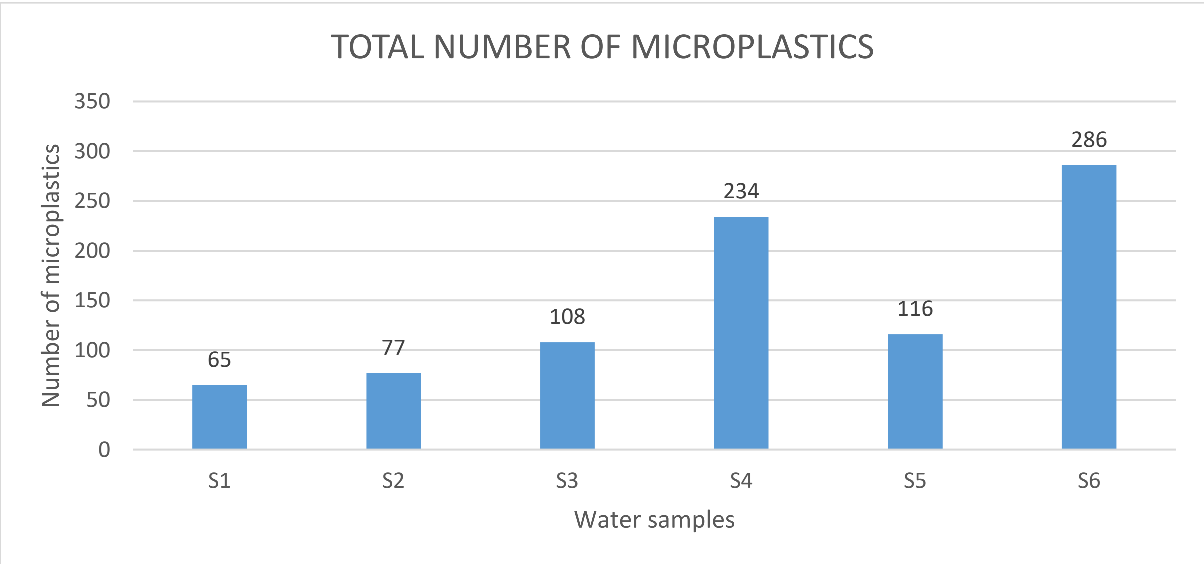

Figure 8 . The number of MPs in the analysed water samples are Marudhamalai (250) and Bharathiar University (642),

3.2.3 Colors of Microplastics identified in collected water sample

Figure 9. **Colors of microplastics**

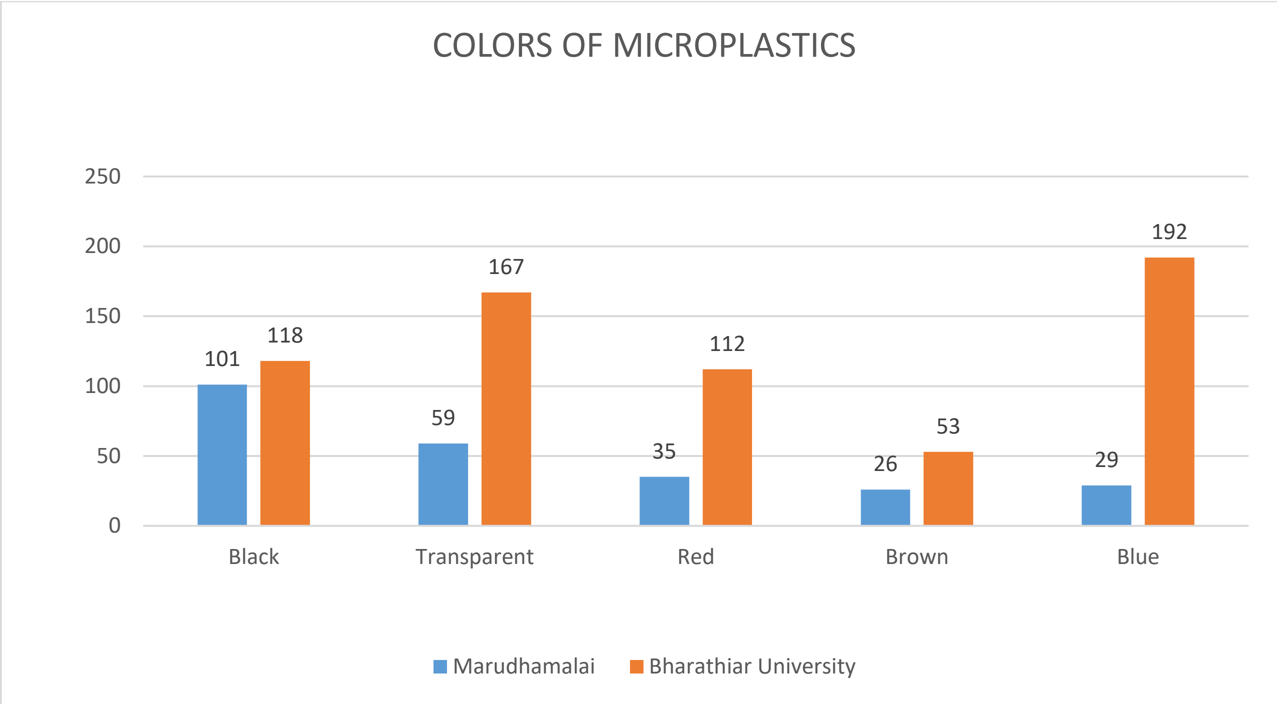

Figure 9. The color that was mostly observed was Transparent (226), Black (219), Red (147), Brown (79), and Blue (221).

3.2.4 Shapes of Microplastics identified in collected water samples

Figure 10. Shape of microplastics

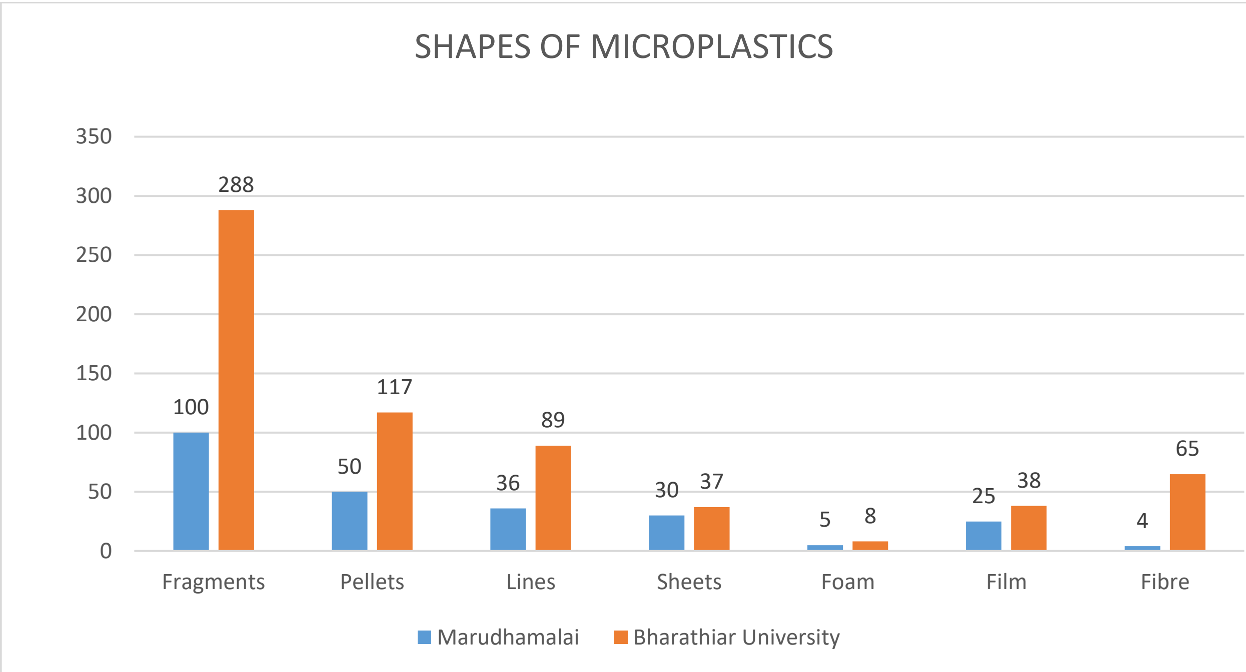

Figure 10. MPs like Fragments (388), Pellets (167), Lines (125), Fibre (69), Sheets (67), Film (63), and Foam (13).

3.3 ATR -FTIR ANALYSIS

ATR-FTIR Analysis

ATR-FTIR analysis was conducted to identify the type of polymer present in the plastic particles. The analysis was performed using the JASCO ATR-FTIR – 4X, with a wave number range between 4000 and 600 cm^{-1} and a resolution of 96.42%. Prior to analyzing the samples, the FTIR spectra of fifteen commonly used virgin plastics were retained as standards to facilitate the comparison of functional groups present in the sample spectra (Jung *et al.*, 2018).

3.3.1 Bharathiar University (S1)

In the water sample collected from Bharathiar University (S1), various types of MPs and polymers were identified using ATR-FTIR analysis. The specific peaks in the ATR-FTIR spectrum indicated the presence of these materials. A summary of the identified polymers and their corresponding peaks is as follows:

1. Nylon: Peaks at 3296.71cm-1and 674.96 cm-1
2. Low Density Polyethylene (LDPE): Peaks at 2903.31cm-1and 1452.14 cm-1
3. Polycarbonate (PC): Peaks at 1744.3cm-1 and 1042.34 cm-1
4. Polystyrene (PS): Peaks at 1643.05cm-1
5. Acrylonitrile Butadiene Styrene (ABS): Peaks at 1536.02cm-1and 1591.92 cm-1
6. Polypropylene (PP): Peaks at 1395.25 cm-1
7. Poly Vinyl Chloride (PVC): Peaks at 1313.29 cm-1
8. Polyethylene Terephthalate (PETE): Peaks at 1237.11cm-1

3.3.2 Bharathiar University (S2)

A water sample was collected from a Bharathiar University (S2), which underwent a digestion process. The sample was then analysed under a microscope to determine the color, shape, and size of the MPs present. Further identification of MPs types was done using ATR- FTIR analysis. The analysis of the water sample revealed the presence of various types of MPs and they are

1. Nylon: Peaks at 3297.68 cm-1
2. Low Density Polyethylene (LDPE): 2913.91cm-1,1451.17cm-1, 1398.14 cm-1,1313.29 cm-1 and 754.03 cm-1
3. Nitrile: Peaks at 2315.12 cm-1
4. Polyethylene Terephthalate (PETE): Peaks at 1744.3
5. Polystyrene (PS): Peaks at 1642.09 cm-1
6. Polycarbonate (PC): Peaks at 1042.34 cm-1

3.3.3 Bharathiar University (S3)

In the water sample collected from Bharathiar University (S3), various types of MPs and polymers were identified through ATR-FTIR analysis. The presence of these substances was indicated by specific peaks in the ATR-FTIR spectrum. Here's a summary of the identified materials and their corresponding peaks:

1. Nylon: Peaks at 3295.75 cm-1
2. Polypropylene (PP): Peaks at 2958.27 cm-1and 2849.31 cm-1
3.Low Density Polyethylene (LDPE): Peaks at 2918.73 cm-1,1451.17 cm-1,1393.32 cm-1, 1313.29 cm-1,754.03 cm-1 and 702.92 cm-1
4. Polyethylene Terephthalate (PETE): Peaks at 1745.26 cm-1 and 1236.15 cm-1
5. Polycarbonate (PC): Peaks at 1040.41 cm-1
6. Cellulose Acetate (CA): Peaks at 900.594 cm-1
7. Polystyrene (PS): Peaks at 1643.05 cm-1

3.3. 4 Marudhamalai foothills (S4)

A water sample was collected from a Marudhamalai foothills (S4), which underwent a digestion process. The sample was then analysed under a microscope to determine the color, shape, and size of the MPs present. Further identification of MPs types was done using ATR- FTIR analysis. The analysis of the water sample revealed the presence of various types of MPs and they are:

1. Nylon: Peaks at 1543.74 cm-1 and 640.25 cm^{-1}
2. Low Density Polyethylene (LDPE): Peaks at 2918.73 cm^{-1}, 1455.99 cm^{-1} and 1338.36 cm^{-1}.
3. High Density Polyethylene (HDPE): Peaks at 2851.24 cm-1 and 693.284 cm-1
4.Polyethylene Terephthalate (PETE): Peaks at 1744.3 cm-1,1711.5 cm-1,1254.47 cm^{-1} and 1042.34 cm-1.

3.3.5 Marudhamalai foothills (S5)

In the water sample collected from Marudhamalai foothills (S5), various types of MPs and polymers were identified through ATR-FTIR analysis. The presence of these substances was indicated by specific peaks in the ATR-FTIR spectrum. Here's a summary of the identified materials and their corresponding peaks:

1. Low Density Polyethylene (LDPE): Peaks at 2917.77 cm-1 and 700.998 cm-1
2. High Density Polyethylene (HDPE): Peaks at 2852.2 cm-1
3. Polycarbonate (PC): Peaks at 1794.44 cm-1and 1744.3 cm-1
4. Polyethylene Terephthalate (PETE): Peaks at 1663.3 cm-1, 1644.2 cm-1 and 1255.43 cm-1
5. Polystyrene (PS): Peaks at 1544.7 cm-1, 1457.92cm-1 and 1040.41cm-1
6. Poly Vinyl Chloride (PVC): Peaks at 1377.89 cm-1and 1315.21cm-1
7. Cellulose Acetate (CA): Peaks at 911.20 cm-1
8. Nylon: Peaks at 640.25 cm-1

3.3.6 Marudhamalai foothills (S6)

A water sample was collected from a Marudhamalai foothills (S6), which underwent a digestion process. The sample was then analysed under a microscope to determine the color, shape, and size of the MPs present. Further identification of microplastics types was done using ATR-FTIR analysis. The analysis of the water sample revealed the presence of various types of microplastics and they are:

1. Nylon: Peaks at 3288.04 cm-
2.Low Density Polyethylene (LDPE): Peaks at 2916.81cm-1, 2853.17 cm-1, 1513.85 cm-1, 1459.85 cm-1, 1318.11 cm-1

3.Polyethylene Terephthalate (PETE): Peaks at 1742.37 cm-1, 1709.59 cm-1, 1664.27 cm-1, 1642.09 cm-1, 1246.75 cm-1
4. Polycarbonate (PC): Peaks at 1037.52 cm-1
5. Cellulose Acetate (CA): Peaks at 897.70 cm-1
6. Polystyrene (PS): Peaks at 700.034 cm-1
7. Polytetrafluoroethylene (PTFE): Peaks at 621.931cm-1

4. Statistical analysis

Table 1, Table 2 Shows statistical analysis was done for the different colors and shape of MPs present in the samples using SPSS software and version 25.

Table 1. Correlation between colors of microplastics

		Transparent	Black	Blue	Red	Brown
Transparent	Pearson Correlation	1	.733	.504	.753	.940**
Black	Pearson Correlation	.733	1	.845*	.991**	.692
Blue	Pearson Correlation	.504	.845*	1	.816*	.531
Red	Pearson Correlation	.753	.991**	.816*	1	.728
Brown	Pearson Correlation	.940**	.692	.531	.728	1

The Pearson correlation matrix for the colors of microplastics (MPs) reveals notable relationships between different color types, which may suggest common sources or environmental interactions. A strong positive correlation ($p < 0.01$) is observed between transparent and brown ($r = 0.940$), as well as black and red ($r = 0.991$), indicating that these colors often appear together, potentially due to similar degradation patterns or shared sources. Moderate correlations ($p < 0.05$) are seen between black and blue ($r = 0.845$), and blue and red ($r = 0.816$), further reinforcing this pattern. On the other hand, the weakest correlation is found between blue and brown ($r = 0.531$), which suggests these colors may have distinct origins or environmental behaviors. These results imply that certain MPs colors could originate from similar industrial sources, such as synthetic fibers, packaging, or rubber materials, while variations in correlation strength may be attributed to different weathering processes.
The correlation analysis between different MPs shapes **Table 2** reveals significant relationships that may indicate shared sources and degradation patterns. A highly significant correlation (**$p < 0.01$**) is observed between **lines and fibres ($r = 0.969$)**, suggesting that synthetic textiles, fishing nets, or plastic threads are common contributors. The strong correlation between **fragments and foams ($r = 0.902$, $p < 0.05$)** implies that these shapes may originate from packaging materials or polystyrene breakdown.

Additionally, **films, sheets, and fibres** show moderate to strong associations, pointing to sources such as **plastic bags, wrappers, and deteriorating synthetic materials**. Conversely, **pellets exhibit weak or negative correlations with most shapes**, suggesting they originate from distinct sourceslike **raw Plastic production rather than environmental degradation**. These findings provide insights into the environmental fate of differed MPs shapes and their potential source.

Table 2. Correlation between shapes of microplastic

		Pellets	Fragments	Lines	Foams	Sheets	Films	Fibres
Pellets	Pearson Correlation	1	.572	-.029	.447	-.140	-.298	.173
Fragments	Pearson Correlation	.572	1	-.258	.902*	.361	-.058	-.238
Lines	Pearson Correlation	-.029	-.258	1	.000	.608	.863	.969**
Foams	Pearson Correlation	.447	.902*	.000	1	.483	.258	.003
Sheets	Pearson Correlation	-.140	.361	.608	.483	1	.830	.452
Films	Pearson Correlation	-.298	-.058	.863	.258	.830	1	.736
Fibres	Pearson Correlation	.173	-.238	.969**	.003	.452	.736	1

5. DISCUSSION

In the present observation the microplastics analysis were made in water. These water samples were collected **Figure 1** from Bharathiar University and Marudhamalai foothills. The collected water samples were digested and then given for qualitative and quantitative analysis to monitor the presence of microplastics. In all the two samples the microplastics with different shapes and colors were recorded and observed. **Figure 8** Totally 892 microplastics were observed in two water sampling sites. Highest microplastics were observed in Bharathiar University and least microplastics were observed in Marudhamalai foothills. The study of (Napper *et al*. (2021), conducted in Ganga River, Overall, 140 microplastic particles were identified. Compared to buffer zone of Maruthamalai high microplastics were observed in these area due to larger plastic debris breaking down over time, combined with runoff from land sources like wastewater, rain, and wind carrying plastic particles into the lake A trinocular microscope was used to quantitatively evaluate the samples, enabling the identification and counting of all microplastics (MPs) present. The total number of MPs Figure 8 in the analyzed water samples were: 250 MPs in Marudhamalai and 642 MPs in Bharathiar University. The MPs exhibited various colors and shapes, with the most frequently observed colors Figure 9 being

Transparent (226), Black (219), Red (147), Brown (79), and Blue (221). The shapes identified included Fragments (388) Pellets (167), Lines (125), Fibers (69), Sheets (67), Films (63), and Foams (13).

A study by Capparelli *et al.* (2021), found that plastic fragments and fibers accounted for 61% and 36%, respectively, of the collected MPs. Of the MPs in that study Figure 10 58% were fragments and 43% were fibers, with transparent plastics being the most abundant (42%), followed by brown (20%), grey (15%), and black MPs (9%). In comparison, the buffer zone of Marudhamalai showed a higher diversity of MPs and colors, likely due to the waste from various districts in Tamil Nadu being disposed of in that area.

Fourier Transform Infrared Spectroscopy (FTIR) is a valuable tool for identifying and analyzing MPs, as it provides information about the chemical structure and functional groups of the materials. FTIR measures the infrared light absorbed or reflected by a sample, and by comparing the resulting spectrum with reference spectra of known polymers, researchers can identify the specific types of plastics present in the MPs. This method plays an important role in understanding the sources and potential environmental impact of MPs contamination (Chen *et al.*, (2020).

In this study, FTIR analysis was conducted on the separated plastic particles from the water samples to compare the functional groups present. The following types of MPs were considered for analysis: Polyethylene Terephthalate (PETE), Nylon, High-Density Polyethylene (HDPE), Low-Density Polyethylene (LDPE), Poly Vinyl Chloride (PVC), Polypropylene (PP), Polystyrene (PS), Acrylonitrile Butadiene Styrene (ABS), Cellulose Acetate (CA), Polycarbonate (PC), Nitrile, and Polytetrafluoroethylene (PTFE).

6. Conclusion

The study of microplastics contamination in water from the buffer zone of the Marudhamalai area in Coimbatore reveals significant environmental pollution concerns. MPs, which are increasingly found in natural water bodies, have become a pervasive form of pollution, caused by both local and global factors. The research identified numerous types and shapes of MPs in the water samples, highlighting the extent of the issue. These findings underscore the potential impact of MPs contamination on water ecosystems and local biodiversity.

Despite the Marudhamalai area buffer zone being considered a protected environment, it is vulnerable to MPs infiltration, primarily through human activities, agricultural runoff, and waste dumping. This contamination poses a risk to human health, as animals that drink contaminated water may accumulate MPs in their bodies, further affecting the entire food chain. The detection of MPs in water is concerning due to their potential effects on bioaccumulation and biomagnification. Given the environmental and health risks associated with MPs pollution, there is a need for more stringent monitoring and mitigation measures to reduce the amount of plastic waste entering natural water systems. Public awareness campaigns, improved waste management practices, and the promotion of alternatives to single-use plastics are essential to address this growing environmental issue.

The findings of this study contribute to the growing body of knowledge on MPs pollution in freshwater ecosystems, particularly in ecologically sensitive areas like the Marudhamalai hills. It is crucial to sustain efforts to protect these critical ecosystems. To prevent MPs contamination in water sources used by animals in the Marudhamalai Hills buffer zone, it is essential to limit human impact on these sensitive environments. By controlling access to vital water sources and implementing effective waste management systems, plastic waste can be kept from entering the environment.

Educating locals and tourists about the dangers of plastics, promoting reusable and biodegradable alternatives, and conducting routine monitoring and clean-up efforts in collaboration with wildlife protection agencies will help reduce MPs pollution. Additionally, natural filtration systems such as wetlands and riparian zones can play a crucial role in trapping and filtering MPs before they enter water bodies. Through these combined efforts, we can ensure the health of the ecosystem while providing animals with clean, high-quality drinking water.

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Compliance with Ethical Standards: This article does not contain any studies involving human or animal subjects.

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