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Original Article

Presence of Microplastic in Bottom Sediments of the Bach Hac River in Phu Tho Province, Vietnam

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Abstract: Microplastic pollution has been one of the alarming environmental problems globally due to its widespread distribution and potential health risks. Rivers are considered one of the main pathways for microplastics receiving and transporting from land to the oceans. Furthermore, sedimentary environments are considered the main reservoirs of microplastics in the aquatic environments. This study was conducted to evaluate the distribution of microplastics in bottom sediment samples collected at Bach Hac River, Phu Tho, Vietnam. Visual verification and chemical identification of microplastics were performed using a µFT-IR spectrometer using a Nicolet iN10 MX Infrared Imaging Microscope. The results found microplastics present in all sediment samples. The concentrations of microplastics detected were in the range of 798.08 – 1454.3 microplastics/kg of dry sediment. The most detected major polymer type was Polyethylene Terephthalate (PET), accounting for 60% of the total polymers found. The most common shape of detected microplastic was fragments (72.02%). Most of the detected microplastics were small in size (20- 150 µm), accounting for 81.80%. The findings from this research could contribute to the database about microplastic pollution in Vietnam and toward the assessment of the potential ecological impacts of microplastics.

Keywords: Microplastics, Polymers, Sediment, µFT-IR spectroscopy.

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1. Introduction

Over the past decade, plastic waste has become a serious problem worldwide [1]. Plastic products were once hailed as a scientific wonder for their durability, lightness and corrosion resistance, making them suitable for a variety of applications, but have now become a threat to the environment globally [2, 3]. Along with widespread production and consumption, the accumulation of plastic waste is increasingly serious due to poor waste management, leading to abundant plastic in nature [1]. Large plastic debris can be partially removed from the environment, but small plastic debris (<5 mm), often referred to as microplastics, is difficult to remove [4]. Therefore, microplastics are posing significant risks to the ecosystem.

Microplastics are plastic pieces or fibers smaller than 5 mm in size, divided into two groups including primary and secondary microplastics [5]. Primary microplastics are released directly into nature and originate from skin care products, industrial waste, etc. Secondary microplastics originate from the fragmentation of large plastic fragments through chemical, physical and biological processes [3]. Microplastics are found worldwide, from water, sediment, and soil to air. Due to their small size, microplastics easily enter the food chain and accumulate at higher ecological levels, causing negative effects on the ecosystem [1]. Currently, worldwide there are many studies on microplastics in different environments, including microplastics in bivalves.

In Vietnam, assessing the presence of microplastics in environmental matrices such as water, sediment, organisms, etc. has been of interest to the scientific community in recent times. However, research on microplastics in river sediments is relatively modest [6-8]. This is considered a transition area, receiving and transporting microplastics from land sources to the ocean. Therefore, it is necessary to continue and expand the scope of research to evaluate microplastic pollution on this subject.

In this study, the research team conducted a survey and collected bottom sediment samples at the Bach Hac River confluence, Viet Tri city to evaluate the presence of microplastics. The Bach Hac junction is the gateway to the intersection of three rivers: Da river, Lo River and Red River. Bach Hac Ward is a community tourism, cultural, and agricultural experience destination, with 2,406 households and nearly 8,000 people. Due to favorable terrain, 60% of the local population mainly travels by waterway, fishing, repairing boats... the rest work as small traders, agricultural and industrial zones. So far there is little research data information on microplastic pollution here. Therefore, this study aims to investigate the presence of microplastics in sediments in this area and along with that provide a science basis for assessing microplastics in other environments.

2. Materials and Methods

2.1. Sampling Site

N°	Sampling	Latitude (°N)	Longtitude (°E)
1	VT1	21°16'35.6"	105°25'41.5"
2	VT2	21°16'35.6"	105°25'41.5"
3	VT3	21°16'35.6"	105°25'41.5"
4	VT4	21°16'35.6"	105°25'41.5"
5	VT5	21°16'35.6"	105°25'41.5"

Figure 1. Information of sampling sites.

Sediment samples were collected from five locations (Figure 1) in the Bach Hac River area in April 2023. Samples were collected using a Wildco deep-water sediment sampler (model: 3-1725-F50, USA) at a depth of 5-7 meters, which is the average depth of the Bach Hac River, suitable for representing sediment samples in this area. Samples were collected in 1 day, each sampling location was repeated 3 times. The weight of samples collected from each location ranged from 2-3 kg. The weather did not affect the sampling too much because this was a deep sediment sample. After collection, the samples were stored in silver zip bags, stored at 4 ºC and transferred to the laboratory of the Institute of Energy and Environmental Science and Technology, Vietnam Academy of Science and Technology for analysis and evaluation.

2.2. Microplastic Extraction

The entire analysis process is performed in an airtight environment. Before analysis, the sediment sample was dried at 60 ºC for 48 to 72 hours in an oven until the sample reached a constant weight. The process of extracting microplastics from sediment samples was performed based on the method of Yang et al., [9]. The sample mass weighed 10 grams and was placed in a 250 mL glass beaker. Add 40 mL of Hydrogen peroxide (H_2O_2, Merck) solution to the beaker. Then, the beaker was placed on a hot plate and heated at 60 ºC for eight consecutive hours. After finishing the digestion process, the sample was allowed to cool naturally, and Zinc chloride ($ZnCl_2$, Merck) solution (d=1.7-1.8 g/cm^3) was added to separate the density. After adding the salt solution to the sample cups, they were placed on a continuous magnetic stirrer or stirred with a glass rod continuously for 1 to 2 minutes. Then, let the sample settle and separate the density for 12 hours. The sample was separated by flotation and filtered with a Sartorius 6-branch vacuum filter system, using cellulose nitrate filter paper with pore diameter = 0.45 µm (Sartorius, Germany). Repeat the process three times to optimize the efficiency of the density separation step. The filter paper obtained after filtration is placed in a glass petri dish and allowed to dry naturally at room temperature to prepare for the following analysis step.

Analysis of microplastic properties in terms of shape, size, density, and types of microplastic polymers by Fourier transform infrared spectroscopy µFTIR using an infrared microscope (Nicolet iN10 MX, Thermo Scientific, America). FTIR spectra of the particles were recorded in the spectral range from 4,000 to 650 cm-1 with an acquisition time of 3 seconds and 16 co-scans for each measurement in transmission mode. The spectral resolution is 8 cm^{-1}, and the aperture size ranges from 50 x 50 µm to 150 x 150 µm depending on the particle size. The Particle Wizard software in the machine performs an integrated process to count the number of particles and size (area, length and width) based on images and determine the polymer type of microplastics based on spectral comparison obtained with the original spectral library. Spectral comparison results with agreement ≥ 85% are accepted. Shape Plastic is determined based on the ratio between the length (L) and width (W) of the microplastic [10]. In this study, microplastics with L/W ratio ≥ 4 are classified as fibers, 1 < L/W <4 are considered flakes, and granules have L/W ratio = 1.

2.3. Data Analysis

After being analyzed, screened, and processed according to statistical methods, microplastic data is graphed using MS Excel software. Results are expressed as mean ± standard deviation. The density of microplastics in soil samples based on dry weight is calculated according to the following formula:

$$C = \frac{n}{M} \times 1000$$

Where: C is the concentration of microplastics (microplastics/kg dry weight); n is the number of microplastic particles determined in the sample; M is the mass of the dry soil sample analyzed (g).

3. Results and Discussion

3.1. Concentrations of microplastics

Microplastic concentration at sampling locations was shown in Figure 2. The order of distribution of microplastic concentration in sediment samples was shown as VT1 (1454.3 ± 107.06 MPs/kg dry weight) > VT2 (1304.3 ± 62.04 MPs/kg) > VT3 (1265.6 ± 125.73 MPs/kg) > VT4 (798.55 ± 86.45 MPs/kg) > VT5 (798.03 ± 99.76 MPs/kg). The locations with the lower microplastic concentration, VT4 and VT5, have the common characteristic of having lower waterway traffic density than locations VT1, VT2 and VT3. Sampling location VT5 is located at the end of the Lo River flowing into the Bach Hac River junction, and sampling location VT4 is located at the end of the Bach Hac River junction. Locations with higher detected microplastic concentrations, such as VT1, 2 and 3, are all located in the center of the Bach Hac River junction. In addition to the high density of waterway traffic, the daily activities of local people in these locations often occur on the river. Factors related to traffic and daily activities significantly impact the concentrations of microplastics in river sediments in the Bach Hac River junction area.

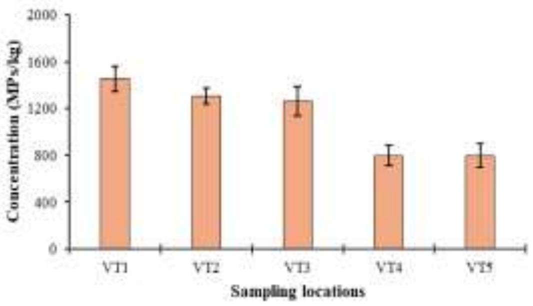

Figure 2. Microplastics concentration in river sediment samples.

3.2. Morphology of Microplastics

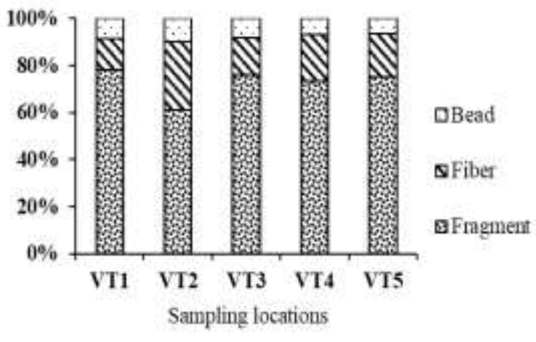

Figure 3. Shape distribution of microplastic in river sediment samples.

The detected microplastic morphology at the Bach Hac River confluence area includes fibers, fragments and beads. The percentage of plastic shapes detected at the research locations is shown in Figure 3.

In this study, fragments microplastics were detected, accounting for the highest proportion of 72.02% of the total detected microplastics. Detected particulate matter was the lowest and accounted for only 8.4%. Although fibers are considered the familiar shape of microplastics, the fragment form appeared the most in this study. Some other studies also have similar results, according to a survey by Thom et al. at Da Nang Beach, fragments account for 76% of the total microplastics [11]. At the Bach Dang estuary of the Red River, Nghi et al., also discovered microplastic fragments accounting for 77% of the total microplastics found in the study[12].

Secondary microplastics are mainly derived from the breakdown of large plastic waste through photodegradation and other weathering mechanisms [13]. They are mainly found in the form of fragments and fibers [14]. Granular or primary microplastics are widely used in daily human life, including in household appliances, clothing, construction, chemicals, and agriculture. They are also widely used in the electrical, telecommunications, automobile manufacturing and medical equipment industries. As a difficult-to-decompose material, plastic beads decompose slowly once they enter the environment.

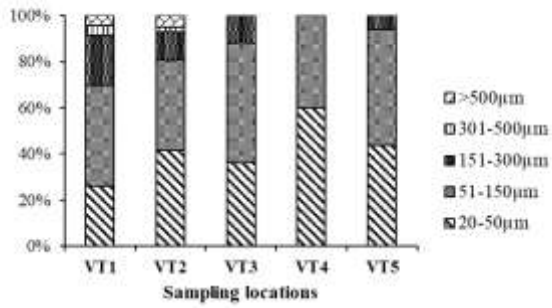

Figure 3. Size distribution of microplastic in river sediment samples.

The size of micro plastics in this study ranged from 22.4 – 1574 µm. The research team divided the sizes of microplastics into five ranges, shown in Figure 4.

The sizes of microplastics are mainly concentrated in groups of 20-50 µm and 50-150 µm. The percentage of plastic particles sized from 300-500 µm is the lowest, accounting for 2.09% of the total microplastics in the study. The largest size group of microplastics is from 50 - 150 µm, accounting for 44.05%.

3.3. Polymer Composition of Microplastics

In this study, the authors discovered eight types of polymers of microplastics. Among them, the group that discovered polyethene terephthalate (PET) accounted for the most at 60%, followed by nylon at 11%. Cellophane is the least detected polymer, accounting for only 1% of all detected microplastics. The presence of PET in the most detected polymers is consistent within the study area. PET is widely used to make plastic drinking bottles and disposable plastic products due to its durable, flexible and heat-resistant structure. In the Bach Hac River Junction area, not only residential areas, bustling boating activities, butalso cultural tourism area are somewhat related to the presence of PET. The pie chart of the percentage of detected polymers is shown in Figure 5.

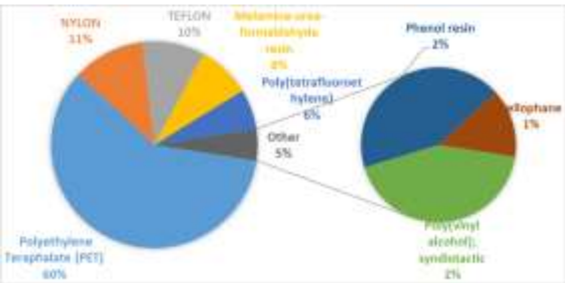

Figure 4. Polymer composition of microplastics in river sediment samples.

The application characteristics of some polymer types include PET, which is used to produce water bottles, nylon in book bags, and furniture packaging materials. Urea-formaldehyde cond (UF) polymers are materials used in the production of complex and shiny surfaces such as toilets. Phenol resin (PF) is known as the first commercial resin. They are used to produce moulded products such as billiard balls, laboratory countertops, and coatings and adhesives. Nylon polymers have significant commercial applications in fabrics and fibres (clothing, flooring and rubber reinforcement), in shapes (moulded parts for automobiles, electrical equipment, etc.) and in films (mainly used for food packaging). Cellophane (CP) is a cellophane used primarily in packaging materials. Poly (tetrafluoroethylene) and teflon have similar properties; they are used as non-stick substances, kitchen utensils, chemical containers and pipes. Poly(vinyl alcohol), also abbreviated as PVA, is an environmentally friendly polymer often used as packaging films and agricultural products.

Some studies on microplastics in sediments, such as Da et al, have discovered five types of Polymers in the Ba Lat estuary: PA, PE, PS, PP and PU [6]. Thom et al., discovered 16 types of polymers on beaches in Da Nang, of which PA or Nylon was the most detected [11]. In river sediment samples in Shanghai, seven types of polymers were also detected, of which Polypropylene (PP) was the most commonly detected polymer. In another assessment of the Yangtze River, Peng et al also discovered six different polymers [14]. The results of different studies show heterogeneity in the types of polymers detected. Factors that greatly influence the appearance of microplastics can be the production activities of factories, aquaculture activities of people, and people's awareness of transporting and dumping, dispose of waste. In addition, river flows and natural disasters also affect the appearance and accumulation of microplastics in river sediments.

Some microplastic peak images scanned with a µFTIR infrared microscope are shown in Figure 6. The blue spectrum is the original spectrum in the µFTIR machine's spectrum library, and the red spectrum is the spectrum of microplastics obtained from the environment.

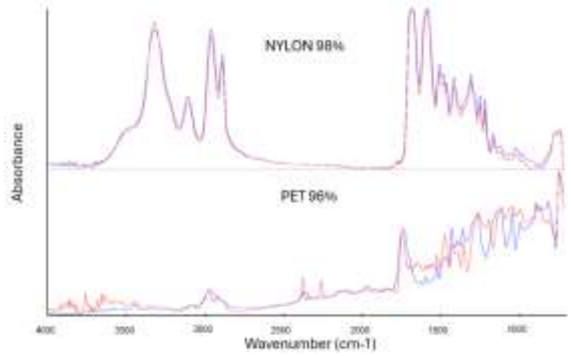

Figure 6. An infrared spectrum of some polymers using µFTIR microscope.

In general, at the Bach Hac River confluence, there is a high density of people living in industries that mainly rely on water. Hence, the influence of daily activities on the concentrations of microplastics in sediment is quite significant. In addition, this is the intersection of large river branches and high traffic density, so conducting a microplastic survey at the Bach Hac River confluence area is a scientific basis for continuing to develop research to evaluate factors affecting the accumulation of microplastics in river sediments.

4. Conclusion

Sediment samples collected from sampling locations in the Bach Hac River confluence area all have rich and different microplastic concentrations. At locations in the centre of the Bach Hac River confluence, places near residential areas and activities on the river, microplastic concentrations levels are higher than in the remaining places. In this study, the average microplastic concentrations in the Bach Hac River confluence area is 1124.2 ± 295.26 MPs/kg dry weight. The shape of microplastics is mainly in pieces; the size of microplastics detected ranges from 22.4 µm – 1574 µm. The study discovered eight types of polymers, the most common being PET. Although there are no regulations on the level of microplastic pollution in the environment, the results from this study will contribute to the scientific basis for continuing to conduct further assessments of the impact of microplastics on the environment, animal and human health.

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References

[1] A. Cózar, F. Echevarría, J. I. G. Gordillo, X. Irigoien, B. Úbeda, S. H. León, Á. T. Palma, S. Navarro, J. G. D. Lomas, A. Ruiz, M. L. F. D. Puelles, C. M. Duarte, Plastic Debris in the Open Ocean, Vol. 111, No. 28, 2014, pp. 10239-10244, https://doi.org/10.1073/pnas.1314705111.

[2] A. Lusher, P. hollman, J. Mendoza, Microplastics in Fisheries and Aquaculture: Status of Knowledge on Their Occurrence and Implications for Aquatic Organisms and Food Safety, 2017.

[3] J. Ding, S. Zhang, H. Zou, Y. Zhang, R. J. E. Zhu, E. Sciences, Occurrence, Sourcea and Ecotoxicological Effect of Microplastics in Freshwater Environment, Vol. 26, No. 9, 2017, pp. 1619-1626.

[4] A. S. Tagg, M. Sapp, J. P. Harrison, J. J. Ojeda, Identification and Quantification of Microplastics in Wastewater Using Focal Plane Array-Based Reflectance Micro-FT-IR Imaging, Analytical Chemistry, Vol. 87, No. 12, 2015, pp. 6032-6040, https://doi.org/10.1021/acs.analchem.5b00495.

[5] R. C. Thompson, Y. Olsen, R. P. Mitchell, A. Davis, S. J. Rowland, A. W. G. John, D. McGonigle, A. E. Russell, Lost at Sea: Where Is All the Plastic?, Vol. 304, No. 5672, 2004, pp. 838-838, https://doi.org/10.1126/science.1094559.

[6] N. D. Le, T. T. H. Hoang, T. T. Duong, N. N. Phuong, P. T. Le, T. D. Nguyen, T. X. B. Phung, T. M. H. Le, T. L. Le, T. H. Vu, T. P. Q. Le, Microplastics in the Surface Sediment of the main Red River Estuary, Vietnam Journal of Earth Sciences, Vol. 45, 2023, pp. 19-32, https://doi.org/10.15625/2615-9783/17486.

[7] T. T. Duong, D. N. Thuy, N. N. Phuong, H. M. Ngo, T. O. Doan, T. P. Q. Le, H. M. Bui, H. N. Van, T. N. Dinh, T. A. N. Nguyen, T. T. N. Cao, T. M. H. Pham, T. H. T. Hoang, J. Gasperi, E. Strady, Microplastics in Sediments from Urban and

Suburban Rivers: Influence of Sediment Properties, Science of the Total Environment, Vol. 904, 2023, pp. 166330, https://doi.org/10.1016/j.scitotenv.2023.166330.

[8] H. Phu, H. T. N. Han, N. L. N. J. V. J. H. Thao, Plastic Waste, Microplastics in the Saigon–Dong Nai River Basin, The Risk of Impacts on the Health of People, Vol. 736, No. 1, 2022, pp. 14-27, https://doi.org/10.36335/VNJHM.2022(736(1)).14-27.

[9] J. Yang, R. Li, Q. Zhou, L. Li, Y. Li, C. Tu, X. Zhao, K. Xiong, P. Christie, Y. Luo, Abundance and Morphology of Microplastics in an Agricultural Soil Following Long-Term Repeated Application of Pig Manure, Environmental Pollution, Vol. 272, 2021, pp. 116028, https://doi.org/10.1016/j.envpol.2020.116028.

[10] M. Kooi, A. A. Koelmans, Simplifying Microplastic Via Continuous Probability Distributions for Size, Shape, and Density, Environmental Science & Technology Letters, Vol. 6, No. 9, 2019, pp. 551-557, https://doi.org/10.1021/acs.estlett.9b00379.

[11] D. T. Thom, B. V. Hoi, D. T. Manh, L. T. Thao, N. Duy, L. V. Ky, H. T. Hao, T. T. Hang, D. V. Manh, Characteristics of Microplastics in Sediment at Danang Beaches - Vietnam, Journal of Science and Technology: Engineering and Technology for Sustainable Development, Vol. 33, 2023, pp. 42-48, https://doi.org/10.51316/jst.170.etsd.2023.33.5.6

[12] T. N. Duong, H. N. Dinh, T. C. K. Le, E. Strady, T. M. H. Bui, D. C. Le, H. T. Nguyen, T. L. Duong, Assessment of Microplastic Pollution in the Environment of the Bach Dang Estuary in the Red River System of Vietnam, Vietnam Journal of Chemistry, Vol, 58, 2020, pp. 140-146 (in Vietnamese).

[13] N. D. T. Cao, D. H. T. Vo, M. D. T. Pham, V. T. Nguyen, T. B. Nguyen, L. T. Le, H. Mukhtar, H. V. Nguyen, C. Visvanathan, X. T. Bui, Microplastics Contamination in Water Supply System and Treatment Processes, Science of the Total Environment, Vol. 926, 2024, pp. 171793.

[14] L. L. Thy, N. K. Qui, N. P. Thao, D. C. Hung, B. X. Thanh, H. N. Bich, N. D. Long, Microfibers in Laundry Wastewater: Problem and Solution, Science of the Total Environment, Vol. 852, 2022, pp. 158412.

[15] Y. Li, Z. Lu, H. Zheng, J. Wang, C. Chen, Microplastics in Surface Water and Sediments of Chongming Island in the Yangtze Estuary, China, Environmental Sciences Europe, Vol. 32, No. 1, 2020, pp. 15.