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Foreword

In an era where technology and artificial intelligence (AI) are rapidly reshaping scientific disciplines, the fields of the Earth and environmental sciences, and geotechnical engineering are experiencing unprecedented advancements. This book, *Advanced Technologies and Artificial Intelligence in the Earth and Environmental Sciences*, marks the inaugural volume in the series *Advances in the Earth, Mining and Environmental Sciences for Safe and Sustainable Development*. It features a selection of high-quality research papers presented at the GeoAI2024 International Conference.

This publication represents the collaborative efforts of VNU University of Science, Vietnam National University, Hanoi, the Interdisciplinary Professor Council of the Earth and Mining Sciences, and a broad network of esteemed institutions and organizations, including the Vietnam Union of Geological Sciences, Vietnam Association of Engineering Geology and Environment, Institute of Geological Sciences - Vietnam Academy of Science and Technology, Norwegian Geotechnical Institute, Vietnam Atomic Energy Institute, Hanoi University of Mining and Geology, and Dong Nai Technology University. The support and cooperation of these institutions have been instrumental in bringing this volume to fruition.

This book represents a focused exploration of the transformative role of technology and AI in addressing critical challenges in sustainability and environmental resilience. The content is organized into three thematic sections:

Part 1: Earth Technology and Geotechnical Engineering

This section explores innovative methods for addressing geotechnical and geological challenges with a focus on sustainability, resilience, and safety. The studies of this part demonstrate how modern technologies and engineering can advance infrastructural development while minimizing environmental risks.

Part 2: Environment and Recycled Materials

This section addresses environmental challenges through creative approaches, including pollution control, resource recovery, and sustainable materials. The research in this part highlights innovative ways to restore and protect the environment, contributing to a more sustainable future.

Part 3: Digital Transformation and GeoAI

The final section demonstrates the transformative power of AI, machine learning, and digital technologies in the Earth and environmental sciences. Contributions cover a wide spectrum of applications, including IoT-based environmental monitoring and AI-assisted disaster detection. This section exemplifies the role of GeoAI in reshaping our

understanding of natural processes and improving decision-making for sustainable development.

We express our sincere gratitude to the authors, researchers, and practitioners whose works have shaped this volume. Special thanks go to the GeoAI2024 International Conference, which provided a vibrant platform for collaboration, innovation, and knowledge exchange. The collective efforts of contributors and organizers have ensured that this book captures the forefront of technological innovation in the Earth and environmental sciences.

This volume aims to inspire researchers, practitioners, and policymakers, encouraging them to explore and implement advanced technologies and AI in tackling some of the most pressing challenges of our time. As the inaugural volume in the book series, it sets the stage for future explorations into the intersections of the Earth and environmental sciences.

We hope the insights shared in this book will contribute to advancing global efforts toward safe and sustainable development.

Editorial Board

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Microplastics distribution in surface water and water column at Cai River estuary (Khanh Hoa) in rainy season 2023

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Abstract: Microplastics are plastic particles smaller than 5 mm in size that have become a global environmental problem due to the accumulation of plastic debris in water bodies over decades. 12 water samples (06 water column and 06 surface water samples) at the Cai River estuary (Khanh Hoa) were collected and analyzed to determine the quantity, shape, color and size of microplastics by using a microscope. The results showed that microplastics were present in all samples but were not consistent between two groups of surface water and the water column, ranged from 89 to 432 MPs/L. For surface water samples, the microfoam predominates with 63.91% and the microfiber is 32.28%. On the contrary, in the water column sample, the microfiber reached the highest value is 55.84% and microfoam only accounted for 36.87%. The remaining two forms are microfragment and some other shapes ranging from the lowest of 0.57% (surface water samples) to 5.17% (water column samples) in the two sample types. The white color predominates and found in approximately 50.7% and 44.3% for surface water and water column samples, respectively. The second most popular color is blue, followed by green, red and several other colors. The ratio of these colors in surface water and water column samples is 26.5, respectively; 15.6; 3.4; 3.8% and 31.3; 17.6; 4.3 and 2.5%, respectively. The size 20-50 μm accounts for the highest proportion for

water column samples (415 MPs/liter) and in the range of 50-150 μm for surface water samples (338 MPs/liter). The source of these microplastics is mainly from residential activities and services on both banks. It is necessary to have appropriate resource and environmental management solutions for plastic emission sources in coastal estuaries in the near future.

Keywords: Microplastic pollution, estuary, water surface, water column.

Introduction

Plastic is a general term for synthetic or semi-synthetic amorphous solid materials. Plastics are usually high molecular weight polymers and may contain other compounds to improve performance or reduce costs. The plastic industry uses codes to identify and classify plastics into several major plastic groups such as low-density polyethylene (LDPE), high density polyethylene (HDPE), polypropylene (PP), polyvinyl chloride (PVC), polyethylene terephthalate (PET), etc. (Besseling, 2018). With superior properties and low production costs, the total plastic production in over the world has increased continuously every year. The plastics waste decomposes into microplastics which accumulated in water, sediments, organisms and affecting the

environment, ecosystems and above all human health (Andrady, 2009).

Microplastics are fragments of any type of plastic less than 5 mm (0.20 in) in length, according to the U.S. National Oceanic and Atmospheric Administration (NOAA) and the European Chemicals Agency. They cause pollution by entering natural ecosystems from a variety of sources, including cosmetics, clothing, food packaging, and industrial processes (NOAA, 2009; ECHA, 2020). Microplastics are divided into two groups: primary microplastics and secondary microplastics. Rivers are a significant contributor to microplastic pollution in the oceans due to their connection to the sea. It is estimated that about 80% of marine waste in Vietnam comes from land-based activities. Infact that is 112 coastal estuaries stretching from North to South where plastic waste flows into the ocean and poses many potential risks that impact the quality of the aquatic ecological environment in the estuary area (Jambeck et al., 2015).

Many studies in Vietnam have been conducted to assess microplastic pollution in the aquatic environment (Lahens et al., 2018; Nguyen et al., 2019; Strady et al., 2020), but published studies about toxicity of microplastic in the coastal

estuary of the South-Central Coast are still quite limited. Therefore, assessing the microplastic pollution in the aquatic environment at the Cai River estuary (Khanh Hoa) is necessary, as a basis for further scientific research.

Methodology

Sampling area

Khanh Hoa is a coastal province, located in the center of the South-Central Coast region and has 3 large river systems: Cai Nha Trang River, Dinh Ninh Hoa River, To Hap River and other independent small rivers and streams. The Cai River is the largest inter-provincial river basin in Khanh Hoa province with a basin area of 1,732 km² and a length of 84 km (Nguyen et al., 2014). Because it flows through many areas with many different socio-economic activities, the amount of waste from these basins flowing into the Cai River mouth is also very large in quantity and complex in composition (Department of Science and Technology of Khanh Hoa province, 2004). 6 sampling points (Figure 1) from Kim Bong River towards Nha Trang Bay are locations with many waste sources or activities related to the discharge of plastic waste.



Figure 1. Sampling area at Cai River estuary (Khanh Hoa)

Sampling method

The process of collecting microplastics in surface water and water column was based on published

methods (NOAA, 2015; Silva, 2018). Neuston nets (with mesh size of 300 μ m) were attached to a water collection box or a Manta trawl (dimensions L x W x H = 30 x 30 x 15 cm) with a flow meter to

calculate the amount of water collected when microplastics through the net. The sampling tools were anchored to the boat at the sampling locations and the water collection box was floated on the water surface to collect all solids floating on the surface water and water column including plastic waste and other solids. The Neuston net was released for 30 minutes. The sampling time was during the rainy season of 2023 at the ebb tide. Samples were stored at 4°C in dark bottles and transported to the laboratory on the same day.

Analytical method

The samples were brought to the laboratory for analysis, microplastic in sediments were treated according to the published method of Masura et al. (2015). The analysis procedure is summarized in the following diagram (Figure 2).

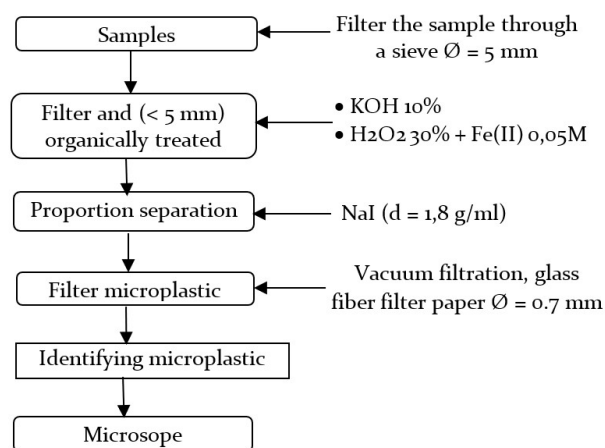


Figure 2. Sample analysis procedure for microplastic in water sample

Calculation data

The data in the study were statistics using software such as GraphPad 6 and Excel 2010. The volume of water pulled through the net will be recorded on the flow meter. The density of microplastics is calculated according to the following formula:

$$C = \frac{n}{V}$$

where is

C: Microplastic density (fragments, fibers, particles/m³);

n: Number of microplastic in the sample (fragments/fibers/particles);

V: volume of water filtered through the mesh (m³).

Results and discussion

Results of microplastic classification by quantity

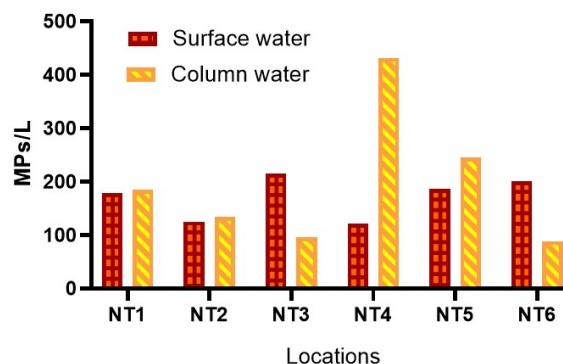


Figure 3. Results of microplastic classification by quantity in surface water and water column samples at Cai River estuary (Khanh Hoa)

The results in Figure 3 showed that all 6 sampling locations have the presence of microplastics. The total number of microplastics by quantity ranges from 89 to 432 MPs/liter. The lowest density of microplastics was recorded at location NT6 for water column samples and NT4 for surface water samples (89 and 121 MPs/liter, respectively). The highest value was observed at location NT4 for water column samples and NT3 for surface water samples (432 and 215 MPs/liter, respectively).

Results of microplastic classification by size

The collected microplastics were classified into size groups including 20-50, 50-150, 100-300, 300-500 and > 500 µm (Table 1). Small microplastics in the range of 20-50 µm accounted for the highest proportion for water column samples (415 MPs/liter) and in the range of 50-150 µm for surface water samples (338 MPs/liter). Large microplastics > 500 µm accounted for the smallest proportion, reaching total values of only 85 and 83 MPs/liter for water column and surface water samples, respectively. In the water column sample, location NT4 obtained the highest value 170 MPs/liter (at the smallest size 20-50 µm) and size > 500 µm was not detected at location NT3. However, in the surface water sample, microplastics were recorded at all locations with different sizes. The highest value was recorded at location NT6 110 MPs/liter (size 50-150 µm) and

the lowest at location NT5 only 2 MPs/liter (size of 20-50 μm).

Results of microplastic classification by shape

Some microplastic shapes such as fiber, particle, fragment and other forms were found at all sampling locations in Cai River estuary. The predominant shape of microplastics such as fibers and particles were observed in all samples under microscopy. However, there was a clear difference

between water column samples and surface water samples. In surface water samples, the particle shape was dominant with 63.91% and the fiber shape was 32.28%. In contrast, in water column samples, the fiber shape was dominant with 55.84% and the particle shape only accounted for 36.87%. The remaining two forms were fragments and some other forms ranging from the lowest of 0.57% (surface water sample) to 5.17% (water column sample) in the two types of samples (Figure 4).

Table 1. Results of microplastic classification by size in surface water (NT_NM) and column water (NT_CN) samples at Cai River estuary (Khanh Hoa)

	20-50 μm		50-150 μm		150-300 μm		300-500 μm		> 500 μm	
Locations	NT_NM	NT_CN	NT_NM	NT_CN	NT_NM	NT_CN	NT_NM	NT_CN	NT_NM	NT_CN
NT1	18	31	76	92	28	32	38	20	18	10
NT2	37	12	26	60	17	20	31	21	10	18
NT3	31	35	15	20	46	20	92	20	33	0
NT4	15	170	57	103	15	32	28	82	9	32
NT5	2	162	63	42	26	8	79	20	8	15
NT6	32	5	101	31	31	36	32	5	5	10
Total	135	415	338	348	163	148	300	168	83	85

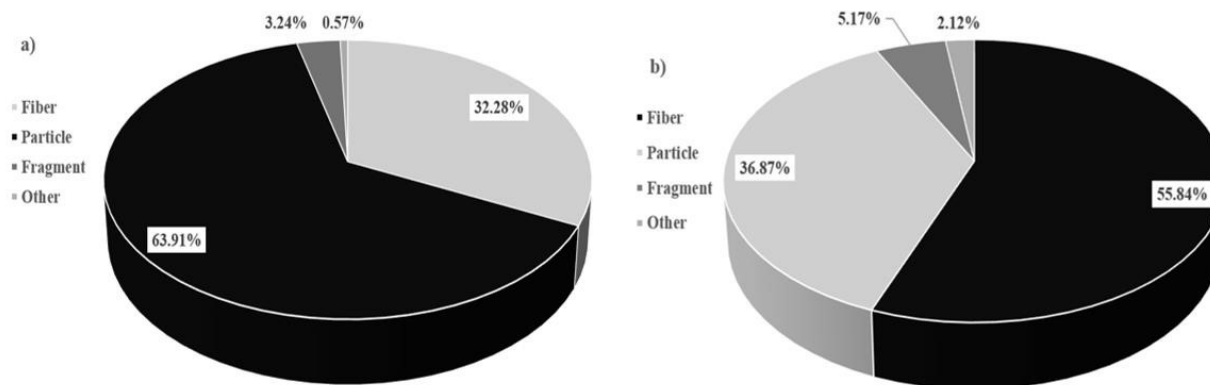


Figure 4. Results of microplastic classification by shape in surface water (NT_NM) and column water (NT_CN) samples at Cai River estuary (Khanh Hoa)

Results of microplastic classification by color

The microplastics found were of various colors (white, red, blue, green and others). Among the classified colors, white color was the most common and consistently present in all sampling locations. Overall, white color accounted for nearly half of the microplastic found, approximately 50.7% for surface water samples

and 44.3% for water column samples. The second most common color was blue, followed by green, red and some other colors. These colors recorded corresponding values in surface water and in water column samples, these proportions accounted off 26.5; 15.6; 3.4 and 3.8% and 31.3; 17.6; 4.3 and 2.5%, respectively (Figure 5).

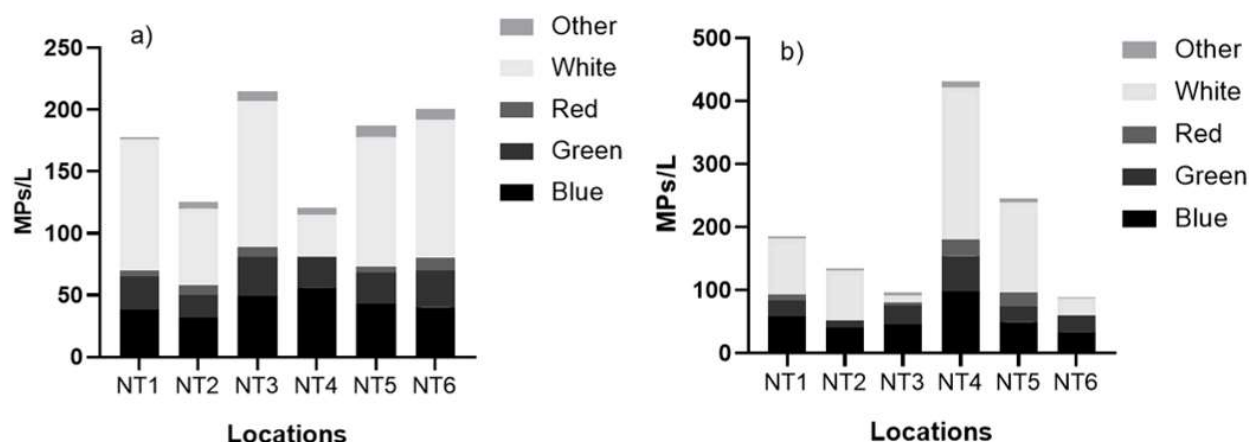


Figure 5. Results of microplastic classification by color in surface water (NT_NM) and column water (NT_CN) samples at Cai River estuary (Khanh Hoa)

The results in Figure 2 showed that the microplastic quantity detected in the river water environment varied significantly between sampling locations and in two types of samples at the Cai River estuary. The microplastic pollution derived from anthropogenic activities so the presence of microplastics in the water environment may be related to discharge sources such as service activities or residential areas. The total of microplastic quantity recorded the largest values of 255 and 235 MPs/liter at location NT5 for water column samples and NT3 for surface water samples. In contrast, the smallest values reached 95 and 130 MPs/liter at location NT6 for water column samples and NT4 for surface water samples. These obtained data showed the heterogeneity of microplastic quantity in the two groups of samples at all 6 surveyed locations.

These results have been recorded in many previous studies (Hernandez et al., 2017; Alam et al., 2019). This heterogeneity may be due to factors such as sampling methods, natural conditions including wind, tides, flow,... and anthropogenic activities in the basin such as wastewater treatment plants, industrial zones and surrounding households (Hernandez et al., 2017). The two sides of the Cai River estuary are adjacent to the sea and the two banks are mainly concentrated with households or hotels, restaurants, tourist areas and fishing villages. This shows that activities in these areas greatly affect the concentration of microplastics in the water environment at the estuary.

Due to their small size, microplastics can pose potential threats to aquatic organisms and ecosystems. Compared to plastic debris, microplastic particles are more likely to harm organisms because they are mistaken for their food (Cole et al., 2014). Furthermore, due to their adsorption properties, plastic debris can be associated with biological processes and accumulate pollutants (Mato et al., 2001; Teuten et al., 2009). When existing for a long time in the environment under the influence of factors such as sunlight, wind, flow rate, etc., large microplastics can decompose into even smaller microplastics. With a size ratio < 300 dominating (Table 1), it showed that the aquatic environment in the study area receives a relatively large source of plastic waste and occurs over a long period of time. Because microplastics can easily be mistaken for food by aquatic organisms (Cole et al., 2014; Avivo et al., 2016), the color of microplastics is also of particular concern in the aquatic environment.

The results of this study are similar to some previous published studies in estuaries areas such as: Pearl River estuary (China), Clyde, Bega and Hunter River estuaries (Australia). Microplastics accumulate more significantly in areas located closer to the estuaries (Luo et al., 2019). High microplastic density was observed in different estuaries around the world: 8902 MPs/m³ (Pearl River estuary, China) (Yan et al., 2019); 98, 246 and 1032 MPs/m³ (Clyde, Bega and Hunter River estuaries, Australia) (Hitchcock et al., 2019).

Several shapes of microplastics were observed in estuaries: fibers, fragments, particles and films with the predominance of fibers and fragments (Luo et al., 2019; Hitchcock et al., 2019). Lenaker et al. (2019) showed that the microplastic

transport cycle from discharge source to estuary, port or reservoir always tends to have concentrations of contaminants in surface layers higher than in water column layers (Lenaker et al., 2019).

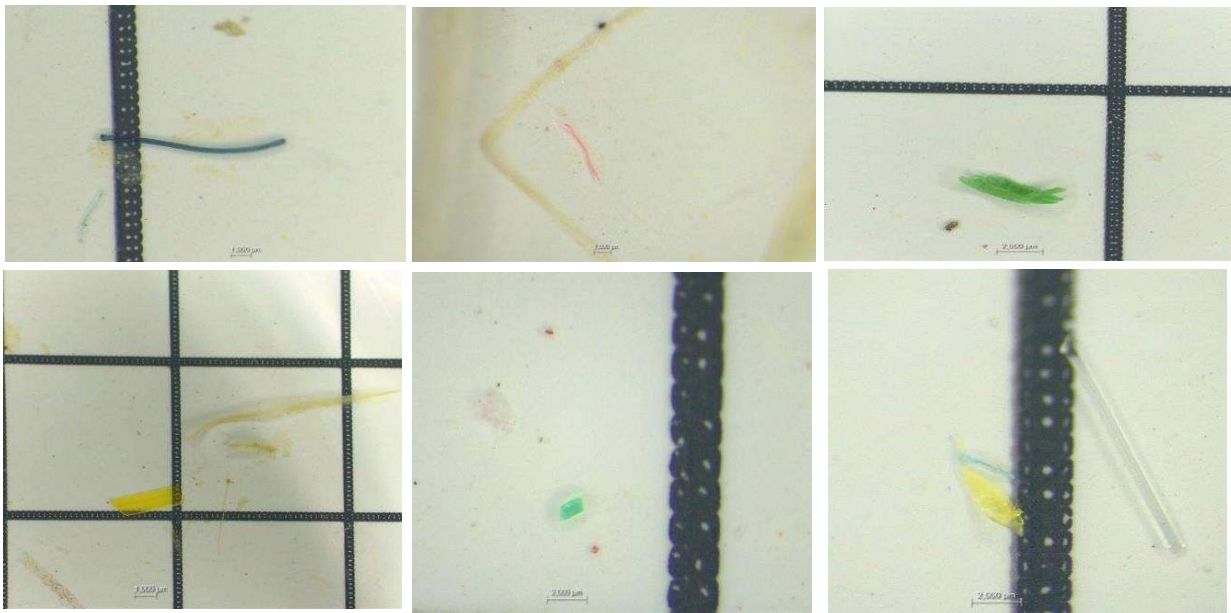


Figure 6. Images of microplastics recorded in surface water and water columns at Cai River estuary (Khanh Hoa) under a microscope (MSZ5000-T-IL-TL, Kruss (Germany), 7-45x)

Conclusion

The study surveyed and collected surface water and water column samples at 6 locations at the Cai River estuary (Khanh Hoa). The characteristics of microplastics were analyzed and compared according to quantity, shape, size and color. The analysis and comparison results showed that all surveyed locations contained microplastics and there was heterogeneity between the two types of samples. Microplastics were small in size, with particle shape dominating in surface water samples and fiber shape dominating in water column samples. The main colors recorded were white, followed by blue, green, red and other colors.

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