HNUE JOURNAL OF SCIENCE
Natural Sciences 2025, Volume 70, Issue 1, pp. 128-139
This paper is available online at http://hnuejs.edu.vn/ns
DOI: 10.18173/2354-1059.2025-0014

NEW DATA ON MICROPLASTICS IN THE SURFACE WATERS AND SEDIMENTS OF THE DAY RIVER ESTUARY, VIETNAM

Cao Thi Thanh Nga[1,2,*], Le Thi Phuong Quynh[2,3] and Duong Thi Thuy[2,4]
[1]*Institute of Human Geography and Sustainable Development, Vietnam Academy of Social Science, Hanoi city, Vietnam*
[2]*Graduate University of Science and Technology, Vietnam Academy of Science and Technology, Hanoi city, Vietnam*
[3]*Institute of Chemistry, Vietnam Academy of Science and Technology, Hanoi city, Vietnam*
[4]*Institute of Science and Technology for Energy and Environment, Vietnam Academy of Science and Technology, Hanoi city, Vietnam*
[*]Corresponding author: Cao Thi Thanh Nga, e-mail: caothithanhnga@gmail.com

Received March 7, 2025. Revised March 25, 2025. Accepted March 31, 2025.

Abstract. The estuary is an intermediate zone that receives water from various sources before flowing into the sea. Over the past few decades, plastics from river estuaries have contributed significantly to marine pollution, raising serious concerns among scientists and authorities worldwide. However, data on plastic pollution in river estuarine regions remain scarce. In Vietnam, the Day River estuary is one of the largest river estuaries flowing into the sea. The results of the present study provide new data on the density, characteristics, and distribution of microplastics in both the surface water and sediments of the Day River estuary. This estuary is heavily polluted with microplastics, with an average density of 564 ± 551.6 microplastics/m³ in the water and 3,636.3 ± 750.6 microplastics/kg in the sediments. The most common microplastic sizes ranged from 300 to 1,000 µm. These microplastics exhibit a wide range of colors, which can be classified into eight distinct groups: black, blue, gray, green, purple, red, white, and yellow. Seven of these groups (black, blue, gray, green, purple, red, and white) were found in the sediments, while six groups (black, blue, purple, red, white, and yellow) were found in the surface waters. Among these, white and black microplastics were the most prevalent in both the surface waters and sediments of the study area. The study results contribute to a more comprehensive understanding of microplastic pollution in estuarine systems in Vietnam.

Keywords: estuary, microplastics, pollution, sediment, water.

1. Introduction

Microplastic pollution has become one of the most pressing environmental issues worldwide. Its origin is linked to the production and consumption of plastic products. Notably, global plastic production has been rising rapidly, from 348 million tons in 2017 to 368 million tons in 2019 [1]. A review indicated that over 8.3 billion tons of plastic were produced and consumed globally between 1950 and 2021, and this amount is projected to double by 2040 [2]. Annually, between 4.8 and 12.7 million tons of plastic enter the marine environment [3]. In the natural environment, plastic is decomposed by various factors that cause it to break into smaller fragments or fibers. These fragments or fibers are categorized into four groups based on size: macro (> 25,000 µm), meso (> 5,000 - 25,000 µm), micro (1-5,000 µm), and nano (< 1 µm) [4], [5]. Microplastics, therefore, refer to plastic fragments or fibers ranging from 1 to 5,000 µm in size. Due to their small size and low weight, microplastics can be easily delivered throughout the environment, persist for extended periods, and accumulate additional pollutants. The increasing accumulation of microplastics has exacerbated environmental pollution. This pollution impacts living organisms, since microplastics can enter the food chain and potentially harm human health [6], [7].

It is estimated that about 50% of plastic products are designed for single-use and are then discarded into the environment. Only a small proportion of plastic waste has been recovered and recycled. Previous studies have shown that plastic waste in Vietnam constitutes about 10 - 12% of household solid waste. In 2019, approximately 2.6 to 2.8 million tons of plastic waste were released into the environment in Vietnam, with an overwhelming portion ending up in water bodies such as rivers, lakes, wetlands, river estuaries, and coastal zones [8].

To date, the origins, emission process, and distribution of microplastics remain insufficiently understood. As a result, conducting a comprehensive assessment of microplastic distribution in the environment remains a challenge. Some studies have shown that up to 80% of plastic in seawater originates from land, and river estuaries are key hotspots for the emission of microplastics from rivers into the ocean [9], [10]. Several studies on microplastics in river estuaries have been conducted in various countries [11]-[17]. However, research on microplastics in Vietnam has primarily focused on a few rivers and lakes within urban areas or agricultural lands [18]-[20]. The issue of microplastic pollution in water and sediment in river estuary regions of Vietnam still receives little attention from scientists and authorities. Additionally, the country still lacks integrated data on the characteristics of microplastics in both surface water and sediment within river estuaries. To address this gap, this study was conducted in the Day River estuary region in northern Vietnam to identify the presence and examine the characteristics (color, shape, and size) of microplastics in the water and sediment of the study area.

2. Content

2.1. Materials and methods

2.1.1. Study area

The Day River estuary originates in Hoa Binh and flows through Hanoi, Ha Nam, and Ninh Binh, eventually flowing into the sea in Ninh Binh Province, northern Vietnam. This estuary plays a crucial role in supplying and regulating water resources for aquaculture and agriculture. In May 2024, we conducted a field trip just before the annual rainy season to collect surface water and sediment samples from the Day River estuary.

Table 1. Co-ordinates of the five study sites

Study site	Co-ordinate
SL1	19°54'26"N; 106°04'25"E
SL2	19°54'58"N; 106°04'25"E
SL3	19°54'46"N; 106°05'06"E
SL4	19°55'23"N; 106°06'11"E
SL5	19°54'21"N; 106°05'16"E

Annually, the estuary region maintains an average water volume, which may be linked to the yearly average concentration of microplastics in both the water and sediment environments in May. Water samples were collected from five selected sites (Table 1). Sediment samples were collected from three sites (SL1, SL3, and SL5), which represent sites on the riverbanks and the joining section between the river and sea (Figure 1).

Figure 1. The sampling sites
(Background map was based on Google Earth Pro)

2.1.2. Sampling and analysis

Sampling and analysis were conducted following Doan et al. (2021) [18], Doan et al. (2023) [19], and Cao et al. (2024) [20]. The water samples from the five sites (SL1, SL2, SL3, SL4, and SL5) were labeled CD1, CD2, CD3, CD4, and CD5. At each site, 50 liters of surface water were collected at 40 cm depth below the river surface using an 80 µm mesh plankton net (5 cm diameter) attached to a flowmeter (General Oceanics) to filter and measure the water volume. Each filtered water sample was transferred to a 500 mL glass bottle and stored at 4 °C until analysis. Sediment samples were taken from a depth of 50 cm at three sites (SL1, SL3, and SL5) and labeled CD6, CD7, and CD8. At each selected site, five sampling spots, approximately 100 m apart from each other, were chosen to collect one kilogram of sediment from each spot using a sediment sampler. The five kilograms of sediment were mixed to obtain a one-kilogram representative sample, which was then wrapped in aluminum foil for preservation and transported to the laboratory for processing and analysis.

Each water sample was processed following the procedure outlined by Strady et al. (2021) [21] and the recommendations of GESAMP [22] to recover microplastics. Specifically, the sample in the glass bottle was passed through a sieve with a mesh size of 5 mm to separate larger particles. The wastewater containing microplastics smaller than 5 mm is retained in the 500 mL glass bottle and then treated with 1 gram of Sodium Dodecyl Sulfate (SDS, Merck®) at 50 °C for 24 hours, followed by biozym SE (protease and amylase) and biozym F (lipase) at 40 °C for 48 hours, and hydrogen peroxide (H_2O_2 30%, Merck®) at 40 °C for 48 hours. After the treatment processes, the sample was filtered through a sieve with a 250 µm mesh size to remove plastic particles smaller than 250 µm. The plastic particles larger than 250 µm were transferred into a clean glass beaker. A saturated NaCl solution (1.18 g/mL) was used to float the microplastics, and this step was repeated at least five times to ensure the complete recovery of microplastics in the sample. Finally, the sample was filtered onto GF/A filter paper (pore size 1.6 µm) using a glass vacuum filter. The filter paper containing the microplastics was stored in sterile glass Petri dishes until observation under a Leica S9 microscope, which was connected to a camera and computer. The size, shape, and color of the microplastics were recorded using LAS® software.

Each sediment sample was dried at 40 °C for 72 hours in a drying oven and then ground into a fine powder. A ten-gram portion of the dried sediment was treated with a 250 mL beaker with the 30% H_2O_2 solution for 4 hours to remove the organic matter. The subsequent steps (sieving, separating, and filtering) were performed following the same procedure as for the water samples.

2.1.3. Microplastic observation

The microplastics were observed using a stereo microscope (Leica S9i) connected to a camera. The observed microplastics were identified based on their criteria following GESAMP [22] and Hidalgo-Ruz et al. (2012) [23]. The shape of the microplastics was classified as fragments and fibers. The color of the microplastics was also determined from observation using the Leica S9i stereo microscope. The size of the microplastics was measured using the LASX® software. In the present study, microplastics were defined as fibers and fragments when their lengths were in the range of 300 - 5000 µm and 45,000 - 2.1 million µm, respectively.

2.2. Results and discussion

2.2.1. Microplastic density

Microplastics were detected in all samples collected from the study area. In surface water, microplastic density ranged from 200 microplastics/m³ to 1,540 microplastics/m³. The highest density was found in the sample CD1, with 1,540 microplastics/m³, while the lowest appeared in the sample CD5, with 200 microplastics/m³. In sediments, the highest microplastic density was found in the sample CD6 (4,400 microplastics/kg), and the lowest appeared in the sample CD8 (2,900 microplastics/kg). The variations in microplastic density across the sampling sites were likely influenced by several factors, including the differing amounts of plastic waste in the environment and the accumulation of microplastics over time and across space (Figures 2, 3) [20].

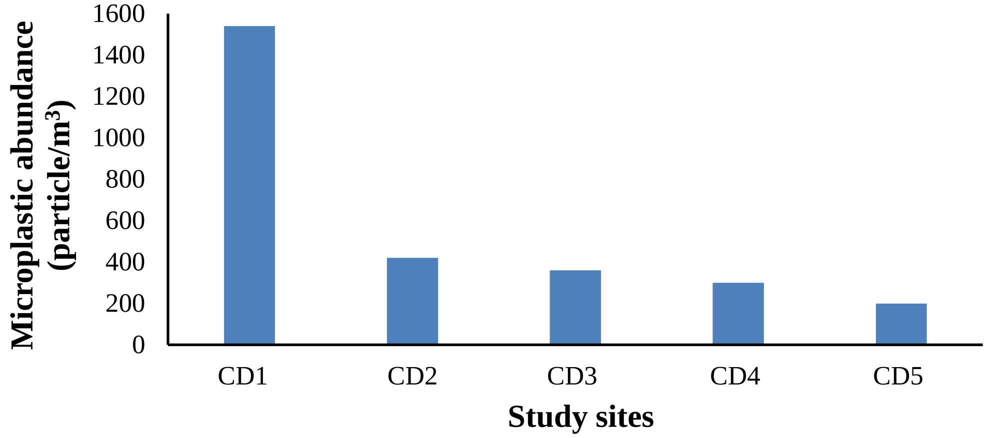

Figure 2. The microplastic density in water

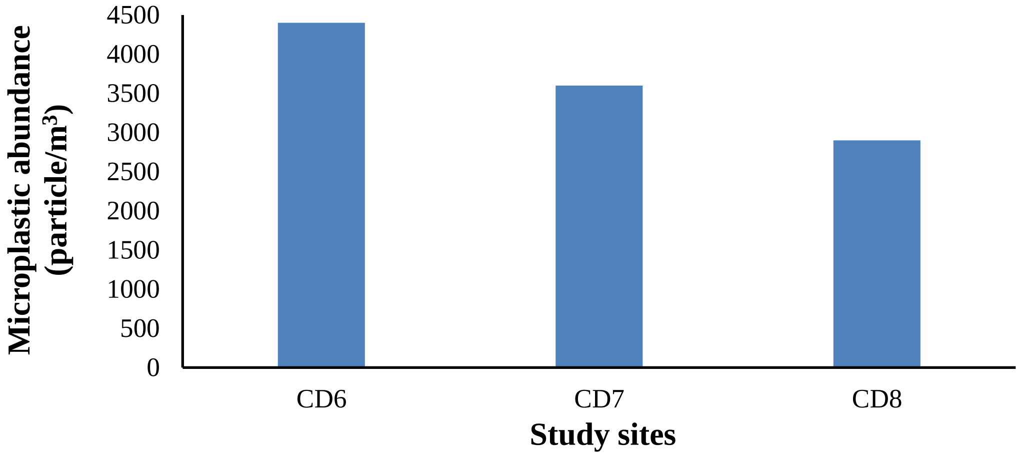

Figure 3. The microplastic density in sediment.

The high microplastic densities in samples CD1 and CD6 suggest that the Day River discharges a vast amount of microplastics into the sea. Both the water sample CD1 and the sediment sample CD6 were collected at the same site, where water from different sources converged before flowing into the sea. The microplastic density recorded in this study was considerably lower than that reported in a previous publication, which recorded plastic densities only in the surface water downstream [18].

The average microplastic density in the water at the Day River estuary was 564 ± 551.6 microplastics/m^3, which is notably higher than that in the estuaries of other rivers in Vietnam, including Thuan An (35 - 175 microplastics/m^3) [24], Dinh (28.4 microplastics/m^3) [21], and Bach Dang (3.42 microplastics/m^3) [25]. It is also higher than that in many river estuaries around the world, such as the Chao Phraya River in Thailand (48 ± 8 microplastics/m^3) [26], the Lawrence River in Canada (120.7 ± 42.2 microplastics/m^3) [11], Delaware Bay in the USA (0.34 ± 0.8 microplastics/m^3) [15], Muttukadu in India (2.75 ± 1.80 microplastics/m^3) [27], Goiana in Brazil (0.26 microplastics/m^3) [28], and the Tamar River in the UK (0.028 microplastics/m^3) [29]. However, this density is much lower compared to that recorded in the estuaries of several rivers, including the Yangtze River in China (4,137.3 ± 2,461.5 microplastics/m^3) [30], the Magallana River in Argentina (16,000 microplastics/m^3) [31], and the Nile River in Egypt (3,760 ± 1,100 microplastics/m^3) [32]. The high microplastic density observed here is likely directly related to the river's capacity to receive waste from human activities [33]. In the Day River estuary, the source of microplastic pollution may be linked to plastic waste from local agricultural activities, such as aquaculture and rice farming [20].

The results of the present study indicated that the Day River estuary accumulates a large amount of microplastics in its sediments, with an average density of 3,636.3 ± 750.6 microplastics/kg. This density is much higher than that in the estuaries of other rivers, including Benoa Bay in Indonesia (31.08 ± 21.53 microplastics/kg) [34], the Thames (118.9 microplastics/kg), Medway (168.4 microplastics/kg), and Blackwater (48 microplastics/kg) in the UK [35], and Muttukadu in India (3.15 ± 1.81 microplastics/kg) [27]. The recorded microplastic density in the sediments is higher than that in the surface water, which is consistent with observations in the Thuan An River estuary [24]. However, this differs considerably from records in the estuaries of two other rivers in China, the Yangtze and Haihe rivers [30], [36], where the microplastic density in sediments is lower than in surface water. This suggests that the deposition of microplastics in sediments or their suspension in the water column is a complex process, influenced by various factors such as the characteristics of the microplastics, river flow rates, and other environmental conditions [37].

2.2.2. Shapes, colors, and sizes of the observed microplastics

Fibers and fragments were the two types of microplastics observed in the study samples. Among these, fiber microplastics were dominant in both the water and sediment samples. In total, 235 microplastics were observed across both water and sediment samples, with only three microplastic fragments found in all the samples. Remarkably, almost all the microplastics observed were fibers, and the fragments were only present in the sediment samples from the study region. The proportion of fiber microplastics in the Day River estuary is similar to that reported in other studies worldwide [12], [13], [30], [32].

Numerous studies have shown that fiber microplastics are found in bivalve species, which partially demonstrates the harmful impact of microplastics on organisms within the material cycle [38], [39].

The fiber microplastics observed in this study varied widely in size, with an average size of 851.4 ± 113.8 µm in surface water and 1,044 ± 78.1 µm in sediment (Figures 4, 5). Almost all of the observed microplastics were smaller than 1,000 µm. These size distributions and proportions are similar to those reported in a previous study by Doan et al. (2021) [18].

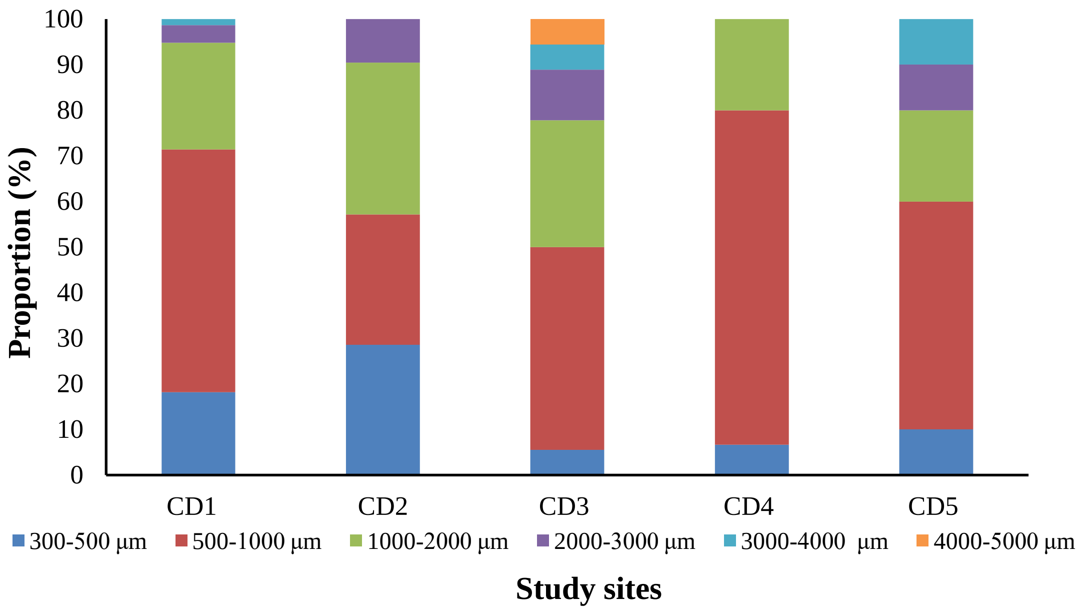

Figure 4. The size distribution of microplastics in surface water

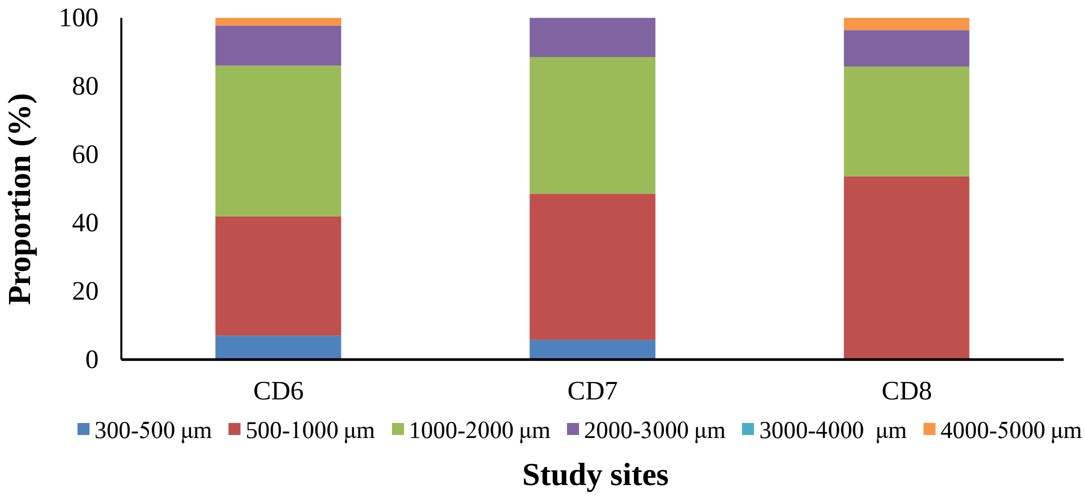

Figure 5. The size distribution of microplastics in sediment

Sunil et al. (2024) found that microplastics smaller than 1,000 µm accounted for 75% of the total microplastics observed in the coastal belt of the Arabian Sea [12]. The sizes and distribution of microplastics in this study are similar to those reported in several previous studies worldwide [11], [14], [31], [34]. Smaller microplastics tend to move more quickly in water and air [40]. The increasing presence of small microplastics in the environment raises concerns about their potential accumulation in the food chain [41], [42].

The microplastics in the studied water and sediment samples were classified into eight color groups: black, blue, gray, green, purple, red, white, and yellow. Seven of these color groups were found in the sediment, while only six were observed in the water (Figures 6, 7). These findings suggest that white plastic products are most commonly used in the Day River estuary region.

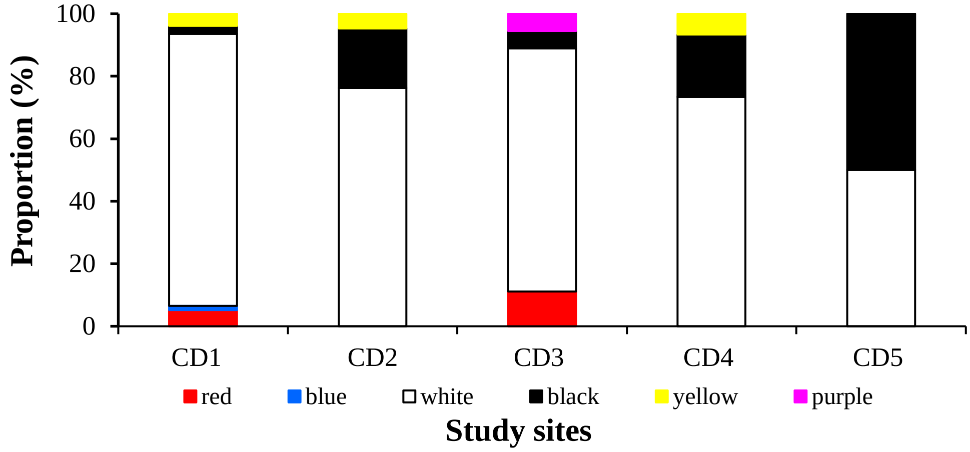

Figure 6. The distribution of microplastic colors in surface water

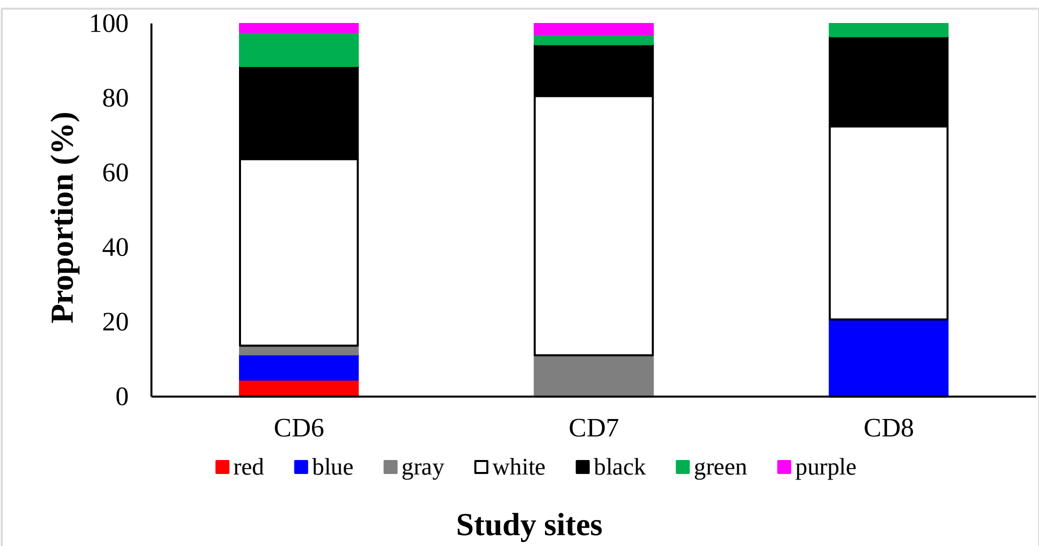

Figure 7. The distribution of microplastic colors in sediment

The distribution of microplastic colors in water and sediment varied between the two environments. However, in both water and sediment, white microplastics constituted the largest proportion compared to other colors, accounting for 72.9% in water samples and 57.1% in sediment. Black microplastics were the second most common, making up 19.4% in water and 21% in sediment. The color of microplastics may pose a threat to aquatic species, as brightly colored plastics are often mistaken for food [43]. When microplastics are ingested by organisms, they can cause harm to the organisms and, through the food chain, affect higher trophic levels via biomagnification. This increases the risk of harm to aquatic ecosystems, the environment, and human health [6], [7].

3. Conclusions

River estuaries are key regions for understanding the causes and extent of microplastic pollution entering the oceans via rivers from human activities, including manufacturing and rice farming. This study provides the first data on microplastic pollution in both surface waters and sediments of the Day River estuary region. The current microplastic pollution in the Day River estuary region may impact the local ecosystem and human health. Therefore, further studies are needed to assess the risks of microplastic pollution in the Day River estuary, which will be crucial for the management and conservation of this river estuary ecosystem.

REFERENCES

[1] OECD, (2022). *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options.*

[2] Wen Z, Xie Y, Chen M & Dinga CD, (2021). China’s plastic import ban increases prospects of environmental impact mitigation of plastic waste trade flow worldwide. *Nature Communications*, 12(1), 425.

[3] Haddout S, Gimiliani GT, Priya KL, Hoguane AM, Casila JCC & Ljubenkov I, (2022). Microplastics in surface waters and sediments in the sebou estuary and Atlantic Coast, Morocco. *Analytical Letters*, 55(2), 256-268.

[4] Anderson JC, Park BJ, and Palace VP, (2016). Microplastics in aquatic environments: Implications for Canadian ecosystems. *Environmental Pollution*, 218, 269-280.

[5] Bancin LJ, Walther BA, Lee YC and Kunz A, (2019). Twodimensional distribution and abundance of micro- and meso-plastic pollution in the surface sediment of Xialiao Beach, New Taipei City, Taiwan. *Marine Pollution Bulletin*, 140, 75-85.

[6] WWF-Vietnam, (2023). *Report on Plastic Waste generation in 2022*. Thanh Nien Publishing House, p.1-65.

[7] Martín J, Santos JL, Aparicio I & Alonso E, (2022). Microplastics and Associated Emerging Contaminants in the Environment: Analysis, Sorption Mechanisms and Effects of Co-Exposure. *Trends in Environmental Analytical Chemistry*, 35. https://doi.org/10.1016/j.teac.2022.e00170.

[8] Government of The Socialist Republic of Vietnam, (2019). *Report No. 233/BC-CP dated May 18, 2020 on environmental protection work in 2019* (in Vietnamese).

[9] Barbuzano J, (2019). Rivers are a highway for microplastics into the ocean. *Eos*, [Online]. Available: https://eos.org/articles/rivers-are-a-highway-for-microplastics-into-the-ocean.

[10] Wright SL, Thompson RC & Galloway TS, (2013). The physical impacts of microplastics on marine organisms: a review. *Environmental Pollution*, 178, 483-492. https://doi.org/10.1016/j.envpol.2013.02.031.

[11] Noreen EK, (2024). Spatial distribution and risk assessment of microplastics in surface waters of the St. Lawrence Estuary. *Science of The Total Environment*, 946. https://doi.org/10.1016/j.scitotenv.2024.174324.

[12] Sunil M, Mithun N, Kalthur G, P. Nair M, Gopinath A, Chidangil S, Kumar S & Lukose J, (2024), Analysis of microplastics in the estuary lying along the coastal belt of the Arabian Sea. *Case Studies in Chemical and Environmental Engineering*, 10. https://doi.org/10.1016/j.cscee.2024.100804.

[13] Vibhatabandhu P, Prachayakul T, Tang-siri J, Benmas P, Sarawut Srithongouthai & Vorapot K, (2024). Effect of tidal current on the settling and accumulation of microplastics in the Chao Phraya River estuary, Thailand. *Marine Pollution Bulletin*, 200. https://doi.org/10.1016/j.marpolbul.2024.116068.

[14] Ribeiro VV, Casado-Coy N, Rangel DF, Sanz-Lazaro C, Castro IB, (2025). Microplastic in bivalves of an urbanized Brazilian estuary: Human modification, population density and vegetation influence. *Journal of Hazardous Materials*, 482. https://doi.org/10.1016/j.jhazmat.2024.136546.

[15] Nitzberg EJ, Parmar S, Arbuckle-Keil G, Saba GK, Chant RJ & Fahrenfeld NL, (2024). Microplastic concentration, characterization, and size distribution in the Delaware Bay estuary. *Chemosphere*, 361. https://doi.org/10.1016/j.chemosphere.2024.142523.

[16] Priya KL, Azhikodan G, Yokoyama K & Renjith KR, (2025). Analysing the influence of hydrodynamic and sedimentary factors on the microplastic distribution in the Ashtamudi estuary, India. *Marine Pollution Bulletin*, 212. https://doi.org/10.1016/j.marpolbul.2025.117537.

[17] Diansyah G, Rozirwan, Rahman MA, Nugroho RY & Syakti AD, (2024). Dynamics of microplastic abundance under tidal fluctuation in Musi estuary, Indonesia. *Marine Pollution Bulletin*, 203. https://doi.org/10.1016/j.marpolbul.2024.116431.

[18] Doan TO, Duong TT, Nguyen TNH, Hoang TQ, Le TPQ, Duong HP, Le PT & Bui HT, (2021). Preliminary results on microplastics in surface water from the downstream of the Day River. *Vietnam Journal of Earth Sciences*, 43(4). https://doi.org/10.15625/2615-9783/16504.

[19] Doan TO, Duong TT, Nguyen TM, Hoang TQ, Luong TT, Pham PT, Cao TTN, Le PT, Phung DH, Le TPQ, Dang TMA, Bui PT, Duong TN & Bui VC, (2023). Preliminary results on microplastic pollution from agricultural soil in Vietnam: Distribution, characterization, and ecological risk assessment. *Vietnam Journal of Earth Sciences*, 45, 405-418. http://doi.org/10.15625/2615-9783/18616.

[20] Cao TTN, Le TPQ, Nguyen TM & Duong TT, (2024). Evidence of microplastics in agricultural water systems of Ninh Binh province, Northern Vietnam. *HNUE Journal of Science*, 69(3), 196-208. DOI: 10.18173/2354-1059.2024-0049.

[21] Strady E, Dang TH, Dao TD, Dinh HN, Do TTD, Duong TN, Duong TT, Hoang DA, Chung TKL, Le TPQ, Mai H, Trinh DM, Nguyen QH, Tran NQA, Tran QV, Truong TNS, Chu VH & Vo VC, (2021). Baseline assessment of microplastic concentrations in marine and freshwater environments of a developing Southeast Asian country, Vietnam. *Marine Pollution Bulletin*, 162.

[22] GESAMP, (2019). Guidelines for the monitoring and assessment of plastic litter in the ocean.

[23] Hidalgo-Ruz V, Gutow L, Thompson RC & Thiel M, (2012). Microplastics in the marine environment: a review of the methods used for identification and quantification. *Environmental Science and Technology*, 46(6), 3060-3075.

[24] Nguyen HNY, Trương TNH, Phan TTL, Vo VM, Le TM, Trinh DM & Tran NQA, (2023). Distribution of microplastics in the surface water and sediment of Thuan An estuary, Thua Thien Hue province. *The University of Danang - Journal of Science and Technology*, 21(3): 97-103 (in Vietnamese).

[25] Dao DC, Duong TL, Nguyen QB, Dao NN, Dang TQ, Nguyen TLH, Duong CD, Duong TN & Dinh NH, (2021). Distribution and characteristics of microplastics in surface water at some beaches in Thanh Hoa province, Viet Nam. *Vietnam Journal of Catalysis and Adsorption*, 10(1S), 193-200. https://doi.org/10.51316/jca.2021.120.

[26] Ta AT & Babel S, (2020). MPs pollution with heavy metals in the aquaculture zone of the Chao Phraya River Estuary, Thailand. *Marine Pollution Bulletin*, 161. https://doi.org/10.1016/j.marpolbul.2020.111747.

[27] Ramakrishnan D & Sathiyamoorthy M, (2024). Seasonal distribution, source apportionment and risk exposure of microplastic contaminants along the Muttukadu backwater estuary, Tamil Nadu, India. *Results in Engineering*, 23. https://doi.org/10.1016/j.rineng.2024.102776.

[28] Lima ARA, Barletta M & Costa MF, (2015). Seasonal distribution and interactions between plankton and microplastics in a tropical estuary. *Estuarine, Coastal and Shelf Science*, 165, 213-225.

[29] Sadri SS & Thompson RC, (2014). On the quantity and composition of floating plastic debris entering and leaving the Tamar Estuary, Southwest England. *Marine Pollution Bulletin*, 81(1), 55-60.

[30] Zhao S, Zhu L, Wang T & Li D, (2014). Suspended microplastics in the surface water of the Yangtze Estuary System, China: first observations on occurrence, distribution. *Marine Pollution Bulletin*, 86(1-2), 562-568.

[31] Ardusso MG, Severini FMD, Abasto B, Prieto G, Rimondino G, Malanca F & Buzzi NS, (2024). First multi-compartment approach to microplastics in an urbanized estuary of Argentina: The case of *Magallana gigas*. *Marine Pollution Bulletin*, 208. https://doi.org/10.1016/j.marpolbul.2024.117027.

[32] Khedre AM, Ramadan SA, Ashry A & Alaraby M, (2024). Abundance and risk assessment of microplastics in water, sediment, and aquatic insects of the Nile River. *Chemosphere*, 353. https://doi.org/10.1016/j.chemosphere.2024.141557.

[33] Leads RR & Weinstein JE, (2019). Occurrence of tire wear particles and other microplastics within the tributaries of the Charleston Harbor Estuary, South Carolina, USA. *Marine Pollution Bulletin*, 145, 569-582.

[34] Suteja Y, Purwiyanto AIS, Purbonegoro T & Cordova MR, (2024). Spatial and temporal trends of microplastic contamination in surface sediment of Benoa Bay: An urban estuary in Bali-Indonesia. *Marine Pollution Bulletin*, 202. https://doi.org/10.1016/j.marpolbul.2024.116357.

[35] Trusler MM, Moss-Hayes VL, Cook S, Lomax BH & Vane CH, (2024). Microplastics pollution in sediments of the Thames and Medway estuaries, UK: Organic matter associations and predominance of polyethylene. *Marine Pollution Bulletin*, 208. https://doi.org/10.1016/j.marpolbul.2024.116971.

[36] Wu N, Zhang Y, Zhang X, Zhao Z, He J, Li W, Ma Y & Niu Z, (2019). Occurrence and distribution of microplastics in the surface water and sediment of two typical estuaries in Bohai Bay, China. *Environmental Science: Processes and Impacts*, 21(7), 1143-1152. https://doi.org/10.1039/C9EM00148D.

[37] Wang W, Ndungu AW, Li Z & Wang J, (2017). Microplastics Pollution in inland freshwaters of China: a case study in urban surface waters of Wuhan, China. *Science of the Total Environment*, 575, 1369-1374.

[38] Li HX, Ma LS, Lin L & Ni ZX, (2018). Microplastics in oysters Saccostrea cucullata along the Pearl River estuary, China. *Environmental Pollution*, 236, 619-625. http://dx.doi.org/10.1016/j.envpol.2018.01.083.

[39] Rodrigues JMS, Pantoja JCD, Oliveira AEP, Ferreira MAP, Nunes ZMP, Nunes B, Costa LP, Santos RM & Rocha RM, (2024). First evidence of microplastics in commercial mussels from Amazonian estuaries. *Regional Studies in Marine Science*, 70. https://doi.org/10.1016/j.rsma.2024.103379.

[40] Sang W, Chen Z, Mei L, Hao S, Zhan C, Li M & Liu J, (2021). The abundance and characteristics of microplastics in rainwater pipelines in Wuhan, China. *Science of the Total Environment*, 755. https://doi.org/10.1016/j.scitotenv.2020.142606.

[41] Barnes DK, Galgani F, Thompson, RC & Barlaz M, (2009). Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1526), 1985-1998.

[42] Cole M, Lindeque P, Halsband C & Galloway TS, (2011). Microplastics as contaminants in the marine environment: A review. *Marine Pollution Bulletin*, 62(12), 2588-2597.

[43] Su L, Deng H, Li B, Chen Q, Pettigrove V, Wu C & Shi H, (2019). The occurrence of microplastics in specific organs in commercially caught fishes from the coast and estuary area of eastern China. *Journal of Hazardous Materials*, 365, 716-724.