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First observation of microplastics in surface sediment of some aquaculture ponds in Hanoi city, Vietnam

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ABSTRACT

A large amount of plastic waste has been released into the environment during the increase in global plastic production in the 21st century. Microplastics (0.1 μm to 5 mm in size) existing in hydro-systems, especially in aquatic sediments, can enter organisms and then human body through food chain. This paper provided the preliminary observation results on microplastic presence in the surface sediment of the aquaculture ponds (fish) in Hanoi city in 2021. Our results showed that microplastic concentrations ranged from 2,767 ± 240 to 2,833 ± 176 items.kg^{-1} dry weights for the surface sediment of the two aquaculture ponds. Two main shape groups of fiber and fragment were detected, of which fibers were dominated (62% and 82% for the two ponds observed). For microplastic fibers, green, white, black and red were main colors, whereas for fragments, yellow, blue and white were main ones. Polyethylene (PE) and polypropylene (PP) were two main polymer types found in the sediment samples. The sources may mainly come from the microplastic contaminated water of the Nhue River, and the direct aquaculture activities. The results of this study contributed to build a dataset on microplastic pollution in aquatic environment, especially aquaculture ponds in Vietnam. Our study also revealed the need for microplastic observation in different environments and organisms, especially in aquaculture zone in Vietnam.

1. Introduction

As of 2015, the total amount of global plastic production was more than five billion tons. China, Europe and North America were the main producing countries. It is forecasted that plastic production will reach to 40 billion tons by 2050 (Zalasiewicz et al., 2016). The rapid increase in plastic production has resulted in a large amount of used plastic being discharged into the environment worldwide due to its low recycling rate and poor waste management Beuson et al. (2021). revealed that approximately 1.6 million tons of plastic wastes were discarded daily worldwide since the outbreak of the COVID-19 pandemic. When entering into environment, plastic waste can be broken down into macroplastics (>25 mm), mesoplastics (5–25 mm), microplastics (0.1 μm - 5 mm) and nanoplastics (< 0.1 μm) (Arthur et al. 2009; GESAMP, 2019).

Microplastics are currently considered as an emerging pollutant and attract great attention in many countries around the world (Wagner and Lambert, 2018). They are diverse in size and type and have high durability, but very slow decomposition rate. Recently, microplastics have been found in many terrestrial ecosystems, freshwater, marine, air, and biota, from very populated regions to remote areas (Free et al., 2014; Zhang et al., 2016; Alam et al., 2019; Gomiero et al., 2019). Previous studies demonstrated that microplastics could accumulate in biota (low trophic fauna, plankton, fish, etc.) and threaten the human health through the food chain accumulation (Andrady, 2011; Bouwmeester et al., 2015). Numerous studies have focused on mi-

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Table 1
Sampling sites for microplastic observation in surface sediment of fish ponds in 2021.

No	Sample name	Kind of aquaculture products	Surface area(ha)	Location
1	Pond 1	*Cyprinus carpio, Ctenopharyngodon idella*	2.2	Cao Bo village, Cao Vien commune, Thanh Oai district, Hanoi
2	Pond 2	*Hypophthalmichthys Labeo rohita*	2.0	Cao Bo village, Cao Vien commune, Thanh Oai district, Hanoi

croplastics in the marine environment (water, sediment, and biota). However, it is still limited for the freshwater environments, especially in Asia where significant plastic pollution was observed due to rapid economic and demographic growth, and urbanization development (Rillig, 2012; Wagner et al., 2014; Phuong et al., 2022).

Microplastics in sediment of freshwater environment, especially in aquaculture system, are currently of great interest. Sediment is known to accumulate large amounts of microplastics and thus is considered as a large microplastic reservoir Hurley et al. (2018). emphasized that microplastic contaminated sediment can pose a significant threat to health of the entire aquatic ecosystem. Besides, aquatic sediment quality is of great concern to scientists in the world due to its important impact on ecosystem functioning, biota and indirectly on human health. Many important biogeochemical processes such as pollutant storage and degradation, adsorption and release with water column can occur in the surface sediment (Li et al., 2020; Le et al., 2021). Moreover, the quality of aquatic sediments can reflect the influence of different point and diffuse sources and provides important information about the transport and accumulation pathways of pollutants (Wagner et al., 2014; Phuong et al., 2022). Some studies have focused on microplastic contaminations in sediments of aquatic environment in many rivers such as the River Thames, UK (Horton et al., 2017); the rivers in Shanghai, China (Peng et al. 2018); the Ciwalengke River, Indonesia (Alam et al., 2019). However, such research in Vietnam is still limited, except for some rivers in the Red River Delta (Duong et al., 2022). To our knowledge, there has been no study addressing the microplastic contamination in surface sediment of the aquaculture ponds in Vietnam.

Aquaculture plays an important role in the global economy, including in Vietnam. Water and sediment quality of aquaculture pond could affect the productivity and the quality of aquaculture products (Qu et al., 2018). Microplastic accumulation in hydro-system could be ingested by low to high trophic level organisms (Phuong et al., 2022). Thus, the study on microplastic contamination in aquaculture ponds is important for both environmental management and sustainable aquaculture development. This paper presented the first observation results of microplastics in the surface sediment of the two aquaculture ponds in Hanoi. These results contributed to build a dataset of microplastic contamination in aquatic environment, and could help environmental protection, especially in aquaculture areas in Vietnam.

2. Study site and methods

2.1. Study site

Hanoi city covers a surface area of 3358.6 km^2 with a total population of $8.24{*}10^6$ in 2020. This city has a total aquaculture area of nearly 23.6 $*10^3$ hectares and the total fishery production of about 116,090 tons, of which 114,363 tons were from aquaculture. Most of aquaculture products in Hanoi were fish (99.9%) according to the statistic data in 2020 (GSO (General Statistics Office), 2020).

In the present study, two aquaculture ponds for fish farming were selected. The ponds located in Cao Bo village, Cao Vien commune, Thanh Oai district, Hanoi city, nearby the Nhue River (Table 1, Fig. 1). Fish products of each pond were about 15 tons per year. Fishes were *Cyprinus carpio, Ctenopharyngodon idella, Hypophthalmichthys* and *Labeo rohita* and fed with artificial feed. Water in the aquaculture ponds was provided by the Nhue River through the irrigation canal (Fig. 1). The Nhue River, a distributary of the Red River, with watershed area of 1,075 km^2 and water discharge of about 74 $m^3.s^{-1}$, takes water from the Red River through the Lien Mac sluice (in Hanoi city), runs through the Hanoi metropolitan area, and receives a large amount of the untreated domestic and industrial wastewater via the To Lich River through the Thanh Liet gate. The Red River, with waterflow of about 2500 $m^3.s^{-1}$, is the largest one in North Vietnam (MONRE (Vietnam Ministry of Environment and Natural Resources), 2015), whereas the To Lich is an urban river with water discharge of about 30 $m^3.s^{-1}$ (Fig. 1).

2.2. Methods

Samplings were carried out in January/February in 2021. Surface sediment (0-30 cm) was sampled using a Van Veen grab sampler. At each pond, three sub-samples were taken at three different sites of pond and then thoroughly homogenized to obtain one representative sample for analysis. Some information concerning the aquaculture ponds were given in Table 1. The samples were put into aluminum foil bags and transported to the laboratory on the same day.

The sediment sample was dried in an oven (40°C) and sieved through a 1-mm sieve to remove all materials higher than 1mm. 30 gram of dried sediment sample was added into a glass bottle and then digested using 30% H_2O_2 solution on a heating plate at 40°C for 3 hours (Strady et al., 2021). The digested solution was then sieved through a 250-µm sieve to keep the sediment fraction with the size higher than 250µm. For separation of microplastics in the sediment samples, saturated NaCl solution was used (Thompson et al., 2004) and overflow producing technique was applied (Hidalgo-Ruz et al., 2012). NaCl solution was chosen to be used in different previous studies when considering the cost of the protocol and sourcing availability of the reagent used, as well as the environmental-friendly status of the reagents (Strady et al., 2020; 2021; Duong et al., 2022). The overflowed solution was then filtered on Whatman GF/A filters (pore sizes of 1.6 µm) using a glassware filtration unit. The representative sample was triplicate analyzed and the results here were the average value and the standard deviation for each pond.

The presence and characteristics (concentration, shape and color) of microplastics in the filtered filters were identified using a microscope (Leica MZ12 stereomicroscope) with a camera attached and image analysis software (LAS software®). According to the GESAMP recommendations (GESAMP, 2019), microplastics with a minimum length of 300 µm and/or with a minimum area of 45000 $µm^2$ were considered in this study.

The polymer type of the sediment samples was determined by Raman spectroscopy (HORIBA XploRA Plus) coupled to the Raman Spectra Database Collection KnowItAll® under the followings acquisition conditions: laser power of 632.8 nm; wavelength range of 700 - 1700 cm^{-1}; acquisition time of 60 s, average of 2 accumulations. About 30 percent of the total items extracted from the pond sediment samples that were suspected to be microplastics were randomly analyzed.

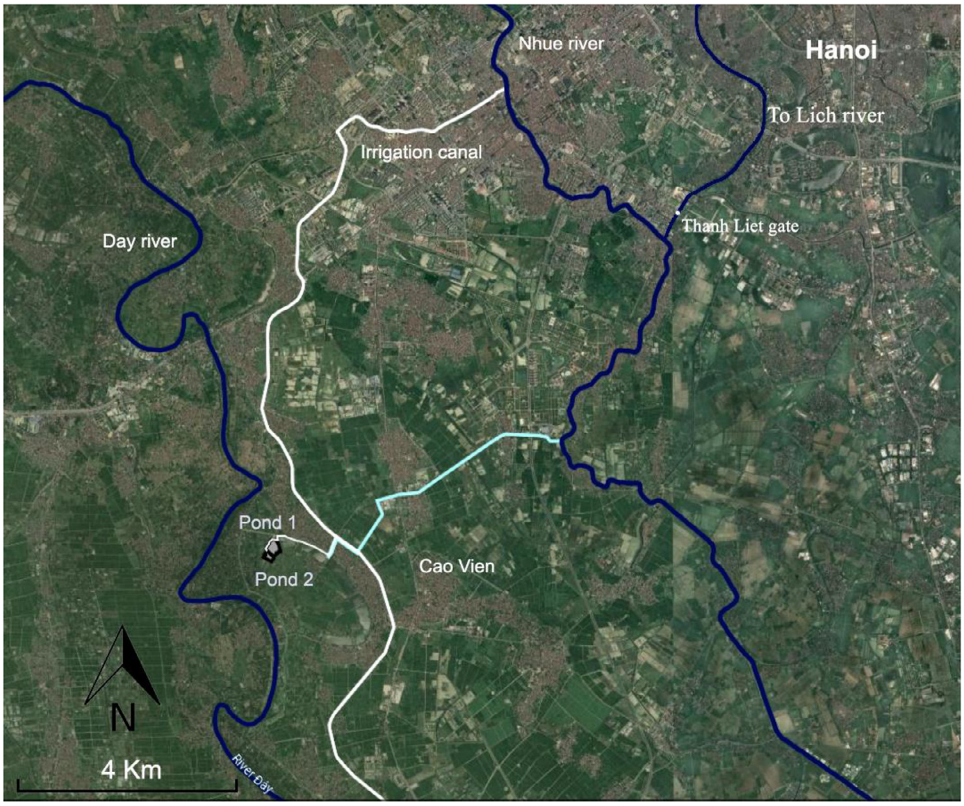

Fig. 1. Location of two fish ponds studied in Hanoi city.

Table 2
Microplastic in the surface sediment of two aquaculture ponds in 2021.

No	Sample names	Microplastic concentrations(*items.kg*$^{-1}$ *dw)*	Total numbers of microplastic items*(items)*	Number of microplastic fragment items *(items)*	Number of microplastic fiber items *(items)*
1	Pond 1	2833 ± 176	85 ± 5	32 ± 5	53 ± 4
2	Pond 2	2767 ± 240	83 ± 7	16 ± 6	67 ± 2

3. Results

3.1. Microplastic concentrations

The microscope results showed the total number of microplastic items in sediments of the two ponds were not clearly different (85 ± 5 and 83 ± 7 items for pond 1 and pond 2, respectively) ($p > 0.05$) (Table 2). That leads to the similar results of the microplastics concentrations, 2,833 ± 176 and 2,767 ± 240 items.kg^{-1} dw for the pond 1 and pond 2, respectively (Table 2).

3.2. Microplastic shapes

The microplastic shapes in the sediment samples were observed in the Whatman GF/A filters by microscopy at 100 times magnification (Fig. 2). Two main shape groups of fiber and fragment were detected. Fibers were dominated microplastic shape, 62% for pond 1 and 81% for pond 2, whereas fragments were 38 and 19%, respectively (Table 2, Fig. 3).

Fibers were reported in several previous researches as a dominate microplastic shape in water and sediment in Vietnam such as in the Nhue River (Duong et al., 2020, 2022) and the Sai Gon River (Lahens et al., 2018) or in other locations (Strady et al., 2021). Fibers were also reported to be main microplastic shape in aquatic sediment in some previous studies in the world such as the Ciwalengke River, Indonesia (Alam et al., 2019), the Ottawa river, Canada (Vermaire et al., 2017), the Changjiang (Peng et al., 2017), the Wei (Ding et al., 2019) and the Pearl rivers, China (Lin et al., 2018).

3.3. Microplastics colors

The microplastic colors in the sediment samples were also observed on the Whatman GF/A filters by microscopy at 100 times magnification. Different colors including red, blue, grey, white, black, yellow, green and purple were found in the sediment samples of both aquaculture ponds. For microplastic fragments, yellow, blue and white were main colors observed, whereas for fibers, green, white, black and red were most found (Fig. 4). Different colors were also reported in the water and the sediment samples of different hydro-sytems in Vietnam (Duong et al., 2020, 2022). Noted that de Sá et al. (2015) reported that microplastic color may be discolored under environmental conditions.

3.4. Microplastics polymer type

The Raman spectrometry analysis ($n = 30$) identified the presence of PE (40%) and PP (50%) in our study (Fig. 5). These values were closed to the reported values in the riverine sediments in the Red River Delta, Vietnam, PE, PP, PET and EVA were 34, 59, 4 and 2%, respectively. In fact, PE and PP were the most common polymers found in both water and sediment compartments in the Asian freshwater, with its relative

Table 3
Microplastics in aquatic sediments in the World.

No	Location	Microplastic concentration(*items.kg*$^{-1}$ *dw)*	Dominated shape	Refs.
1	River Thames, England	185 ± 42 to 660 ± 7	Fragment (91%)	Horton et al. (2017)
2	Ottawa River, Canada	220	Fiber	Vermaire et al. (2017)
3	Netravathi river, India	96	Fragment (44.4%)	Amrutha et al. (2020)
4	Ciwalengke river, Indonesia	58.5 ± 32.8	Fiber	Alam et al. (2019)
5	Nakdong river, Korea	1970 ± 62	Fragment (84%)	Eo et al. (2019)
6	Chao Phraya River, Thailand	91 ± 13	Fragment, fiber	Ta and Babel (2020)
7	Shanghai River, China	802 ± 594	Pellets (88.9%)	Peng et al. (2018)
8	Changjiang River, China	121 ± 9 (20 - 340)	Fiber (93%)	Peng et al. (2017)
9	Wen-Rui Tang, China	32,947 ± 15,342	Fragment (45.9%) and foam (29.5%)	Wang et al. (2018)
10	Wei River, China	360 - 1320	Fiber (42.25% -53.20%)	Ding et al. (2019)
11	Pearl river, China	80 - 9597	Fiber	Lin et al. (2018)
12	To Lich river, Vietnam	55,950 ± 10,111	Fiber	Duong et al. (2022)
13	Taihu Lake, China	11 - 235	Fiber	Su et al. (2016)
14	Dongting Lake, China	210 - 520	Fiber	Hu et al. (2020)
15	Veeranam lake, India	309 (92-604)	Fragment	Bharath et al. (2021)
16	*Fish ponds, Vietnam*	*2,767 ± 240 to 2,833 ± 176*	*Fiber*	*This study*

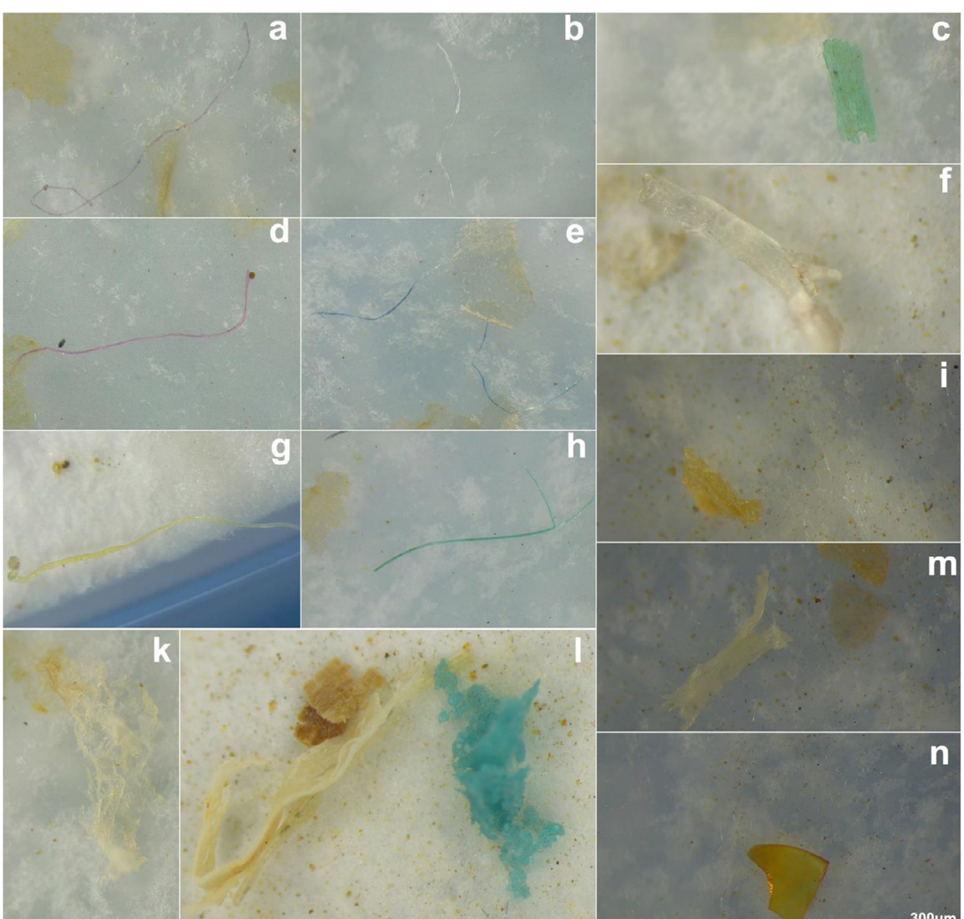

Fig. 2. Some photos of microplastic presence (fiber and fragment) observed in surface sediments of two aquaculture ponds.

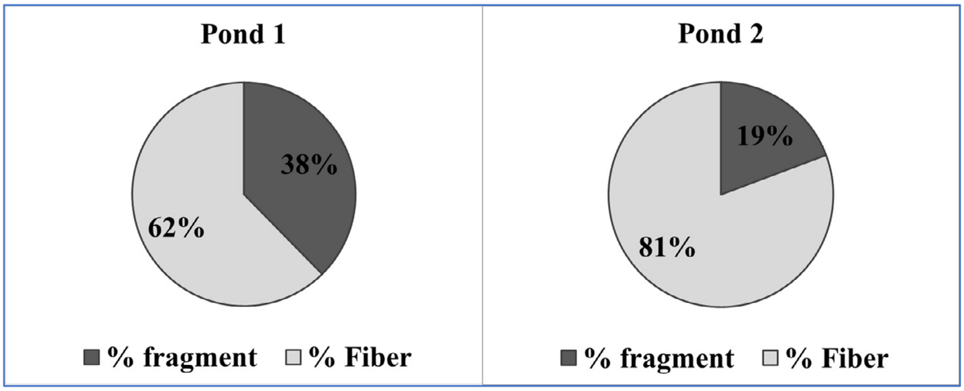

Fig. 3. Distribution of microplastic shape (%) in surface sediments of two aquaculture ponds in Hanoi.

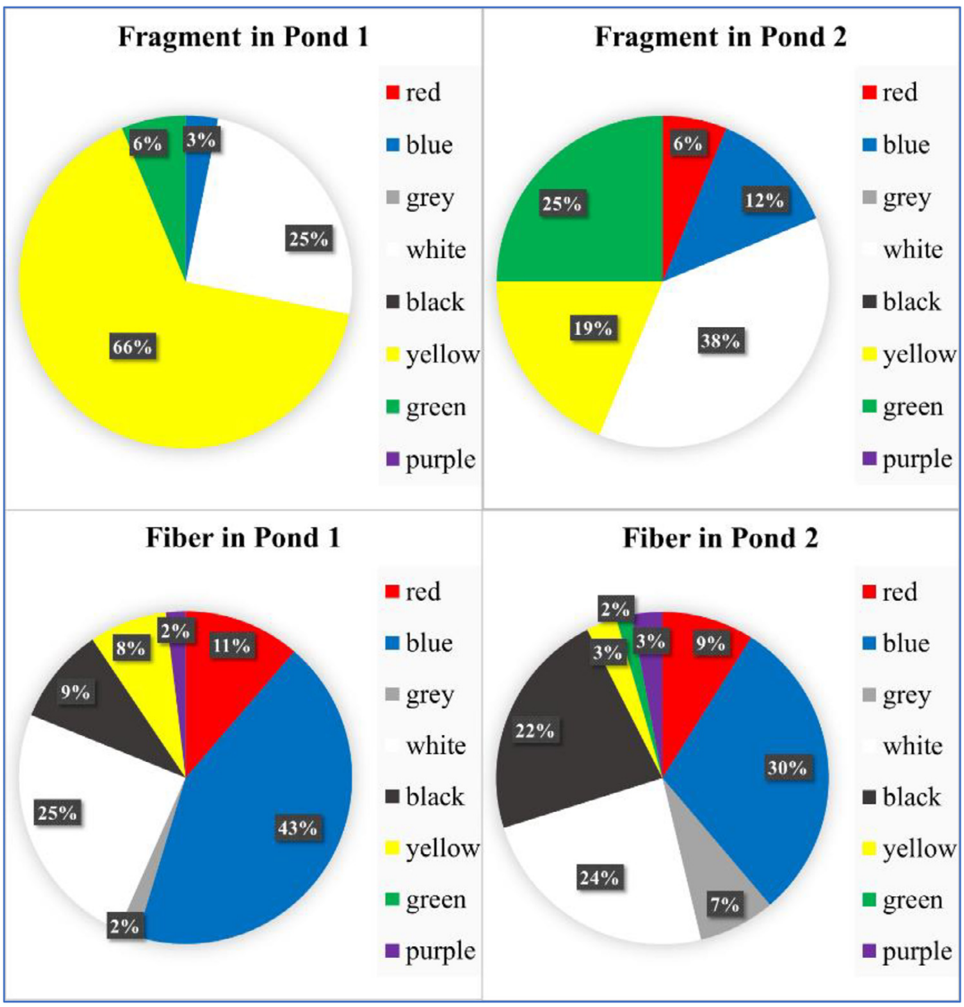

Fig. 4. Distribution of microplastic color in the sediment samples of aquaculture ponds.

abundances of 31% and 37%, respectively (Phuong et al., 2022). This is in line with the fact that these two polymers have been produced for nearly half of the total plastic production (PlasticsEurope, 2020).

4. Discussions

4.1. Microplastic contamination levels in aquaculture ponds

To present, there are a number of studies on microplastics in hydro-systems in the countries in different continents such as America, Europe, Asia and Africa. The results of microplastic observation in freshwater sediment (river, and lake/pond) in the world demonstrated that the concentration and the shape were different, depending on the sampling location, the influence of waste sources, the hydro-climate characteristics, and also the studied methods (the sampling and analysis methods) (Dris et al., 2015). Phuong et al. (2022) reported that microplastic concentrations in sediment of fresh hydro-systems varied in a high range from 1 to over 30,000 items.kg^{-1} dw. In terms of microplastic shape, fibers and fragments were commonly encountered at different sites in the world (Table 3).

Our survey results showed that the microplastic concentrations in the surface sediments of the two fish ponds in Hanoi were 2,767 ± 240

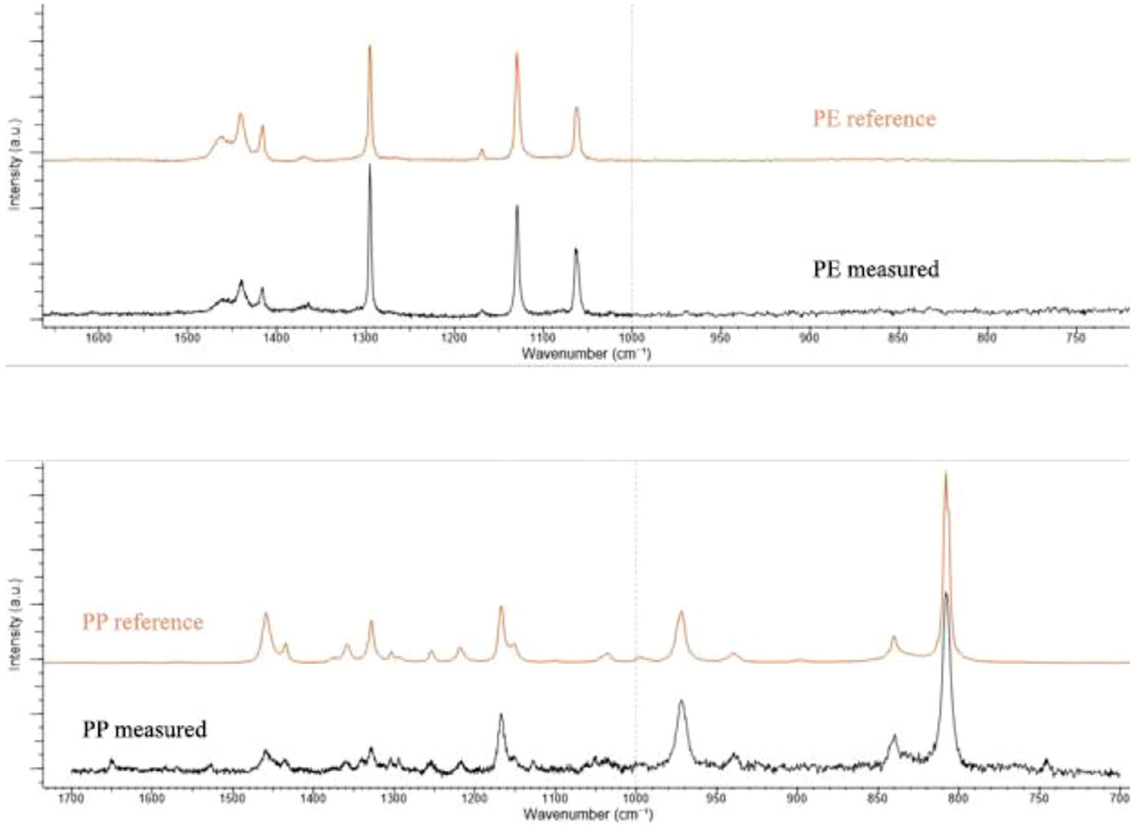

Fig. 5. Raman spectrums of PE and PP in the sediment samples of aquaculture ponds.

and 2,833 ± 176 items.kg^{-1} dw, much higher than in the Taihu Lake (Su et al., 2016), the Dongting Lake (Hu et al., 2020), the Wei (branch of the Yellow river) (Ding et al., 2019) in China, or the Ciwalengke River in Indonesia (Alam et al., 2019). However, these values were much lower than in the Wen-Rui Tang in China (32,947 ± 15,342 items.kg^{-1} dw) (Wang et al., 2018) or the maximal value of the urban To Lich river in Vietnam (55,950 ± 10,111 items.kg^{-1} dw) (Duong et al., 2022) (Table 3).

4.2. Possible microplastics sources in aquaculture pond sediments

Microplastic concentrations in the aquatic environment were proportional to high population density, urbanization, industrialization and other human activities (Wang et al., 2017; Le et al., 2021). Previous study indicated that Asia was considered a “hot spot” for plastic pollution in the world due to its dense population density and high human activities (Phuong et al., 2022). Microplastics can be discharged into aquatic environment from industrial and agricultural production, domestic wastewater, aquaculture and fishing, atmospheric deposition, wastewater from wastewater treatment plants, and solid waste (Andrady, 2011; Dris et al., 2015; Eerkes-Medrano et al., 2015).

Our study revealed that the microplastic concentrations in the surface sediments of two fish-ponds in Hanoi were quite high (2,767 ± 240 and 2,833 ± 176 items.kg^{-1} dw) in comparison with some rivers/lakes as mentioned earlier. In our case, the microplastic sources of two fish-ponds may come from the polluted water of the Nhue River, direct aquaculture activities (including fishing net and artificial feeds), and human activities surrounding the ponds including agriculture.

The important microplastic sources for the two studied aquaculture ponds may firstly come from the riverine water of the Nhue River. Noted that the high value of microplastic concentrations (up to 1,826 items.m^{-3}) in the Nhue-To Lich River water was also reported in the previous study (Duong et al., 2020). Duong et al. (2022) reported that microplastics in riverine sediment in the Red River Delta where the Nhue-To Lich system located varied in a very high range from 1,450 ± 494 items.kg^{-1} at the Ba Da site in the Nhue River to 55,950 ± 10,111 items.kg^{-1} at the TL site in the To Lich River. These authors emphasized that untreated wastewater or sewage (about 960,000 m^3 per day) from Hanoi city could be responsible for the very high microplastic abundance in the sediments of the urban To Lich and Nhue rivers. Regarding microplastic shape, two main groups of fiber (dominated, 62% and 82% for the two ponds) and fragment were found in our observation Duong et al., (2020). also revealed that the dominated microplastic fibers in the water of the urban Nhue – To Lich rivers were due to domestic wastewater and other polluted sources in Hanoi city. Fibers were also the most dominant shape in the surface sediments of the different rivers (the Day, Nhue, and To Lich) in the Red River Delta (Duong et al., 2022). Previous studies highlighted that microplastic fibers could originate from numerous sources including domestic clothes washing, textile industry, and plastic waste generated in the industrial production (Geyer et al., 2017; Alam et al., 2019) or from the breakdown of large plastic pieces under different natural factors (Peters et al., 2016) Gasperi et al., (2018). emphasized that fibers in aquatic environment predominantly originated from plastic textiles (cloth, fishing nets and lines) which had an annual production of 60 million metric tons. The research on the sediment of the Ciwalengke River, Indonesia, revealed that dominated fibers found at the study sites could be derived from clothes washing of local inhabitants and from textile industry wastewater in the river basin (Alam et al., 2019). Similar results were reported for the Sai Gon River where fibers were found to be much higher due to textile industry wastewater (Gasperi et al., 2018; Lahens et al., 2018).

Fishery and aquaculture activities contribute an important microplastic contamination in freshwater environments. Indeed, microplastics were from the breakdown of fishing tools, such as fishing nets, lines, and ropes which contributed a large number of plastic fragments and fibers to the aquatic environments (Yuan et al., 2019; FAO, 2020; Napper et al., 2021). For example, intense fishing or fisheries industry with the decay of fishing tools were responsible for the fragment contamination in the case of some lakes and reservoirs in China (Ramadan and Sembiring 2020; Hu et al., 2020). In our case, the decay of fishing tools may accelerate the microplastic contamination in the observed ponds. In addition, microplastics can also be released into the aquaculture environments from artificial feeds and pharmaceutical products containing microplastics that were utilized in aquaculture activities (Lv et al., 2019; Zhou et al., 2020).

Besides domestic wastewater and solid waste in the surrounding area, agricultural activities may also contribute to microplastic contamination of the two ponds in our study. Note that these two ponds are located in the Red River Delta where rice and vegetables were intensively cultivated. Some previous studies highlighted that the application of chemical fertilizers, pesticides, fish food, and decomposition of agricultural tools in agricultural areas may contribute microplastic contamination to hydro-system (Yuan et al., 2019; Lv et al., 2019; Battulga et al., 2020; Lestari et al., 2020). The study in the Jiaozhou bay in China reported that the high microplastic abundance was from the important source of agricultural diffuse (Ouyang et al., 2020). In addition, other previous studies revealed that microplastic film and foam abundance were found in the water and sediment at the sites nearby extensive farming or vast agricultural planting areas (Lv et al., 2019). In our study, the dominate microplastic shapes were fibers and fragments, which may suggest that the impact of agricultural activities may be less than the one from domestic and industrial wastewater.

Due to the small size, microplastics can easily penetrate living organisms in aquatic ecosystems through the direct ingestion or the consumption of other microplastic-contamination organisms Phuong et al (2022). reported that microplastics of different concentrations were detected in biota samples in Asia, depending on the locations and species studied. The recent research showed that microplastics were accumulated in the stomach and/or intestines of some seafood species (fish and molluscs) which were the daily food of local people in Indonesia (Rochman et al., 2015) or in native mussels in the Adriatic coast (Gomiero et al., 2019) or in fish stomachs in the Jiaozhou bay in China (Ouyang et al., 2020). In Vietnam, microplastics were found from 1.0 ± 0.1 to 1.7 ± 0.6 items.g^{-1} in green mussel *Perna viridis* Linnaeus in natural aquaculture ponds at different sites including in Hue city, and Nam Dinh and Binh Dinh provinces (Doan et al., 2021), or averaged 2.60 items.$individual^{-1}$ and 0.29 items.g^{-1} of wet tissue in *Perna Viridis* in Thanh Hoa province (Nam et al., 2019). In these two case studies fiber microplastics were predominated. Previous studies have indicated that the dominant shape of fibers in urban rivers, and sediment in water may lead to high accumulation rate of microplastics in mussels, invertebrates and vertebrates (Mizraji et al., 2017; Qu et al. 2018). It is important to note that microplastic accumulation in aquatic organisms may enter human body through the food chain (Van Cauwenberghe et al., 2015). With widespread microplastic pollution as it is today, it is essential to reduce the amount of plastic waste released. Our study revealed the need for microplastic observation in different environments and organisms, especially in aquaculture zone in Vietnam.

4.3. Limitation of this study

The number of the observed aquaculture ponds in this study is still limited. In addition, we have not measured microplastics in different compartments of the aquaculture pond such as water column, biota (fish) or suspended solids. Thus, further studies on the microplastic observation and their potential risk to ecosystem and human health in the aquaculture areas, in particular in Vietnam need to be carried out.

5. Conclusions

Our observation showed that microplastic concentrations in the surface sediment of the two aquaculture ponds in Hanoi city were 2,767 $\pm$ 240 and 2,833 $\pm$ 176 items.kg^{-1} dw, with two main shape groups of fiber and fragment, of which fibers were dominated (62% and 82% for the two ponds observed). Different colors of microplastics were found in this study. For fragments, the yellow, blue and white were main observed colors, whereas for fibers, the green, white, black and red were main colors. PE and PP were two main polymer types detected in the sediment samples in this study.

The microplastics may mainly come from the microplastic contaminated water of the Nhue River and direct aquaculture activities (e.g. fishing net, artificial feeds). Microplastics can easily penetrate living organisms in aquatic ecosystems and hence may affect human health. Thus, our study revealed the need for microplastic observation in different environments and organisms, especially in the aquaculture zones in Vietnam. Our study also emphasized that it is necessary to reduce the amount of plastic waste in order to minimize microplastic pollution in Vietnam as well as in developing countries.

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Data availability statement

The main part of the research data is included in the article. Other data can be made available from the corresponding author upon request.

Declaration of Competing Interest

The authors declare that there are no conflicts of interest.

CRediT authorship contribution statement

Nhu Da Le: Conceptualization, Methodology, Investigation, Funding acquisition, Data curation, Writing – original draft. **Thi Thu Ha Hoang:** Formal analysis, Resources. **Thi Thuy Duong:** Methodology, Formal analysis, Writing – original draft. **XiXi Lu:** Resources, Writing – original draft. **Thi Mai Huong Pham:** Formal analysis, Resources. **Thi Xuan Binh Phung:** Formal analysis, Resources. **Thi My Hanh Le:** Formal analysis. **Thi Huyen Duong:** Data curation, Resources. **Tien Dat Nguyen:** Data curation, Resources. **Thi Phuong Quynh Le:** Conceptualization, Methodology, Formal analysis, Funding acquisition, Data curation, Writing – original draft.

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References

Alam, F.C, Sembiring, E., Muntalif, B.S., Suendo, V., 2019. Microplastic distribution in surface water and sediment river around slum and industrial area (case study: Ciwalengke River, Majalayadistrict, Indonesia). Chemosphere 224, 637–645.

Amrutha, K., Warrier, A.K., 2020. The first report on the source-to-sink characterization of microplastic pollution from a riverine environment in tropical India. Sci. Total Environ. 739, 140377.

Andrady, A.L., 2011. Microplastics in the marine environment. Mar. Pollut. Bull. 62, 1596–1605.

Arthur, C., Baker, J., Bamford, H., 2009. Proceedings of the International Researchworkshop on the Occurrence, eFfects and fate of Microplastic marine debris. NOAA Technical Memorandum NOS-OR & R-30. NOAA, p. 530 Silver Spring,September 9-11, 2008.

Battulga, B., Kawahigashi, M., Oyuntsetseg, B., 2020. Behavior and distribution of polystyrene foams on the shore of Tuul River in Mongolia. Environ. Pollut. 260, 113979.

Beuson, N.U., Bassey, D.E., Palanisamic, T., 2021. COVID pollution: impact of COVID-19 pandemic on global plastic waste footprint. Heliyon 7 (2), e06343.

Bharath, K.M., Srinivasalu, S., Natesan, U., Ayyamperumal, R., Kalam, S.N., Anbalagan, S., Sujatha, K., Alagarasan, C., 2021. Microplastics as an emerging threat to the freshwater ecosystems of Veeranam Lake in south India: a multidimensional approach. Chemosphere 264, 128502. doi:10.1016/j.chemosphere.2020.128502.

Bouwmeester, H., Hollman, P.C., Ruud, J.B.P., 2015. Potential health impact of environmentally released micro-and nanoplastics in the human food production chain: experiences from nanotoxicology. Environ. Sci. Technol. 49 (15), 8932–8947.

De Sá, L.C., Luís, L.G., Guilhermino, L., 2015. Effects of microplastics on juveniles of the common goby (*Pomatoschistus microps*): confusion with prey, reduction of the predatory performance and efficiency, and possible influence of developmental conditions. Environ. Pollut. 196, 359–362.

Ding, L., Mao, R.F., Guo, X., Yang, X., Zhang, Q., Yang, C., 2019. Microplastics in surface waters and sediments of the Wei River, in the northwest of China. Sci. Total Environ. 667, 427–434.

Doan, T.O., Duong, T.T., Nguyen, T.N.H., Hoang, T.Q., Vu, T.N., Phuong, N.N., Pham, Q.T., Ngo, T.X.T., Bui, H.T., Le, T.P.Q, 2021. Efficiency assessmentof microplastic extraction from green mussel *Perna viridis* Linnaeus. Acad. J. Biol. 43 (4), 55–66. doi:10.15625/2615-9023/16153.

Dris, R., Gasperi, J., Rocher, V., Saad, M., Renault, N., Tassin, B., 2015. Microplastic contamination in an urban area: a case study in greater Paris. Environ. Chem. 12, 592–599.

Duong, T.T., Le, T.P.Q., Doan, T.O., Nguyen, N.H., Le, N.D., Duong, H.P., Le, P.T., Trinh, V.T., 2020. Preliminary assessment of microplastics pollution in surface water of the Nhue River. In: Proceedings of the 45th Conference of Vietnam Academy of Science and Technology on Environment and Energy, Hanoi, p. 4.

Duong, T.T., Le, P.T., Nguyen, T.N.H., Hoang, T.Q., Ngo, H.M., Doan, T.O., Le, T.P.Q., Bui, H.T., Bui, M.H., Trinh, V.T., Nguyen, T.L., Le, N.D., Vu, T.M., Tran, T.K.C., Ho, T.C., Phuong, N.N., Strady, E., 2022. Selection of a density separation solution to study microplastics in tropical riverine sediment. Environ. Monit. Assess. 194 (65). doi:10.1007/s10661-021-09664-0.

Eerkes-Medrano, D., Thompson, R.C., Aldridge, D.C., 2015. Microplastics in freshwater systems: a review of the emerging threats, identification of knowledge gaps and prioritisation of research needs. Water Res. 75, 63–82.

Eo, S., Hong, S.H., Song, Y.K., Han, G.M., Shim, W.J., 2019. Spatiotemporal distribution and annual load of microplastics in the Nakdong River, South Korea. Water Res. 160, 228–237.

FAO, 2020. The state of world fisheries and aquaculture 2020. doi:10.4060/ca9229en.

Free, C.M., Jensen, O.P., Mason, S.A., Eriksen, M., Williamson, N.J., Boldgiv, B., 2014. High-levels of microplastic pollution in a large, remote, mountain lake. Mar. Pollut. Bull. 85, 156–163.

Gasperi, J., Wright, S.L., Dris, R., Collard, F., Mandin, C., Guerrouache, M., Langlois, V., Kelly, F.J, Tassin, B., 2018. Microplastics in air: are we breathing it in? Curr. Opin. Environ. Sci. Health 1, 1–5.

GESAMP, 2019. Guidelines or the monitoring and assessment of plastic litter and microplastics in the ocean. United Nations Environment Programme (UNEP), p. 138.

Geyer, R., Jambeck, R.R., Law, K.L., 2017. Production, use, and fate of all plastics ever made. Sci. Adv. 3 (7), e1700782.

GSO (General Statistics Office), 2020. Statistical Yearbook of Vietnam. Statistical Publishing House, HaNoi.

Gomiero, A., Strafella, P., Øysæd, K.B., Fabi, G., 2019. First occurrence and composition assessment of microplastics in native mussels collected from coastal and offshore areas of the northern and central Adriatic Sea. Environ. Sci. Pollut. Res. 26, 24407–24416. doi:10.1007/s11356-019-05693-y.

Hidalgo-Ruz, V., Gutow, L., Thompson, R.C., Thiel, M., 2012. Microplastics in the marine environment: a review of the methods used for identification and quantification. Environ. Sci. Technol. 46 (6), 3060–3075.

Horton, A.A., Svendsen, C., Williams, R.J., Spurgeon, D.J., Lahive, E., 2017. Large microplastic particles in sediments of tributaries of the River Thames, UK - Abundance, sources and methods for effective quantification. Mar. Pollut. Bull. 114, 218–226.

Hu, D., Zhang, Y., Shen, M., 2020. Investigation on microplastic pollution of Dongting Lake and its affiliated rivers. Mar. Pollut. Bull. 160, 111555.

Hurley, R., Woodward, J., Rothwell, J.J., 2018. Microplastic contamination of river beds significantly reduced by catchment-wide flooding. Nat. Geosci. 11, 251–257. doi:10.1038/s41561-018-0080-1.

Lahens, L., Strady, E., Kieu-Le, T.C., Dris, R., Boukerma, K., Rinnert, E., Gasperi, J., Tassin, B., 2018. Macroplastic and microplastic contamination assessment of a tropical river (Saigon River, Vietnam) transversed by a developing megacity. Environ. Pollut. 236, 661–671.

Le, N.D., Le, T.P.Q., Duong, T.T., Nguyen, T.D., Nguyen, T.A.H., Dinh, L.M., Le, T.M.H., 2021. Microplastics in riverine sediment: present situation and polluted sources. In: Proceedings of the 3rd National Conference of the Vietnam Nature Museum System. Natural Science and Technology Publishing House, Hanoi, pp. 673–683.

Lestari, P., Trihadiningrum, Y., Wijaya, B.A., Yunus, K.A., Firdaus, M., 2020. Distribution of microplastics in Surabaya River, Indonesia. Sci. Total. Environ. 726, 138560.

Li, M., Zhang, Q., Sun, X., Karki, K., Zheng, C., Pandey, A., Rawat, B., Zhang, F., 2020. Heavy metals in surface sediments in the trans-Himalayan Koshi River catchment: Distribution, source identification and pollution assessment. Chemosphere 244, 125410.

Lin, L., Zuo, L.Z., Peng, J.P., Cai, L.Q., Fok, L., Yan, Y., Li, H.X., Xu, X.R., 2018. Occurrence and distribution of microplastics in an urban river: a case study in the Pearl River along Guangzhou City, China. Sci. Total Environ. 644, 375–381.

Lv, W., Zhou, W., Lu, S., Huang, W., Yuan, Q., Tian, M., Lv, W., He, D., 2019. Microplastic pollution in rice-fish co-culture system: a report of three farmland stations in Shanghai, China. Sci. Total Environ. 652, 1209–1218.

Mizraji, R., Ahrendt, C., Perez-Venegas, D., Vargas, J., Pulgar, J., Aldana, M., Patricio Ojeda, F., Duarte, C., Galbán-Malagón, C., 2017. Is the feeding type related with thecontent of microplastics in intertidal fish gut? Mar. Pollut. Bull. 116, 498–500.

MONRE (Vietnam Ministry of Environment and Natural Resources), 1960-2015. 2015. Report Annual on hydrological observation in Vietnam during the period 1960–2015, Hanoi, Vietnam (in Vietnamese).

Nam, P.N., Tuan, P.Q., Thuy, D.T., Quynh, L.T.P., Amiard, F., 2019. Contamination of microplastic in bivalve: first evaluation in Vietnam. Vietnam J. Earth Sci. 41 (3), 252–258. doi:10.15625/0866-7187/41/3/13925.

Napper, I.E., Baroth, A., Barrett, A.C., Bhola, S., Chowdhury, G.W., Davies, B.F.R., Duncan, E.M., Kumar, S., Nelms, S.E., Niloy, M.N.H., Nishat, B., Maddalene, T., Thompson, R.C., Koldewey, H., 2021. The abundance and characteristics of microplastics in surface water in the transboundary Ganges River. Environ. Pollut. 274, 116348.

Ouyang, W., Zhang, Y., Wang, L., Barceló, D., Wang, Y., Lin, C., 2020. Seasonal relevance of agricultural diffuse pollutant with microplastic in the bay. J. Hazard. Mater. 396, 122602. doi:10.1016/j.jhazmat.2020.122602.

Peng, G., Zhu, B., Yang, D., Su, L., Shi, H., Li, D., 2017. Microplastics in sediments of the Changjiang estuary, China. Environ. Pollut. 225, 283–290.

Peng, G., Xua, P., Zhu, B., Bai, M., Li, D., 2018. Microplastics in freshwater river sediments in Shanghai, China: a case study of risk assessment in mega-cities. Environ. Pollut. 234, 448–456.

Peters, C.A., Bratton, S.P., 2016. Urbanization is a major influence on microplastic ingestion by sunfish in the Brazos river basin, Central Texas, USA. Environ. Pollut. 210, 380–387.

Phuong, N.N., Duong, T.T., Le, T.P.Q., Hoang, T.K., Ngo, H.M., Phuong, N.A., Pham, Q.T., Doan, T.O., Ho, T.C., Le, N.D., Nguyen, T.A.H., Strady, E., Fauvelle, V., Ourgaud, M., Schmidt, N., Sempere, R., 2022. Microplastics in Asian freshwater ecosystems: current knowledge and perspectives. Sci. Total Environ. 808, 151989. doi:10.1016/j.scitotenv.2021.151989.

PlasticsEurope, 2020. Plastics e the facts 2020: an analysis of European plastics production, demand and waste data.

Qu, X., Su, L., Li, H., Liang, M., Shi, H., 2018. Assessing the relationship between theabundance and properties of microplastics in water and in mussels. Sci. Total Environ. 621, 679–686.

Ramadan, A.H., Sembiring, E., 2020. Occurrence of microplastic in surface water of Jatiluhur Reservoir. In: Proceedings of the E3S Web of Conferences. EDP Sciences, p. 148.

Rillig, M.C., 2012. Microplastic in terrestrial ecosystems and the soil. Environ. Sci. Technol. 46, 6453–6454.

Rochman, C.M., Tahir, A., Williams, S.L., Baxa, D.V., Lam, R., Miller, J.T., et al., 2015. Anthropogenic debris in seafood: Plastic debris and fibers from textiles in fish and bivalves sold for human consumption. Sci. Rep. 5, 14340.

Strady, E., Kieu-Le, T.C., Gasperi, J., Tassin, B., 2020. Temporal dynamic of anthropogenic fibers in a tropical river-estuarine system. Environ. Pollut. 259, 113897.

Strady, E., Dang, T.H., Dao, T.D., Dinh, H.N., Do, T.T.D., Duong, T.N., Duong, T.T., Hoang, D.A., Kieu-Le, T.C., Le, T.P.Q., et al., 2021. Baseline assessment of microplastic concentrations in marine and freshwater environments of a developing Southeast Asian country, Viet Nam. Mar. Pollut. Bull. 162, 111870.

Su, L., Xue, Y., Li, L., Yang, D., Kolandhasamy, P., Li, D., Shi, H., 2016. Microplastics in Taihu Lake, China. Environ. Pollut. 216, 711–719. doi:10.1016/j.envpol.2016.06.036.

Ta, A.T., Babel, S., 2020. Microplastic contamination on the lower Chao Phraya: abundance, characteristic and interaction with heavy metals. Chemosphere 257, 127234.

Thompson, R.C., Olsen, Y., Mitchell, R.P., Davis, A., Rowland, A.S.J., John, A.W.G., McGonigle, D., Russell, A.E., 2004. Lost at Sea: where is all the plastic? Science 304 (5672), 838.

Van Cauwenberghe, L., Devriese, L., Galgani, F., Robbens, J., Janssen, C.R., 2015. Microplastics in sediments: a review of techniques, occurrence and effects. Mar. Environ. Res. 111, 5–17.

Vermaire, J.C., Pomeroy, C., Herczegh, S.M., Haggart, O., Murphy, M., 2017. Microplastic abundance and distribution in the open water and sediment of the Ottawa River, Canada, and its tributaries. Facets 2, 301–314.

Wagner, M., Scherer, C., Alvarez-Munoz, D., Brennholt, N., Bourrain, X., Buchinger, S., Fries, E., Grosbois, C., Klasmeier, J., Marti, T., 2014. Microplastics in freshwater ecosystems: what we know and what we need to know. Environ. Sci. Eur. 26, 1–9.

Wagner, M., Lambert, S., 2018. Freshwater microplastics. Emerging environmental contaminants. The Handbook of Environmental Chemistry, 58. Springer Open, Cham, Switzerland.

Wang, J., Peng, J., Tan, Z., Gao, Y., Zhan, Z., Chen, Q., Cai, L., 2017. Microplastics in the surface sediments from the Beijiang River littoral zone: composition, abundance, surface textures and interaction with heavy metals. Chemosphere 171, 248–258.

Wang, Z., Su, B., Xu, X., Di, D., Huang, H., Mei, K., Dahlgren, R.A., Zhang, M., Shan, X., 2018. Preferential accumulation of small (<300 μm) microplastics in the sediments of a coastal plain river network in eastern China. Water Res. 144, 393–401.

Yuan, W., Liu, X., Wang, W., Di, M., Wang, J., 2019. Microplastic abundance, distribution and composition in water, sediments, and wild fish from Poyang Lake,China. Ecotoxicol. Environ. Saf. 170, 180–187.

Zalasiewicz, J., Waters, C.N., Ivar do Sul, J.A., Corcoran, P.L., Barnosky, A.D., Cearreta, A., Edgeworth, M., Gałuszka, A., Jeandel, C., Leinfelder, R., McNeill, J.R., Steffen, W., Summerhayes, C., Wagreich, M., Williams, M., Wolfe, A.P., Yonan, Y., 2016. The geological cycle of plastics and their use as a stratigraphic indicator of the Anthropocene. Anthropocene 13, 4–17.

Zhang, K., Su, J., Xiong, X., Wu, X., Wu, C., Liu, J., 2016. Microplastic pollution of lakeshore sediments from remote lakes in Tibet plateau, China. Environ. Pollut. 219, 450–455.

Zhou, G., Wang, Q., Zhang, J., Li, Q., Wang, Y., Wang, M., Huang, X., 2020. Distribution and characteristics of microplastics in urban waters of seven cities in the Tuojiang River basin. Environ. Res. 189, 109893.