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Research Article

Riverine Microplastic Pollution in Vietnam: A Review of Current Scientific Knowledge and Legal Policies

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Abstract

Plastic litter and microplastic pollution in the aquatic environment have become a major concern since scientists, politicians, and citizens began to learn about the impacts in recent years. This in-depth desk review of scientific papers and Vietnamese policies aims to state the current knowledge, legal framework, and action plan relative to microplastic assessment, release, and control in Vietnamese aquatic environments, especially rivers. Regarding scientific literature, this paper focuses on (i) the occurrence of microplastics in riverine surface water and sediments, (ii) the fate and transfer of microplastics in Vietnam's canals-riverine-estuarine systems, (iii) their accumulation in biota, and (iv) effects to receiving river basins and human health through ingestion of seafood and salts. This paper also points out and describes the main and current Vietnamese policies on plastic litter, including microplastic, and the control of their release into the aquatic environment. Based on the needs identified from the scientific literature review and the action plan to be implemented in the near future, recommendations are given for both scientists and decision-makers to tackle microplastic pollution and provide a sustainable approach.

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Introduction

Plastics are used in a very wide range of applications, including packaging, building and construction, transportation, medicine and health, sports and leisure, electronics, agriculture, and design and manufacturing. Due also to their low production costs, plastics have enabled technological advances, design solutions, eco-performance enhancements, and monetary savings, and became a key component of our daily life. Global plastic production is continuously increasing, from 1.7 million tons in 1950 to 368 million tons in 2019 [1], and is estimated to quadruple by 2050 [2]. As a result of poor waste management and low recycling rate, the production and consumption of plastic products for decades produce a significant number of plastic waste which ended up in the worldwide continental environment and in marine ecosystems [3]. The fate of plastic debris, from larger sizes as macro-plastic to smaller sizes as microplastic, in aquatic systems has become a major worldwide environmental concern in terms of adverse consequences to aquatic life and potentially human health.

Microplastics, i.e., plastic items in the size range of 1 µm to 5 mm, are ubiquitous in the environment. Microplastics are made up of plastic particles of various shapes, e.g., microbeads, pellets, fibers, fragments, films, foams, and various chemical compositions, e.g., polyethylene (PE), polypropylene (PP), polyethylene

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terephthalate (PET), polyester, polystyrene (PS), polyvinyl chloride (PVC), etc. The primary microplastics are pellets, which are a few millimeters spherical shape particles used as input materials in the plastic industry, and microbeads, which are less than a millimeter spherical shape particles added to personal care products such as toothpaste or facial cleanser. These primary microplastics can be discharged directly into the environment following their use and released into wastewaters. The secondary microplastics originate from the fragmentation of larger plastic items due to the effects of weather agents such as ultraviolet radiation, or mechanical, chemical, and biological degradation processes; from the degradation, wear, and tear of synthetic textile and garment products, especially during their processing and washing steps, which are then released to the environment from both domestic and industrial (treated and untreated) wastewaters; from the tire erosion process. Therefore, they can have the form of fragments, films, foams, or fibers. The transport of microplastics via waterways especially rivers [4] and air [5] induce that they can enter: the terrestrial environment and accumulate in soils [6], flora [7], and fauna [8]; the freshwater and marine environments and then accumulate in water and sediments; and finally can enter the human body [9] via drinking water [10], foods [11–12], and air breathing [13]. During their transfer, microplastics can both act as vectors of persistent organic pollutants [14], trace metals [15], and microorganisms like pathogens [16], as well as a sink of toxic inorganic and organic chemicals and additives [16–17]. The toxicological effects of microplastics on aquatic organisms are observed on three levels: individual, cellular, and molecular [18]. Their physical and chemical properties such as size, shape, solubility, surface chemistry and composition, also impact human health via inhalation and ingestion, causing biochemical effects [19].

Asia, especially South East Asia, is considered as a hotspot for plastic pollution, and a large emitter of plastic waste to the oceans [20]. A high variability of microplastic abundances in freshwater and sediment has been observed [21]. Surface water was the most investigated compartment (e.g., 62 studies), followed by sediment (e.g., 41 studies) and biota (e.g., 15 studies). Rivers were the most studied systems, compared to lakes, reservoirs, and dams. To guide future research and to improve microplastic pollution management for sustainable development of highly populated regions such as Asia, the authors recommended standardized methods for microplastic sampling, sample treatment, and laboratory analysis and emphasized microplastic assessment and fluxes estimation. They also highlighted that research can provide a scientific basis for establishing policies and regulatory tools at regional, national, and international scales to, for example, strictly reduce the use of single-use plastics or to replace them [21].

Vietnam, home to over 98 million people in 2021 [22], shifted from a centrally planned to a market economy which transformed the country from one of the poorest in the world into a lower middle-income country, being now one of the most dynamic emerging countries in Southeast Asia region. Between 2012 and 2017, Vietnam's plastic industry expanded at a rate of 11.6% per year on average, outpacing the global plastic industry's 3.9% rise [23]. Over 80% of this plastic production, including consumer products, packaging, and the textile and garment industry, is localized in the South of Vietnam, near Ho Chi Minh City (HCMC) – the economic capital of the country and Binh Duong Province. The poor domestic and industrial wastewater treatments (only 13% of domestic wastewaters, 16% of small and medium- sized enterprises industrial wastewater, and 88% of large-sized enterprises industrial wastewaters are treated [24]) have participated to the tremendous concentrations evidenced for the first time in a Vietnamese aquatic environment, the Saigon River [25]. Those first observations coupled with the fact that fishing is one of Vietnam's primary industries (i.e., the coastline of 3,620 km) motivated then Vietnamese scientists to conduct research on microplastic distribution, sources, and fate in Vietnamese aquatic environments. In the meantime, the weaknesses of solid waste management have pushed Vietnam to be among the main contributors of plastic waste to the oceans [20]. In this context, Vietnam has made strong political commitments and has carried out practical activities to manage and reduce plastic waste, including ocean plastic waste. Resolution No. 36-NQ/TW of October 22, 2018, of the Eighth Conference of the Party Central Committee XII on the strategy for sustainable development of Vietnam's marine economy to 2030, with a vision to 2045, set the goal of "Preventing, controlling, and significantly reducing pollution of the marine environment; becoming a regional leader in minimizing ocean plastic waste" [26]. The Government issued Resolution No. 01/NQ-CP of January 1, 2019, on the main tasks and solutions to implement the socio-economic development plan and state budget estimate in 2019, with the mission of reducing plastic waste and strengthening international cooperation in solving the problem of plastic waste in the ocean [27]. Following this resolution, the Ministry of Natural Resources and Environment has presided over and coordinated with ministries, branches, localities, agencies, organizations, experts, scientists, and international partners concerning the drafting of the Prime Minister's Decision on the

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issuance of the National Action Plan for Management of Marine Plastic Litter by 2030 [28].

Over the past five years, plastic release in the aquatic environment has become a priority environmental concern for researchers, citizens, and policy-makers. This review paper aims to conduct an in-depth desk review of scientific knowledge achieved on microplastic distribution in Vietnamese riverine environments and on the current status of Vietnamese policies and regulations taken regarding microplastics. It also aims to provide some recommendations and perspectives for future research and sustainable action between researchers and decision-makers to reduce the release of microplastics into the environment.

Methodology

The review of scientific literature focused on riverine microplastics in Vietnam. The papers were selected using: Web of Science database, Google Scholar databases, three websites recording Vietnamese scientific journals (http://tapchikttv.vn; https://vjs.ac.vn; http://stdjns.scienceandtechnology.com.vn), and hard copies of research papers published without online versions; keywords: microplastic AND Vietnam AND fiber OR river OR estuary OR biota; and published status or accepted for publication status until December 2021. After screening, the publications related to wastewater treatment plants, marine environments, or plastic debris, were out of the scope of the study and thus not considered. A total of 15 scientific publications were collected (Figure 1).

The review of national policies and regulations on controlling microplastic (and plastic) pollution was conducted by collecting policy documents issued by Ministry of Environment and Natural Resources, Ministry of Agriculture and Rural Development, and Ministry of Science and Technology. The keywords for the search were plastic, microplastic, monitoring, wastewater treatment plant, in both English and Vietnamese languages. A total of 15 documents were selected, including 8 Decisions, 1 Directives, 3 Laws, 2 Resolutions, and 1 Decree.

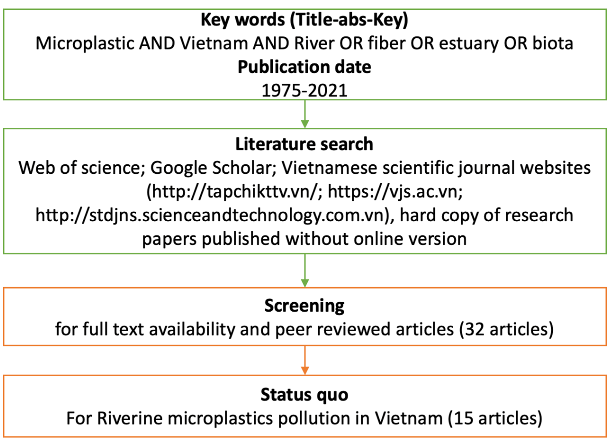

Figure 1 Methodology employed to select the papers.

Current status of microplastic occurrence and fate in Vietnamese riverine ecosystems

The assessment of microplastics in Vietnamese aquatic environments began quite recently; the first study was published in 2018 in the Environmental Pollution [25]. Since then, their occurrence in several rivers, lakes, estuaries, bays, beaches, and even atmospheric fallouts have been assessed in both fresh and marine waters. Until December 2021, 15 research papers focusing on Vietnamese freshwater environments including estuaries (Figure 2) have been published in international and domestic journals, respectively 6 and 9 papers.

1) Occurrence of microplastic in Vietnamese riverine surface waters and sediments

The Saigon River, crossing the megacity of Ho Chi Minh City, was the first environment assessed for microplastic pollution in Vietnam and among the first tropical rivers worldwide (Table 1). At that time, the sampling and analysis protocols were still under analytical development and testing and differed from current recommendations [29]. Microplastics were assessed in the Saigon River and four of its main urban canals by sampling bulk water for anthropogenic fiber analysis and 300 µm mesh size plankton net exposition for fragment analysis. Fibers and fragments were highly concentrated, respectively 172,000 to 519,000 fibers m^{-3} and 10 to 223 fragments m^{-3}, found in various colours and shapes, and were mainly made of polyethylene and polypropylene while the anthropogenic fibers were mainly made of polyester [25]. The temporal dynamic of anthropogenic fibers, e.g., gathering synthetic fibers, artificial fibers, and natural fibers, was also first assessed in this system through monthly sampling in the survey for over a year and a half [30]. For an observation size range of [40–5,000 µm], their concentration varied from a minimum of 22 items L^{-1} observed in July 2017 to a maximum of 251 items L^{-1} observed in August 2016, with 82% of the fibers was in the [40–300 µm] size range, which was smaller than the mesh size of plankton net devices recommended for sampling microplastic in the marine environment [29].

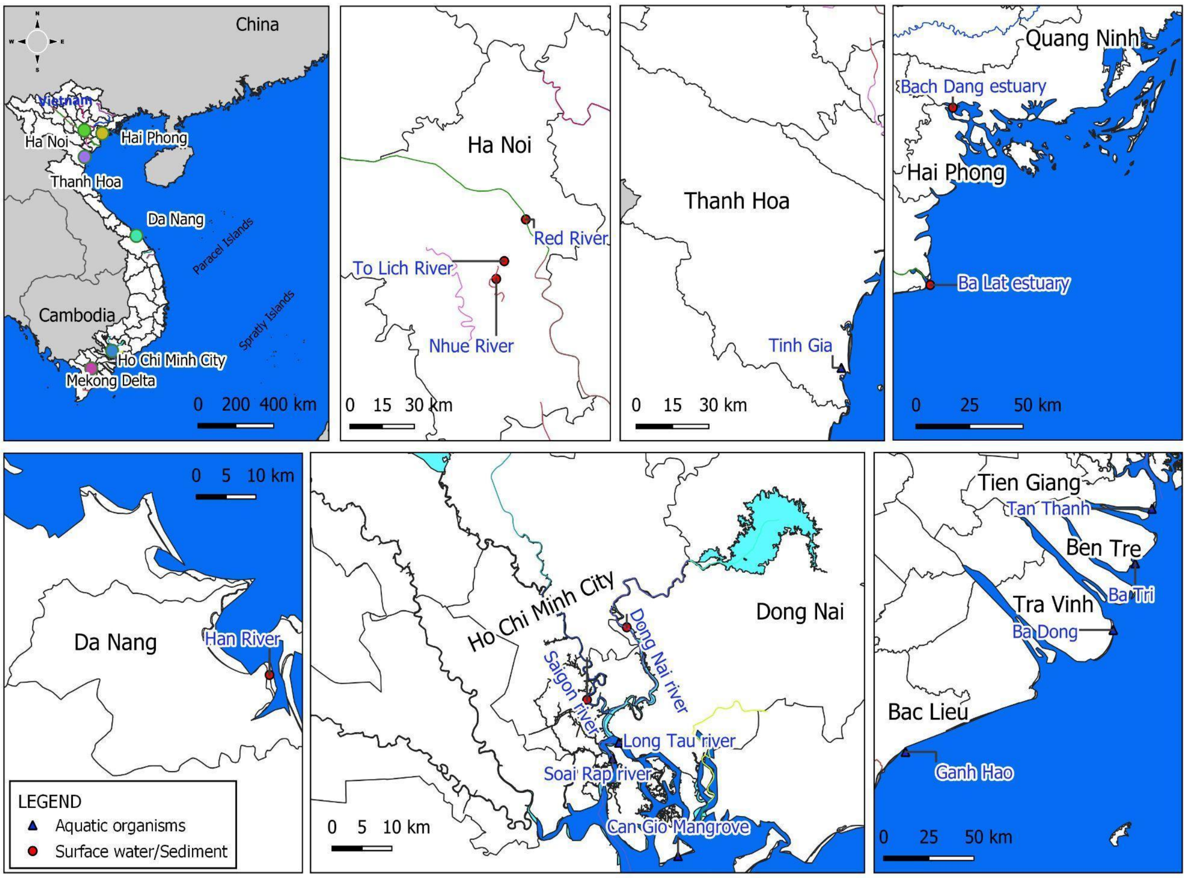

Figure 2 Study areas on riverine microplastic pollution in Vietnam until December 2021.

Table 1 Microplastic, fibre or fragment concentrations measured in riverine waters and sediments from Vietnamese environments

System	Microplastic concentrations		Observation size range (μm)	Polymer identification (% in subsample)	References
	Surface water (items m^{-3})	Sediments (items kg^{-1} dry weight)			
Saigon River	Fibers: 172,000 – 519,000		Fibres: [50 – 5,000]	70% polyester, 9% PET, 5% PE, 4% PP, 4% PE-PP copolymer, 4% rayon, 1% of PP-vistalon, 1% viscose 1% acrylic	[25]
	Fragments: 10 – 223		Fragments: [50 – 5,000]	40% PE, 25% PP, 14% PE/PP, 3 % PS, 2% PA, 2% of PVC, 2% polyepoxy, 2% polyester, 2% of PE/ethyl acrylate, 8% of non-plastic (cellulose, mineral)	
Saigon River	Fibers: 22,000 – 251,000		[40 – 5,000]		[30]
Saigon River, Tau Hu and Ben Nghe canals	778 to 6,566		[500 – 5,000]		[31]

Table 1 Microplastic, fibre or fragment concentrations measured in riverine waters and sediments from Vietnamese environments (*continued*)

System	Microplastic concentrations		Observation size range (µm)	Polymer identification (% in subsample)	References
	Surface water (items m^{-3})	Sediments (items kg^{-1} dry weight)			
Saigon River -	Fibers: 228,120			PE 51%, PP 27%, PVC 14%,	[32]
Dong Nai River	3.9		[300 – 5,000]		[33]
Red River	2.3		[300 – 5,000]		[33]
To Lich River	2,522		[300 – 5,000]		[33]
Han River	2.7		[300 – 5,000]		[33]
Nhue River	93.7		[300 – 5,000]		[33]
Ba Lat estuary		70 – 2,830	[1 – 5,000]		[34]
Bach Dang Estuary	0.98 – 3.42	170 – 650	[300 – 5,000]		[35]

Other researchers also measured microplastic concentration in the Saigon-Dong Nai system [32]. It is interesting to note that despite the different sampling methodologies and observation size range, those authors observed a very similar range of concentrations in this system.

The studies conducted in the Saigon-Dong Nai system pointed out the necessity to conduct in-depth research to understand the source, fate, and transfer of microplastic, but also pointed out the limitations in terms of study comparability when different sampling protocols, laboratory analyses, and observation size range are applied. To address this issue, an adapted methodology was developed and commonly adopted by Vietnamese researchers participating in the COMPOSE project (Creating an Observatory for Measuring Plastic Occurrence in Society and Environment, 2019–2021, funded by the French Ministry of Europe and Foreign Affairs) to implement microplastic monitoring in sediments and surface waters of 21 environments (rivers, lakes, bays, beaches) of eight cities or provinces [33], and extended under the CounterMEASURE2 project (2021–2022, UNEP) to 39 environments from Northern to Southern Vietnam. Based on an observation size range of [300–5,000 µm], the microplastic concentrations measured in January 2020 varied from 0.35 to 2,522 items m^{-3}, with the lowest concentrations recorded in bays and the highest in rivers which were dominated by fibers. Interestingly, the main Vietnamese rivers exhibited lower concentrations than the urban and smaller rivers. Nevertheless, the microplastic concentrations measured in the studied riverine environments were all lower than the ones previously measured in the Sai Gon River and its urban canals, crossing Ho Chi Minh City. Downstream of the Red River Delta system, microplastic concentrations in sediments in the Ba Lat estuary and the mangrove area were dominated by fibers [34] and microplastic concentrations in surface waters and sediments in the Bach Dang Estuary were decreasing from upstream to downstream [35].

In all surveys mentioned, microplastics exhibited different colors, dominated by blue, red, or purple. The nature of polymers observed was analysed in most surveys using Fourier Transform Infrared Spectroscopy (FTIR) or Raman spectrometry and evidenced mainly the presence of polyester, polyethylene, polypropylene, polyamide, polystyrene, and polyvinyl chloride.

2) Fate and transfer of microplastics in the Vietnamese canal-riverine-estuarine system

The fate and transfer of microplastics in the canal-riverine-estuarine system are influenced by various factors and parameters. In Vietnam, few studies have yet addressed those factors. In the Saigon River, Lahens et al. [25] evidenced lower concentrations in the upstream rural part of the river, compared to the sites located in the city center area, close to the domestic wastewater outlets (e.g. the sites located in the urban canals) and downstream of the industrial zones. The authors evidenced that the presence of textile and apparel industries and the high population inhabitants in the Saigon River basin, coupled with the quasi absence of treatment of domestic (i.e., 10%; [36]) and industrial wastewaters (e.g. discharge into the river estimated at 200,000 m^3 d^{-1};

[37]) at that time were an important source of fiber contamination in the Saigon River and its canal system. The tendency of higher concentrations observed in the denser urban zone with low wastewater treatment capacity was confirmed in the same system [31–32]. It was also evidenced in the Red River system with a tendency of decreasing concentrations of microplastics in the Day River surface water from places with high population density to low population density [38] and in the Bach Dang Estuary with decreasing concentrations towards the estuary mouth probably due to water mixing with seawater [35]. In the Day River, the influence of rainfall on the observed concentrations was also suggested as higher concentrations were observed during the sampling of the rainy season than during the one of the dry seasons. The authors hypothesized that surface runoff is dragging along a vast amount of microplastics into the rivers, contributing to its increasing density of microplastics [38]. At the national level, the comparison of rivers, lakes, and bays evidenced the influence of population density and outlets of treated and untreated wastewaters on the measured concentrations in the surface waters [33].

More specifically, the temporal dynamic of anthropogenic fibers in the Saigon River showed that anthropogenic fiber variations in this system were not related to rainfall, monthly water discharges or abiotic factors like temperature, salinity, pH, total suspended solid concentrations and Chlorophyll-a concentrations. Interestingly, the authors evidenced that anthropogenic fiber colour and length distribution varied monthly suggesting variations in the sources and sinks of those fibers in the surface waters of the system. In fact, anthropogenic fibers are composed of fibers of various densities, ranging from 0.91 g cm^{-3} (i.e., polyethylene) to 1.38 g cm^{-3} (i.e., polyester) meaning that they have both the theoretical ability to remain buoyant and to sink in the surface water. Various factors can affect the fate of fibers in the water column and their sinking velocity: the general shape of particles (e.g., spherical, cylindrical, elongated), the spatial orientation of the sinking fibers, the diameter of the fibers, and the turbulence or currents at the water column's surface [39–42].

In the Saigon River, as 50% of the anthropogenic fibers observed ranged between 40 and 80 μm length, Strady et al. [30] hypothesized that the turbulence induced by water current, tides, wind and/or intense navigation are keeping the fibers in the turbulence mixing layer (i.e. the surface water). The low proportion of longest fibers in the surface water (>500 mm) may reflect the fact that they are more likely to sink in the water column. From the anthropogenic fiber concentrations measured monthly in 2017, the authors estimated an annual emission of anthropogenic fibers from the river to the downstream coastal zone of 115–164×10^{12} items per year. Several assumptions underlined this estimation like constant residual river discharge (i.e., net positive water flow) over the whole month; constant concentrations of anthropogenic fibers at low tide over a month; neglection of input and output of anthropogenic fibers into/from the surface water from the sampling site at Bach Dang until the coastal zone; absence of anthropogenic fiber sinking in the water column. This estimation was the first yearly emission of anthropogenic fibers and microplastic toward the ocean based on measurements and showing the impact that those particles may have on the marine ecosystem and especially the biota.

3) Microplastic accumulation in aquatic biota

The ingestion of microplastics was reported for four bivalve species, eight small fish species, and two shrimp species originating from three Vietnamese aquatic environments: the brackish water zone of Tinh Gia in Thanh Hoa province, the Mekong Delta and the Dong Nai Estuary Can Gio mangrove system in Southern Vietnam (Table 2).

In the Asian green mussel *Perna viridis* from Tinh Gia, the measured microplastic concentrations were of 2.60 ± 1.14 item $individual^{-1}$ or 0.29 ± 0.14 item g^{-1} wet weight soft tissues. Despite the low number of individuals measured during this snapshot study (n = 5), the levels are similar to the ones measured with the same digestion's protocol in mussels *Mytilus edulis* (0.61 ± 0.56 item $individual^{-1}$) and oysters *Crassostrea gigas* (2.10 ± 1.71 items $individual^{-1}$) on the French Atlantic coast [43]. The microplastic measured in the green mussels were quite small, from 15 to 400 μm long, and were mainly composed of PP (31%) and PS (23%).

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Table 2 Microplastic concentration in the aquatic organisms from Vietnam

Study area	Studied species of organism	Concentrations	References
Brackish water zone in Tinh Gia, Thanh Hoa Province	Asian green mussel *Perna viridis*	2.60 ± 1.14 item individual^{-1}	[43]
		0.29 ± 0.14 item g^{-1} wet weight soft tissues	
Mekong River delta in Vietnam	Asian clam *M. Lyrata*	1.38 ± 0.11 item g^{-1} of wet weight tissue	[44]
Can Gio mangrove system, Saigon Dongnai river-estuary system	Asian clam *M. Lyrata*	3.6 ± 2.1 fibers individual^{-1}	[45]
		2.7 ± 2.4 fibers g^{-1} wet weight	
Saigon Dongnai river-estuary system, at the branch separation into the Soai Rap River and Long Tau River	Two species of wild shrimps, i.e., *Metapenaeus ensis, Metapenaeus brevicornis*, and six species of wild fishes, i.e., *Cynoglossus puncticeps, Scianidae, Polynemus melanochir, Pseudapocryptes elongatus, Clupeoides borneensis* and *Glossogobius sp*	1.33 to 9.33 fibers individual^{-1}	[46]

In Southern Vietnam, at the outlet of the Mekong Delta, the Asian Clam *M. Lyrata* presented microplastic concentrations of 1.38 ± 0.11 item g^{-1} of wet weight tissue [44]. The protocol used by those authors differed from the current recommendations [47] in terms of reagents and temperature of digestion used. High temperature and strong acid can indeed digest and destroy the plastic polymer itself [47] resulting in an under-evaluation of microplastic concentrations. In the Can Gio beach system strongly influenced by the Saigon-Dong Nai mouth estuary and located a few hundred of kilometers North of the Mekong Delta, Kieu-Le et al. [45] investigated the accumulation of anthropogenic fibers in the Asian clams. The authors targeted anthropogenic fibers instead of microplastics as fragments represented less than 1% of the microplastic-like particles observed, and as a systematic determination of fiber polymers was not possible to perform due to the difficulty to analyse small fibers by FTIR. The measured average concentrations were of 3.6 ± 2.1 fibers individual^{-1} or 2.7 ± 2.4 fibers g^{-1} wet weight during a seven-month sampling period, and no temporal variations were evidenced. As mentioned above, those concentrations are a bit higher than the ones measured by Nguyen et al. [44] is probably due to under-evaluation related to the digestion protocols. Nevertheless, they are of the same range of concentrations as measured in other worldwide bivalve species: (0.4–5.0 items individual^{-1} or 0.3–4.9 items g^{-1} ww in Asian clams (*Corbicula fluminea*) from Taihu Lake, China [48], 0.6–1.3 items g^{-1} wet weight in clams (*Donax cuneatus*) from the Tuticorin coast of the Gulf of Mannar, India [49], 0.69 items individual^{-1} or 0.23 items g^{-1} wet weight in Mediterranean mussels (*Mytilus galloprovincialis*) [50]. The median fiber length over the seven-month period was 627 µm, i.e., for [300–5,000 µm] observation size range, and fibers shorter than 1,000 µm represented nearly 70% of total fibers. Anthropogenic fibers were investigated in different parts of the clams and showed prevalent fiber concentrations measured in the remaining tissues than in the gills and digestive systems. Besides respiration, ingestion, digestion, and excretion processes play a crucial role in the accumulation of non-digestible particles including microplastics, their adherence from the surrounding environment to the remaining tissues was evidenced. The vertical distribution of fibers in the sediment coupled with the clam burying mobility in the sediment influences the number of fibers that can be both ingested by clams or may adhere to their remaining tissues.

In the Saigon-Dong Nai river-estuary system, at the branch separation into the Soai Rap River and Long Tau River, microplastic concentrations were assessed in two species of wild shrimps, and six species of wild fishes (Table 2) [46]. Fragments represented less than 1% of the microplastics observed in the organisms, therefore the concentrations were expressed by the authors in anthropogenic fibers. Anthropogenic fiber concentrations in each individual of each species varied from 1.33 to 9.33 fibers individual^{-1} with the lowest and highest concentrations found in *Polynemus melanochir* and *Clupeoides borneensis*, respectively. The concentrations were a bit higher than the ones measured in 26 species of wild fish from the Pearl River

Estuary, China (0.17 to 1.33 items individual^{-1} [51] and the sizes of fibers, i.e., for [300–5,000 μm] observation size range were also rather small with a median fiber length fluctuated from 503 μm in *Cynoglossus puncticeps* to 868 μm in *Polynemus melanochir* [46].

4) Environmental concerns in receiving river basins and aquatic environments in Vietnam

Microplastics are a threat to the environment, to the biota living in those environments, and to humans depending on resources from those environments. Plastics, including microplastics, are both sinks and sources of contaminants, especially trace metals and organic compounds, to the aquatic environment [14–15]. At Minh Chau Island and Ba Lat estuary, downstream of the Red River Delta in Northern Vietnam, plastic resin pellets leaked in the environments were collected to study their dichloro-diphenyl-trichloroethanes (DDTs), polychlorinated biphenyls (PCBs) and hexachlorocyclohexanes (HCHs) contents [52]. The authors evidenced that the high concentrations of DDTs in pellets from Minh Chau Island might be due to contamination from land sources during long-range transport to the island, rather than from the Minh Chau ambient environment itself, showing the role of carrier of contaminant by the pellets.

The few studies conducted on the microplastic accumulation in aquatic organisms reared in Vietnam evidenced the systematic presence of microplastic in the organisms. There is thus a direct threat relating to the consumption of that seafood, especially for small size and wild fish and shrimp which are usually consumed entirely without removing the gastrointestinal tract [46]. The number of anthropogenic fibers ingested annually by one person from the ingestion of white clams was estimated at about 324 fibers inhabitant^{-1} [45]. Two studies investigated the concentrations of microplastic in Vietnamese sea salts, which constitute another route of exposure for humans and which is also closely related to the state of the upstream basin pollution. Microplastic abundance measured in iodate fine sea salt samples was lower (340 ± 26 items kg^{-1}) than that in raw sea salt samples (878 ± 101 items kg^{-1}), and microplastic abundance among iodate fine table sea salt samples is similar for all regions in Vietnam [53]. The difference between branded and non-branded salts was also investigated and evidenced by microplastic concentrations up to 402.67 items kg^{-1} in non-branded salts compared with a maximum of 276.25 items kg^{-1} in branded salts [54]. According to those last authors, the quality of non-branded salts was affected by not only the seawater where their pellets were crystalized but also the quality of local water sources, production environment where coarse salt was ground and packaged. For both raw and fine sea salts, fibers were the predominant type of microplastics, accounting for 60 to 83 % of total microplastic particles [53]. The chemical composition of microplastic fluctuated between the two studies, as PE, PP and PS were found by FTIR [53] and PET (34%), followed by PE (25%), PS (20%) and PVC (9%) were measured by Raman [54]. As mentioned by Ha [53], the abundance of microplastics in raw sea salt samples collected from Vietnam is similar to that observed in China, Korea, Thailand and the USA (100–700 items kg^{-1}), and higher than observed in Italy, Spain, UK, Indonesia and India (20–300 items kg^{-1}).

In summary, microplastics were found in different aquatic environments and biota in Vietnam with varied levels and characteristics, posing potential threats to the ecosystem and human health via the ingestion of sea foods and salts. The knowledge of the fate and transport of microplastics in the aquatic environment is still limited and needs to be deepened for better control of microplastic pollution.

Present status of Vietnamese policies targeting microplastic in aquatic environments

Before 2018, the Vietnamese policies and laws were not directly addressing the issue of plastic in aquatic environment and its control. Plastics were addressed via the implementation of a tax on some plastic bags to discourage their use [55], of a scheme to decrease the use of non-biodegradable plastic bags by 2020 [56] and of waste sorting at-source and the principle of solid waste 3R (Reduce – Reuse – Recycle) [57]. The publication of Jambeck et al. [20] ranking Vietnam as the top 4th country emitting the most plastic waste into the global oceans was a turning point in the awareness of citizens, researchers and policy makers of the extent of plastic pollution in Vietnam. In June 2018, Vietnam committed to global cooperation in solving marine plastic debris issue at the Canadian G7 summit. Then, Vietnam promulgated policies and laws in order to reduce plastic waste and microplastic release into the aquatic environment, the five most important documents being (i) Resolution No. 36-NQ/TW of the Eighth Conference of the Party Central Committee XII on the strategy for sustainable development of Vietnam's marine economy to 2030, with a vision to 2045 dated on October 22, 2018 [26]; (ii) Decision No. 1746/QĐ-TTg dated on December 4, 2019 on the National Action Plan for Management of Marine Plastic Litter by 2030 [28], (iii) Directive No. 33/CT-TTg 2020 dated on August 20, 2020 on Strengthening the management, reuse, recycling, treatment and minimisation of plastic waste [58], (iv) the Law of Environmental Protection 2020 dated on November 17, 2020 [59] and (v) Decree 08/2022/NĐ-CP dated on January 10, 2022 detailing a number of articles of the Law on Environmental Protection 2020 [60].

Based on these documents, national and local authorities have come up with action plans carried out with the participation of ministries, governments from the central to the local level, businesses, research units, and individual citizens. Those action plans aimed to implement international commitments on reducing marine plastic litter, strengthen the research capacity of plastic-related issues and build monitoring networks on plastic litter and microplastics in the Vietnamese aquatic environment, and build a legal basis to implement national plans on plastic waste, and are deepened in following sections.

1) Focus on the National Action Plan for Management of Marine Plastic Litter by 2030

On December 4th, 2019, the Prime Minister approved the Decision No. 1746/QD-TTg promulgating the National Action Plan for Management of Marine Plastic Litter by 2030 which defined four general objectives:

(1) Effectively implement innovations and fulfill Vietnam's commitments to other countries regarding resolution for marine plastic litter, to eliminate plastic litter from land-based and ocean-based sources, and strive to become a pioneering country in mitigation of marine plastic litter in the region;

(2) Contribute to the implementation of the national strategy for general management of solid waste by 2025 with a vision towards 2050 approved by the Prime Minister via the Decision No. 491/QD-TTg dated May 07, 2018 [61] and ensure development and deployment of the scheme for the improvement of solid waste management in Vietnam;

(3) Take an approach suitable to the circular economy model and facilitate plastic waste collection, recycling, and reuse in Vietnam;

(4) Improve the community and society's awareness towards behaviors and habits concerning single-use plastics and non-biodegradable plastic bags.

Two timelines were defined to implement and achieve the specific objectives. By 2025, (i) reduce marine plastic litter by 50%; collect 50% of abandoned, lost, or discarded fishing gear; prevent the use of single-use plastics and non-biodegradable plastic bags in 80% of coastal tourism areas; ensure nationwide beach clean-up campaigns to be launched at least twice a year; and strive for 80% of marine protected areas to be free of plastic litter; (ii) monitor marine plastic litter annually and assess their abundance every 5 years at a number of estuaries in the 5 major drainage basins in the North, North Central Coast, the central region of Central Vietnam, South Central Coast and the South, and islands with tourism potential located in the 12 insular districts. By 2030: (i) reduce marine plastic litter by 75%; collect 100% of abandoned, lost, or discarded fishing gear, and put an end to disposal of fishing gear in the sea; prevent the use of single-use plastics and non-biodegradable plastic bags in 100% of coastal tourism areas; and strive for 100% of marine protected areas to be free of plastic litter; (ii) monitor marine plastic litter annually and assess their abundance every 5 years at a number of estuaries in the 11 major drainage basins and in the 12 insular districts. Specific tasks and solutions were designed to implement and achieve the objectives, including (i) education and change to behaviour pertaining to plastics and marine plastic litter; (ii) collection, classification, storage, transfer, and processing of plastic waste from coastal and ocean-based activities; (iii) control of plastic litter at source with a special concern to produce solutions to control microplastics release from wastewater of urban areas and industrial parks, especially for coasts, estuaries and coastal waters; (iv) international cooperation, scientific research, application, development and transfer of marine plastic litter processing technologies including the assessment of pollution risks and impacts of plastic litter and microplastics on oceans, marine ecosystems, environment, and human health; and (v) implementation of consistent and effective investigation, survey, review, research and formulation of mechanisms for marine plastic litter management.

2) Policies addressing microplastic control and release

The control of microplastic release into the aquatic environment including the riverine environment, is addressed by different actions supported by specific policies:

2.1) Building plan for reducing and banning the use of primary microplastics in products and goods

Microplastics in products and goods were defined as plastic particles with a diameter less than 5 mm, which are mixed in personal care products, cosmetics, tooth-paste, and detergents [60]. The projects to strengthen the management of those microplastics in products and goods [62–63] specified the establishment of (i) a roadmap to limit the production and import of single-use plastic products, non-biodegradable plastic packaging, and products and goods containing microplastics, (ii) research and evaluation of production, import and use activities of products and goods containing microplastics and propose management solutions for Vietnam, and

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(iii) organizing the implementation of programs and projects on scientific research, application and transfer of advanced and modern technologies in recycling, plastic waste treatment, and production of environmentally friendly products to replace bags, non-biodegradable plastic products, disposable plastic products and products and goods containing microplastics. The roadmap to restrict the production and import of single-use plastic products, non-biodegradable plastic packaging, and products and goods containing microplastics were detailed in Article 64 of Decree 08/2022/ NĐ-CP (dated January 2022) by mentioning two main steps [60]. The first one is from January 1st, 2026, to not manufacture and import non-biodegradable plastic bags with dimensions smaller than 50 cm x 50 cm and a film thickness of less than 50 µm, except the production for export or manufacture and import for packing products and goods. After December 31, 2030, to stop the production and import of single-use plastic products (except for products certified with Vietnam's eco-label), non-biodegradable plastic packaging, and products and goods containing microplastics, except for the production for export and the production and import of non-biodegradable plastic for packaging products and goods.

2.2) Reducing the use and release of plastic and microplastics from fisheries and aquaculture activities

The Decision No. 687/QĐ-BNN-TCTS dated February 5, 2021 approving the Action Plan for Management of Marine Plastic Waste in the Fishery Sector, period 2020–2030, addresses to (i) develop and implement projects to collect lost and discarded fishing gear in the sea in conservation zones, aquatic resource protection zones and other sea areas; (ii) research the impact of microplastics on the chain of seafood production; and (iii) investigate and evaluate for building and updating the database of ocean plastic waste management in the seafood industry [64]. The reduction of microplastic release is targeted indirectly, via the reduction of larger plastic items which might then degrade in-situ into microplastics. More specifically on this issue, by 2030, the plan aims at minimizing the use of disposable plastic supplies and tools: 20% or more of fishing vessels and aquaculture establishments should replace some specialized supplies and tools with environmentally friendly materials or reusable plastics; 50% reduction in the use of foam buoys in marine farming; 80% or more of small-scale seafood processing establishments should replace 30% of single-use plastic bags with environmentally friendly ones or reusable ones. The plan intends to improve the rate of collection, classification, and transfer to the treatment of plastic waste or reuse from seafood production activities like fishing boats (100% of activities targeted), aquaculture establishments (100% of activities targeted), small aquaculture establishments (70% of activities targeted), small-scale processing establishments (80% of activities targeted), fishing ports (100% of activities targeted). Finally, the plan targets to complete the database on marine plastic waste in the seafood industry.

2.3) Controlling the release of microplastics from wastewater

The Decision No. 1746/QĐ-TTg 2019 on the National Action Plan for Management of Marine Plastic Litter by 2030 is targeting to tighten control over waste disposal into water bodies and produce solutions to microplastics from wastewater of urban areas and industrial parks, especially for coasts, estuaries, and coastal waters" [28]. Decision No. 2626/QĐ-UBND was promulgated by the HCMC government on the local action plan for ocean plastic waste management in Ho Chi Minh City until 2030. Action programs directly related to microplastic pollution have been mentioned, including (i) the development and implementation of research projects to assess pollution risks and impacts of plastic waste, especially microplastics, on the seas and oceans, marine ecosystems, the environment, and human health; (ii) research on technology and techniques for collecting, transporting, treating and minimizing ocean plastic waste and microplastic treatment in wastewater [65].

2.4) Assessing and monitoring the level, accumulation, and impact of microplastics

The Decision No. 1746/QĐ-TTg 2019 on the National Action Plan for Management of Marine Plastic Litter by 2030 is targeting to formulate and launch research projects on scientific evidence for marine plastic litter, to assess pollution risks and impacts of plastic litter, especially microplastics, on oceans, marine ecosystems, environment, and human health [28]. In 2021, the Decision No. 1891/QĐ-BKHCN on approving the list of national-level science and technology tasks for selection starting from 2022, approved the research and evaluation of the accumulation and impact of microplastics on the estuarine ecosystem in the South-Central Coast [66]. The three objectives are specifically to evaluate the accumulation and impacts of microplastics on the riverine ecosystem in the South-Central Coast, to develop a technical guide to determine the accumulation and ecotoxicity of microplastics in estuary ecosystems, and to apply the technical guide to assess the level of accumulation and ecotoxicity of microplastics for some aquatic species in the study area. The implementation of these objectives has been carried out with the participation of national and international experts in different scientific projects.

2.5) Reducing the release of plastic through Extended Producer Responsibility (EPR)

Decree 08/2022/NĐ-CP (dated January 2022) also controlled the release of plastic into the environment by clarification of the responsibility of producers in recycling the products and packages. The producers and importers have to contribute to the Vietnam Environmental Protection Fund for recycling support. In dealing with the activities relating to EPR, the plan to establish the National EPR Council was also mentioned. The responsibility of this Council is to advise and assist the Minister of Natural Resources and Environment in managing, supervising, and supporting the implementation of the responsibilities of exporters and importers (EPR) for recycling products and packages, collecting and treating waste according to the regulation of law [60].

Conclusions and recommendations

The current policies and laws enforced by the Vietnam Government indicate deep concern for plastic and microplastic pollution issue in the aquatic environment and strong endeavour of implementing Vietnam's commitment in reducing marine plastic litter. This review highlighted that both knowledge acquisition and policies enforcement are progressing alongside, leading to science-based policies. The interactions between scientists and policy-makers could be enhanced on specific tasks, evidenced by the in-depth review, to reinforce the sustainability of the actions, consisting of: (i) to standardize protocols for microplastic monitoring at national and provincial levels; (ii) to deepen the identification of microplastic sources in the environment, especially the contribution of wastewaters; (iii) to measure microplastic accumulation in seafood, drinking water, salt, air and investigate their potential risk and impact to human health; and (iv) to deepen the knowledge on microplastic release from aquacultural and agricultural activities and encourage research on materials to substitute plastics.

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Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Plastic Europe, Plastic - The facts 2020, 2021.

[2] Bourguignon, D. Plastics in a circular economy - Opportunities and challenges. European Parliamentary Research Service, May 2017.

[3] Geyer, R., Jambeck, J.R., Law, K.L. Production, use, and fate of all plastics ever made. Science Advances, 2017, 3(7), e1700782.

[4] Lu, H.C., Ziajahromi, S., Neale, P.A., Leusch, F.D.L. A systematic review of freshwater microplastics in water and sediments: Recommendations for harmonisation to enhance future study compa-risons. Science of the Total Environment, 2021, 781, 146693.

[5] Dris, R., Gasperi, J., Saad, M., Mirande, C., Tassin, B. Synthetic fibers in atmospheric fallout: A source of microplastics in the environment?. Marine Pollution Bulletin, 2016, 104(1), 290–293.

[6] Kim, S.K., Kim, J.S., Lee, H., Lee, H.J. Abundance and characteristics of microplastics in soils with different agricultural practices: Importance of sources with internal origin and environmental fate. Journal of Hazardous Materials, 2021, 403, 123997.

[7] Leifheit, E.F., Lehmann, A., Rillig, M.C. Potential effects of microplastic on Arbuscular Mycorrhizal Fungi. Frontiers in Plant Science, 2021, 12, 626709.

[8] Rezania, S., Park, J., Md Din, M.F., Mat Taib, S., Talaiekhozani, A., Yadav., K.K., Kamyab, K. Microplastics pollution in different aquatic environments and biota: A review of recent studies. Marine Pollution Bulletin, 2018, 133, 191–208.

[9] Prata, J.C., da Costa, J.P., Lopes, I., Duarte, A.C., Rocha-Santos, T. Environmental exposure to microplastics: An overview on possible human health effects. Science of the Total Environment, 2020, 702, 134455.

[10] Oßmann, B.E. Microplastics in drinking water? Present state of knowledge and open questions. Current Opinion in Food Science, 2021, 41, 44–51.

[11] Zhang, Q., Xu, E.G., Li, J., Chen, G., Ma, L., Zeng, E.Y., Shi, H. A review of microplastics in table salt, drinking water, and air: Direct human exposure. Environmental Science and Technology, 2020, 54(7), 3740–3751.

[12] Kwon, J.H., Kim, J.W., Pham, T.D., Tarakdar, A., Hong, S., Chun, S.H., …, Jung, J. Microplastics in food: A review on analytical methods and challenges. International Journal of Environmental Research and Public Health, 2020, 17(18), 6710.

[13] Gasperi, J., Wright, S.L., Dris, R., Collard, F., Mandin, C., Guerrouache, M., …, Tassin, B. Microplastics in air: Are we breathing it in?. Current Opinion in Environmental Science & Health, 2018, 1, 1–5.

[14] Rochman, C.M., Browne, M.A., Halpern, B.S., Hentschel, B.T., Hoh, E., Karapanagioti, H.K., …, Thompson, R.C. Classify plastic waste as hazardous. Nature, 2013, 494(7436), 169–171.

[15] Ashton, K., Holmes, L., Turner, A. Association of metals with plastic production pellets in the marine environment. Marine Pollution Bulletin, 2010, 60(11), 2050–2055.

[16] Naik, R.K., Naik, M.M., D'Costa, P.M., Shaikh, F. Microplastics in ballast water as an emerging source and vector for harmful chemicals, antibiotics, metals, bacterial pathogens and HAB species: A potential risk to the marine environment and human health. Marine Pollution Bulletin, 2019, 149, 110525.

[17] Paluselli, A., Kim, S.K. Horizontal and vertical distribution of phthalates acid ester (PAEs) in seawater and sediment of East China Sea and Korean South Sea: Traces of plastic debris?. Marine Pollution Bulletin, 2020, 151, 110831.

[18] Browne, M.A., Underwood, A.J., Chapman, M.G., Williams, R., Thompson, R.C., van Franeker, J.A. Linking effects of anthropogenic debris to ecological impacts. Proceedings of the Royal Society B: Biological Sciences, 2015, 282(1807). 20142929.

[19] WHO, Dietary and inhalation exposure to nano- and microplastic particlesand potential implications for human health. 2022.

[20] Jambeck, J.R., Andrady, A., Geyer, R., Narayan, R., Perryman, M., Siegler, T., …, Lavender Law, K. Plastic waste inputs from land into the ocean. Science, 2015, 347(6223), 768–771.

[21] Phuong, N.N., Duong, T.T., Quynh Le, T.P., Hoang, T.K., Ngo, H.M., Phuong, N.A., …, Sempere, R. Microplastics in Asian freshwater ecosystems: Current knowledge and perspectives. Science of the Total Environment, 2022, 808. 151989.

[22] General Statistics Office of Vietnam. Population and Employment. Population. 2022.

[23] Vietnam Plastic Association, Vietnam Plastics Industry Overview. 2019.

[24] Monre, V. Vietnam National Environmental Status Report 2018: Water Environment of River Basins.

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

[26] Resolution No. 36-NQ/TW of the Eighth Conference of the Party Central Committee XII dated on October 22, 2018 on the strategy for sustainable development of Vietnam's marine economy to 2030, with a vision to 2045.

[27] Resolution No. 01/NQ-CP dated on January 1, 2019 on the main tasks and solutions to implement the Socio-Economic Development Plan and State Budget in 2019.

[28] Decision No. 1746/QD-TTg dated on December 4, 2019 on the National Action Plan for Management of Marine Plastic Litter by 2030.

[29] GESAMP, Guidelines for the monitoring and asseement of plastic litter in the ocean, 2019.

[30] Strady, E., Kieu-Le, T.C., Gasperi, J., Tassin, B. Temporal dynamic of anthropogenic fibers in a tropical river-estuarine system. Environmental Pollution, 2020, 259, 113897.

[31] Nguyen, N.T., Han, N.T.N., Duyen, D.V.K., Nhon, N.T.T., Quyen, D.T.T., Hien, T.T. Abundances, distributions and characteristics of microplastics in Tau Hu - Ben Nghe Canal. Microplastics Water Environment Conference. Koh Samui Thailand, 2019.

[32] Huynh Phu, Huynh Thi Ngoc Han, Nguyen Ly Ngoc Thao, Dang Van Dong, and Trinh Gia Han, Nghien cuu muc do o nhiem vi nhua trong nuoc va tram tich song Sai Gon–Dong Nai. Tạp Chi Khi Tuong Thu Van, 2021, 73, 69–81.

[33] Strady, E., Dang, T.H., Dao, T.D., Dinh, H.N., Do, T.T.D., Duong, T.N., …, Vo, V.C. Baseline assessment of microplastic concentrations in marine and freshwater environments of a developing Southeast Asian country, Viet Nam. Marine Pollution Bulletin, 2021, 162, 111870.

[34] Hien, H.T., Cuc, N.T.K. Bouc dau tim hieu ve su phan bo va dac diem cua vi nhua trong lop tram

tich be mat vung cua song Ba Lat, mien Bac Viet Nam. IUCN & ISPONRE, 2021.

[35] Nghi, D.T., Ngoc, D.H., Chung, K.L.T., Strady, E., Huyen, B.T.M., Coung, L.D., …, Lim, D.T. Danh gia o nhiem microplastic trong moi truong cua song Bach Dang thuoc he thong song Hong Viet Nam. Vietnam Journal of Chemistry, 2020, 58(6E12), 140–146, 2020.

[36] FAO, Ed., Strengthening the enabling environment for food security and nutrition. Rome: FAO, 2014.

[37] Vo, P.L. Urbanization and water management in Ho Chi Minh City, Vietnam-issues, challenges and perspectives. GeoJournal, 2007, 70(1), 75–89.

[38] Oanh, D.T., Thuy, D.T., Huong, N.T.N., Quynh, H.T., Quynh, L.T.P., Phu, D.H., …, Thuong, B.H. Preliminary results on microplastics in surface water from the downstream of the Day River. Vietnam Journal of Earth Sciences, 2021.

[39] Bagaev, A., Mizyuk, A., Khatmullina, L., Isachenko, I., Chubarenko, I. Anthropogenic fibres in the Baltic Sea water column: Field data, laboratory and numerical testing of their motion. Science of the Total Environment, 2017, 599–600, 560–571.

[40] Khatmullina, L., Isachenko, I. Settling velocity of microplastic particles of regular shapes. Marine Pollution Bulletin, 2017, 114(2), 871–880.

[41] Reisser, J., Slat, B., Noble, K., du Plessis, K., Epp, M., Proietti, M., …, Pattiaratchi, C. The vertical distribution of buoyant plastics at sea: An observational study in the North Atlantic Gyre. Biogeosciences, 2015, 12(4), 1249–1256.

[42] Waldschläger, K., Schüttrumpf, H. Effects of particle properties on the settling and rise velocities of microplastics in freshwater under laboratory conditions. Environmental Science and Technology, 2019, 53(4), 1958–1966.

[43] Nam, P.N., Tuan, P.Q., Thuy, D.T., Quynh, L. T.P., Amiard, F. Contamination of microplastics in biavalve: First evaluation in Vietnam. Vietnam Journal of Earth Sciences, 2019, 41(3), 252–258.

[44] Hang, N.T.G., Nhi, D.T.K., Dao, T.T.A., Mai, N.T.T.T., Thanh, T.B., Thuyen, L.X., O nhiem vi nhua trong ngheu (*Meretrix lyrata* Sowerby, 1851) tại Dong bang song Cuu Long, Viet Nam. Tap Chi Phat Trien Khoa Hoc Va Cong Nghe - Khoa Hoc Tu Nhien, 2021, 5(4), 1443–1454.

[45] Kieu-Le, T.C., Tran, Q.V., Truong, T.N.S., Strady, E. Anthropogenic fibres in white clams, *Meretrix lyrata*, cultivated downstream a developing megacity, Ho Chi Minh City, Viet Nam. Marine Pollution Bulletin, 2022, 174, 113302.

[46] Chung, K.L.T., Thinh, T.Q., Sang, T.T.N., Strady, E. First evaluation on microplastics abundance level in several wild aquatic organisms captured in the downstream of the Saigon – Dong Nai River system, Vietnam. Vietnam Journal of Science, Technology and Engineering, 2020.

[47] Dehaut, A., Cassone, A.L., Frere, L., Hermabessiere, L., Himber, C., Rinnert, E., …, Paul-Pont, I. Microplastics in seafood: Benchmark protocol for their extraction and characterization. Environmental Pollution, 2016, 215, 223–233.

[48] Su, L., Cai, H., Kolandhasamy, P., Wu, C., Rochman, C.M., Shi, H. Using the Asian clam as an indicator of microplastic pollution in freshwater ecosystems. Environmental Pollution, 2018, 234, 347–355.

[49] M. Narmatha Sathish, K. Immaculate Jeyasanta, and J. Patterson, Monitoring of microplastics in the clam Donax cuneatus and its habitat in Tuticorin coast of Gulf of Mannar (GoM), India. Environmental Pollution, 2020, 266, 115219.

[50] Gedik, K., Eryasar, A.R. Microplastic pollution profile of Mediterranean mussels (*Mytilus galloprovincialis*) collected along the Turkish coasts. Chemosphere, 2020, 260, 127570.

[51] Lin, L., Ma, L.S., Li, H.X., Pan, Y.F., Liu, S., Zhang, L., …, He, W.H. Low level of microplastic contamination in wild fish from an urban estuary. Marine Pollution Bulletin, 2020, 160, 111650.

[52] Le, D.Q., Takada, H., Yamashita, R., Mizukawa, K., Hosoda, J., Tuyet, D.A. Temporal and spatial changes in persistent organic pollutants in Vietnamese coastal waters detected from plastic resin pellets. Marine Pollution Bulletin, 2016, 109(1), 320–324.

[53] Ha, D.T. Microplastic contamination in commercial sea salt of Vietnam. Vietnam Journal of Science and Technology, 2021, 59(3), 333.

[54] Khuyen, V.T.K., Le, D.V., Anh, L.H., Fischer, A.R., Dornack, C. Investigation of Microplastic Contamination in Vietnamese Sea Salts Based on Raman and Fourier-Transform Infrared Spectroscopies. EnvironmentAsia, 2021, 14, 113.

[55] Law on Environmental Protection Tax No. 57/2010/QH12 dated on November 15, 2010.

[56] Decision No. 582/QĐ-TTg dated on April 11, 2013 approving the scheme on improving the environmental pollution control for the use of non-biodegradable plastic bags by 2020.

[57] Law on Environmental Protection No. 55/ 2014/ QH13 dated on June 23, 2014.

[58] Directive No. 33/CT-TTg 2020 dated on August 20, 2020 on strengthen the management, reuse, recycling, treatment and minimisation of plastic waste.

[59] Law on Environmental Protection No. 72/2020/ QH14 dated on November 11, 2020.

[60] Decree 08/2022/NĐ-CP dated on January 10, 2022 detailing a number of articles of the Law on Environmental Protection 2020.

[61] Decision No. 491/ĐD-TTg dated on May 7, 2018 on approving the adjusted national strategy on integrated management of solid wastes up to 2025, with a vision toward 2050.

[62] Decision No. 2436/QĐ-BTNMT, 2021.

[63] Decision No. 1316/QD-TTg, 2021.

[64] Decision No. 687/QĐ-BNN-TCTS dated on February 5, 2021 on approving the Action Plan for Management of Marine Plastic Waste in Fishery Sector, period 2020 – 2030.

[65] Decision No. 2626/QĐ-UBND promulgated by the HCMC government on local action plan for ocean plastic waste management in Ho Chi Minh City until 2030.

[66] Decision No. 1891 /QĐ-BKHCN on approving the list of national-level science and technology tasks for selection starting from 2022.