DOI: 10.31276/VJSTE.2025.0018

Microplastics in Vietnamese seafood and potential human exposure: A mini-review

Trung-Hau Nguyen[1, 2], To Thi Hien[2, 3], Thanh-Son Dao[2, 4*]

[1]Faculty of Biology and Biotechnology, University of Science, 227 Nguyen Van Cu Street, Cho Quan Ward, Ho Chi Minh City, Vietnam
[2]Vietnam National University Ho Chi Minh City, Linh Trung Ward, Thu Duc City, Ho Chi Minh City, Vietnam
[3]Faculty of Environment, University of Science, 227 Nguyen Van Cu Street, Cho Quan Ward, Ho Chi Minh City, Vietnam
[4]Faculty of Environment and Natural Resources, Ho Chi Minh City University of Technology (HCMUT), 268 Ly Thuong Kiet Street, Dien Hong Ward, Ho Chi Minh City, Vietnam

Received 26 March 2025; revised 17 April 2025; accepted 20 May 2025

Abstract:

In this article, we review the occurrence and characteristics of microplastics (MPs) in marine organisms used as food (seafood) from Vietnam and assess the consumers' health risks related to MPs-contaminated seafood. Twenty-one marine species of fish, shrimp, and bivalves were reported to accumulate MPs in their tissues, with the highest abundance in fish (*Decapterus maruadsi,* 87 items/individual) and the lowest abundance in hard clam (*Meretrix lyrata,* 0.25 items/individual). The mean values of MPs abundance (items/g wet weight - ww) were 2.44, 0.73, and 0.85 in fish, shrimp, and bivalves, respectively. Fibre was the most common shape of MPs, but fragmented MPs were also observed in the tissues of marine organisms, and beads were only found in shrimp. Various MPs colours and more than ten MPs polymers were noted in the seafood. The estimated daily intake of microplastics (pEDI) was low (<1) based on the consumption of each seafood group, but it became high (>1) when pooled for all seafood. The total MPs that one person can ingest from seafood could be up to 22,876 items annually. Further quantitative studies of MPs in other kinds of food, spices, drinks, and air in Vietnam are necessary for a comprehensive assessment of human health risks associated with MPs exposure.

Keywords: **bivalves, fish, human health risks, microplastics, shrimp.**

Classification numbers: **3.2, 5.3**

1. Introduction

Microplastics (MPs, size 1-5,000 µm) have been considered an emerging contaminant and are of high concern for environmental quality, ecological risks, and human health worldwide [1-3]. MPs can be primarily produced for various industrial, agricultural, and cosmetic applications and can also be secondarily formed through the fragmentation of macroplastics under extreme environmental conditions [1, 4]. MPs are widely found in different environments, especially in marine waters. Between 8 and 10 million tons of plastics annually end up in the ocean, and between 75 and 199 million tons of plastics in the marine environment have been estimated globally [5]. The highest MPs abundance in water could exceed 500 items/l [6]. Z. Xu, et al. (2024) [5] estimated that approximately 171 trillion MPs particles (~2.3 million tons) are present on the ocean surface, but this amount will continue to increase due to (i) the rise in plastic production and emissions into the environment [7], and (ii) the continuous fragmentation of macroplastics in the environment.

Marine organisms such as bivalves, shrimp, and fish can ingest and accumulate MPs by directly consuming suspended MPs from their surrounding habitats or by indirectly consuming MPs-contaminated prey. The presence of MPs in marine bivalves, shrimp, and fish has been widely documented [5, 8-10]. Fish have served as an important source of protein for human beings for over 42,000 years, yet more than 320 marine fish species have been reported to be contaminated with MPs [10]. Marine bivalves are harvested at up to 15 million tons annually for human consumption [11]. The total shrimp production for human consumption exceeded 3.2 million tons in 2022 [12]. Therefore, MPs-contaminated seafood has attracted the attention of researchers, industries, environmental managers, and public consumers worldwide due to the common and popular consumption of seafood and the high potential health risks associated with MPs [13]. MPs, plastic additives, and biofouling pollutants on plastic surfaces can cause various potentially harmful physical and chemical

*Corresponding author: Email: dao.son@hcmut.edu.vn

impacts on human health at the genetic, cellular, and organ levels [1, 10, 14, 15]. Consequently, several diseases related to the cardiovascular and immune systems, as well as the digestive tract, are assumed to be potentially contributed to by MPs and their associated pollutants.

The first publication of MPs from Vietnam was reported by L. Lahens, et al. (2018) [6]. Since then, many studies on MPs in various environments, including water and sediment [16-20], air [21], sand [22], soil [23], and road dust [24], have been reported. During the same period, MPs in organisms, including fish, shrimp, and bivalves, have been investigated [4, 25-34]. These marine organism groups are commonly served in the meals of many Vietnamese, and the amount of seafood consumed in Vietnam is quite high [31, 35, 36]. Studies have estimated MPs ingestion from some bivalves in Vietnamese consumers [4, 32]. However, this issue may be underestimated because many other MPs-contaminated seafood species in Vietnam have not been taken into account. Therefore, this review was conducted to provide an integrated overview of MPs in Vietnamese seafood, including the abundance and physical and chemical characteristics of MPs, as well as the potential MPs exposure for consumers through seafood consumption. This is crucial for potential health risk assessment and food safety issues related to MPs in Vietnam.

2. Methods

We collected original scientific publications on MPs in marine organisms from Vietnam over the last seven years (from 2018 to 2024), using Scopus, Web of Science, ScienceDirect, SpringerLink, Wiley Online Library, Google Scholar, and PubMed. A combination of the following keywords was employed: “microplastics”, “bivalves”, “fish”, “shrimp”, “marine animals”, and “Vietnam”. To ensure the focus of the present study, relevant articles were downloaded. This process was repeated until no additional articles were identified. The obtained articles were further screened and checked to identify those describing MPs in marine organisms used as seafood in Vietnam (hereafter referred to as seafood). Only 17 articles met the criteria, in which fish, shrimp, and bivalves in Vietnam were reported to be contaminated with MPs in their tissues (Fig. 1).

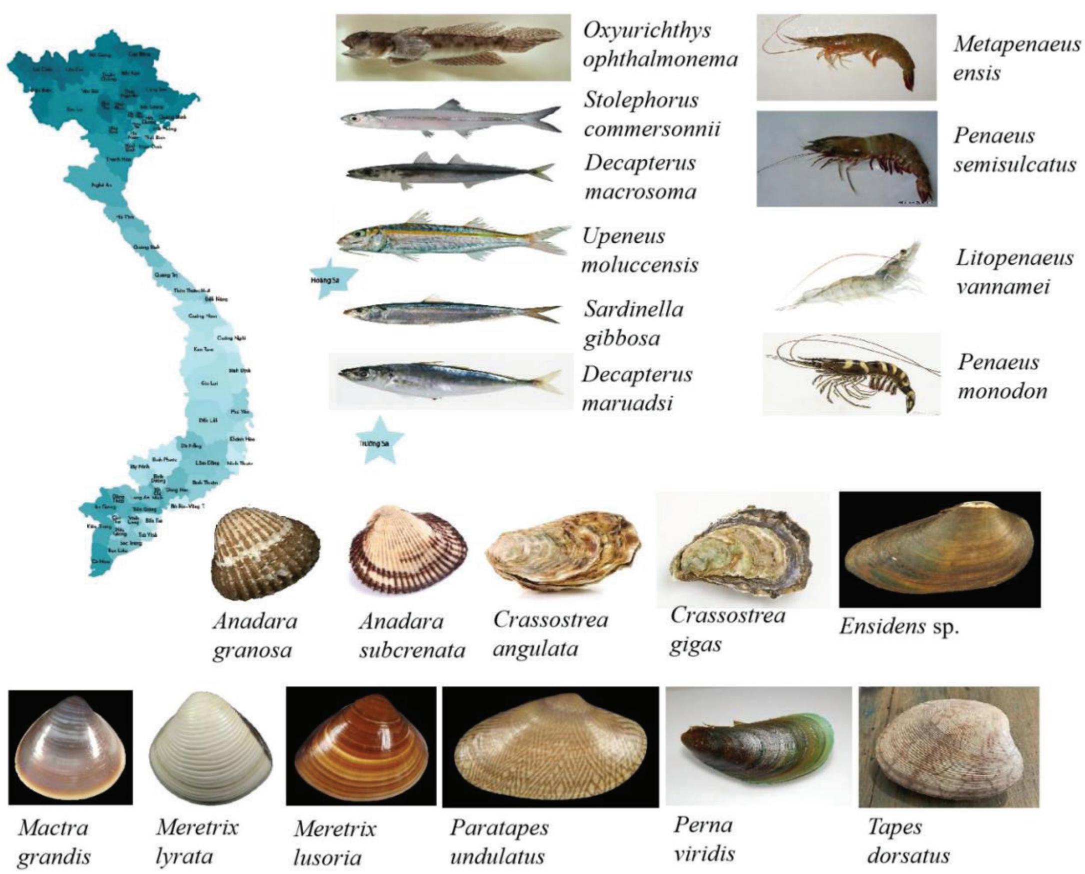

Fig. 1. Microplastic-contaminated fish, shrimp, and bivalves along the coastal waters of Vietnam.

The estimated daily intake of plastic (pEDI) for human exposure was calculated based on the equation: pEDI (oral) = (pi × RI)/BW [37], where pi is the MPs abundance in seafood tissue, RI is the average amount of seafood consumed daily by an adult, and BW is the average body weight of an adult (60 kg). When pEDI >1, it indicates a high intake of MPs, while pEDI <1 reveals a low intake. The total MPs ingestion through each type of seafood in one year was calculated by multiplying the pEDI value by 365 (days).

3. Microplastics in seafood

Microplastics were reported in the tissues of six species of fish, four species of shrimp, and eleven species of bivalves collected along the coastal waters of Vietnam (Fig. 1). Generally, most publications from Vietnam reported MPs in bivalves, including oysters, clams, and mussels; whereas only two papers described MPs in fish and one paper noted MPs in shrimp from Central Vietnam (Table 1). Among the MPs-contaminated organisms, the most frequently investigated include hard clams (*Anadara granosa, Meretrix lyrata*), mussels (*Perna viridis*), and oysters (*Crassostrea gigas*) from several regions across Vietnam (Table 1).

It is not surprising that the total number of peer-reviewed papers related to MPs in seafood from Vietnam is much lower than that in Asia and the rest of the world. For example, there are up to 650 papers reporting MPs in 46 species of marine bivalves (mussels, oysters, clams, scallops, cockles) worldwide [5]. Another review by J. Oza, et al. (2024) [10] examined 112 publications and reported 234 marine fish species in Asia accumulating MPs in their tissues. However, the assessment and prediction of human health risks for Vietnam would be more realistic based on the outcomes of MPs case studies conducted within the country. Therefore, the MPs-reviewed information from Vietnam will help determine the status of MPs-contaminated seafood in the region, as well as perspectives on addressing MPs in seafood.

The number of MPs in individual organisms varied significantly, from 0.25 items/individual (in the clam *Meretrix lyrata*) to 87 items/individual (in the fish *Decapterus maruadsi*). This variation is likely due to the organisms' sizes, feeding behaviours, microhabitats, and the MPs-contaminated environments [10]. Even within the same species, such as the hard clam *M. lyrata*, MPs abundance varied from 0.25 items/individual collected in Nam Dinh coastal waters to 10 items/individual collected in Thai Binh coastal waters (Table 1). The accumulation of MPs in these organisms is influenced by their surrounding environments; therefore, the significant differences in MPs abundance among organisms can be attributed to the varying levels of MPs contamination at local coasts in Vietnam. Additionally, within the same species at the same location, larger or older individuals may accumulate more MPs than smaller or younger ones [4]. To compare different groups of organisms, MPs abundance was expressed as items per gram of wet weight (items/g ww). The MPs abundance in fish varied considerably, with lower abundance in the species *Sardinella gibbosa* (0.44-0.59 items/g ww) and *Decapterus maruadsi* (0.9-1.1 items/g ww), and higher abundance in the species *Upeneus moluccensis* (3.45-4.12 items/g ww; Table 1). The average levels of MPs abundance in shrimp collected from the coastal region of Cau Hai lagoon, Central Vietnam, ranged from 0.5 to 1.1 items/g ww. In bivalves, MPs abundance varied from 0.02 to 5.36 items/g ww in *M. lyrata* (Table 1). If the reported MPs information for the fish, shrimp, and bivalve species in Table 1 is representative of Vietnamese seafood, the mean values of MPs abundance were 2.44 (±1.37) items/g ww in fish, 0.73 (±0.26) items/g ww in shrimp, and 0.85 (±1.90) items/g ww in bivalves.

Marine fish in Asia have been reported to accumulate MPs from 0.05 items/individual (in the species *Selaroides leptolepis*) to 95.65 items/individual (in *Auxis thazard*) [10]. In bivalves, MPs abundance also varies significantly among species and locations of sample collection worldwide. For example, the lowest observed MPs abundance was 0.01 items/individual of *Cerastoderma glaucum* from a natural area in Italy, while the highest was 178 items/individual

Table 1. Microplastic abundance in seafood from Vietnam.

No	Species	MP abundance (items/idv)	MP abundance (items/g ww)	MP sizes (µm)	Polymers	Extraction methods	Locations	Ref.
	Fish							
1	*Decapterus maruadsi*	71-87	0.9-1.1	<0.1-0.5	N/A	KOH (10%), and NaI	Phu Yen and Hue coastal	[28]
2	*Decapterus macrosoma*	4.7-23.8	0.3-5.16	115-5,000	PE, polyvinyl ether, polymethacrylate, polydichloroethylene, polydivinyl ester, poly ester, polytetrafluoroethylene (PTFE)	KOH (10%)	Binh Dinh coastal	[34]
3	*Oxyurichthys ophthalmonema*	6.2-17.2	1.3-4.6	92-5,000			Binh Dinh coastal	[34]
4	*Sardinella gibbosa*	11.6±4.9	0.44-0.59	102-5,000			Binh Dinh coastal	[34]
5	*Stolephorus commersonnii*	9.7-21.3	1.09-6.21	95-5,000			Binh Dinh coastal	[34]
6	*Upeneus moluccensis*	12.1-14.3	3.45-4.12	133-5,000			Binh Dinh coastal	[34]
	Shrimp							
1	*Metapenaeus ensis*	2.5±0.5	0.7±0.3	0.1-1	Rayon, PA, PE, PET, PS, polyacrylic	KOH (10%), NaI	Dam Cau Hai	[29]
2	*Penaeus semisulcatus*	2.3±0.7	0.6±0.2	0.1-1	Rayon, PA, PE, PET, PS, polyacrylic	KOH (10%), NaI	Dam Cau Hai	[29]
3	*Litopenaeus vannamei*	8.6±3.5	1.1±0.4	0.1-1	Rayon, PA, PE, PET	KOH (10%), NaI	Dam Cau Hai	[29]
4	*Penaeus monodon*	7.7±3.5	0.5±0.3	0.1-1	Rayon, PA, PE, PET	KOH (10%), NaI	Dam Cau Hai	[29]
	Bivalves							
1	*Anadara granosa*	8.9±5.4	4.2±3.2	0.3-5	PET, PE, rayon	KOH (10%)	Mekong river estuaries	[31]
2	*Anadara granosa*	3.26-13	N/A	0.3-5	N/A	KOH (10%)	Thi Nai lagoon	[39]
3	*Anadara subcrenata*	1-3	0.1-0.8	N/A	PET	KOH (10%), NaI	Phu Yen coastal	[30]
4	*Anadara granosa*	12.6±2.7	3.77±0.54	0.3-2	PE, PP	KOH (10%), KI (50%)	Thai Binh coastal	[40]
5	*Crassostrea angulata*	0.67±8.33	0.02±0.33	0.3-5	Acrylate, alkyd, PP, polyester, PE, PET	KOH (10%)	Cha Va river	[32]
6	*Crassostrea gigas*	1-9	0.1-0.5	N/A	PET	KOH (10%), NaI	Phu Yen coastal	[30]
7	*Crassostrea gigas*	33.25±25.93	2.36±2.14	0.001-5	Nylon, rayon, PFs, EVOH, PTFE, MUF, PAH, polyester, PA, PE, PVA, CPP, CP	KOH (10%), H_2O_2 (30%), NaI	Da Nang coastal	[27]
8	*Crassostrea gigas*	8.2±0.45	1.24±0.26	0.3-2	PE, PP	KOH (10%), KI (50%)	Thai Binh coastal	[40]
9	*Crassostrea rivularis*	1.11	0.06	0.3-5	PA, PE, PP	KOH (10%)	Can Gio coastal	[41]
10	*Ensis sp.*	5.9±2.8	0.7±0.3	0.3-5	PET, rayon	KOH (10%)	Binh Dien market	[31]
11	*Mactra grandis*	9.40±1.82	1.06±0.25	0.3-2	PE, PP	KOH (10%), KI (50%)	Phu Yen coastal	[30]
12	*Meretrix lusoria*	1-3	0.2-0.5	N/A	PET	KOH (10%), NaI	Phu Yen coastal	[30]
13	*Meretrix lyrata*	0.25-0.54	0.02-0.04	1.61-4.70	PE, PET, PP, nylon, EVA	KOH (10%)	Nam Dinh coastal	[26]
14	*Meretrix lyrata*	0.33-0.67	0.25-0.28				Quang Ninh coastal	[26]
15	*Meretrix lyrata*	N/A	1.38± 0.1	N/A	N/A	H_2O_2 (30%), HCl (37%), NaOH (5M)	Tan Thanh, Ba Tri, Ganh Hao, Ba Dong coastals	[42]
16	*Meretrix lyrata*	6.4±2.6	1.1±0.4	0.3-5	PET, rayon	KOH (10%)	Binh Dien market	[31]
17	*Meretrix lyrata*	1.33	0.40	0.3-5	PA, PE, PS, PP	KOH (10%)	Can Gio coastal	[41]
18	*Meretrix lyrata*	4.71±2.15	5.36±2.69	0.3-5	PA, PE, PET, PP, polyester, PAN, PVOH, PVC, LDPE, PDMS	KOH (10%), NaCl	Han and Cu De estuaries	[16]
19	*Meretrix lyrata*	10.0±0.7	2.13±0.69	0.3-2	PE, PP	KOH (10%), KI (50%)	Thai Binh coastal	[40]
20	*Paratapes undulatus*	2.17±0.43	2.38±1.28	0.3-5	PA, PE, PET, PP, polyester, PAN, PVOH, PVC, LDPE, PDMS	KOH (10%), NaCl	Han and Cu De estuaries	[16]
21	*Perna viridis*	2.6±1.14	0.29±0.14	0.015-0.4	Polyester, PP, PS, PE, PA, PVA	KOH (10%), KI (50%)	Thanh Hoa coastal	[25]
22	*Perna viridis*	1-5	0.1-1.0	N/A	PET	KOH (10%), NaI	Phu Yen coastal	[30]
23	*Perna viridis*	27.00	7.03	0.22-1.465	Nylon, EVOH, PTFE, polyester, PET, PP, HDPE	KOH (10%), H_2O_2 (30%), NaCl, $ZnCl_2$	Ha Long bay	[43]
24	*Perna viridis*	22.26±16.0	3.41±2.97	0.019-2.377	PA, PE, PET, PVA, MUF, PTFE, HDPE, EVOH	KOH (10%), H_2O_2 (30%)	Quang Ninh coastal	[33]
25	*Perna viridis*	2.13 (±2.70)-6.75 (±6.63)	0.33 (±0.44)-1.36 (±0.78)	0.05-2	PE, PP, PVC	KOH (10%), KI (50%)	Quang Ninh and Nam Dinh coastal	[44]

Values are showed as min - max, or mean ± SD; ww: Wet weight; idv: Individual; PA: Polyamide; PE: Polyethylene, PET: Polyethylene terephthalate; PS: Polystyrene; PFs: Phenol resin; PVC: Polyvinyl chloride; EVOH: Ethylene vinyl alcohol; PTFE: Polytetrafluoroethylene; MUF: Melamine-urea-formaldehyde resin; PAH: Polyallyl-amine hydrochloride; PVA: Polyvinyl alcohol; CPP: Chlorinated polypropylene; CP: Cellophane; EVA: Ethylene vinyl acetate copolymer; HDPE: High density polyethylene; LDPE: Low density polyethylene; PAN: Polyacrylonitrile; PVOH: Polyethylene vinyl alcohol copolymers; PDMS: Polydimethylsiloxane; N/A: Not available.

of *Mytilus edulis* from a farmed area in Canada [5]. To date, there has been no comprehensive review of MPs in shrimp globally, and there are fewer studies on MPs in macro-crustaceans than in bivalves and fish. S. Abbasi, et al. (2018) [8] found 1.5 items/g ww in the prawn *Penaeus semisulcatus*. The MPs abundance in other shrimp species varied from 0.04 (in *Fenneropenaeus indicus*) to 3.87 (in *Metapenaeus monocerous*) items/g ww [9]. Conversely, the MPs abundance in bivalves, shrimp/crabs, and fish has been reported as 0.2-4, 0.75, and 1-7 items/g ww, respectively [38], which encompasses the range of MPs abundance in the three seafood groups in Vietnam mentioned above. Fish and shrimp are common and daily sources of protein for the Vietnamese population, and available data are primarily from parts of Central coastal Vietnam. Therefore, further studies on MPs in these two groups of organisms collected along coastal areas from the North to the South of Vietnam are recommended to gain a better understanding of the potential exposure for consumers.

The fibre, fragment, and bead were the MPs shapes found in bivalves, fish, and shrimp from Vietnam, with fibre being the most common shape in bivalves (up to 90%), while beads were only observed in shrimp (Fig. 2). Fragment particles were more commonly found in shrimp (40%) than in fish (24%) and bivalves (10%). In marine fish from Asia, fibres represented the highest proportion (71%), followed by fragments (16%) [10], while film, microbeads, and foam contributed 6, 5, and 2% of the total MPs, respectively. In bivalves collected worldwide, fibres also accounted for the highest proportion at 76%, followed by fragments (14.2%), filaments, and beads [5]. In shrimp from the Persian Gulf in Asia, S. Abbasi, et al. (2018) [8] found that nearly all MPs consisted of filamentous fragments. However, M. Keshavarzifard, et al. (2021) [9] noted that the dominant shape was fibre (comprising 78.6% of the total), followed by film (16.1%), with beads (spheres) and fragments also present. Therefore, fibre was the most common and dominant MPs shape detected in marine fish, shrimp, and bivalves from Vietnam and Asia. This suggests a similarity in MPs shapes and the dominance of fibres in the coastal waters of Vietnam and Asia, which requires further study to clarify.

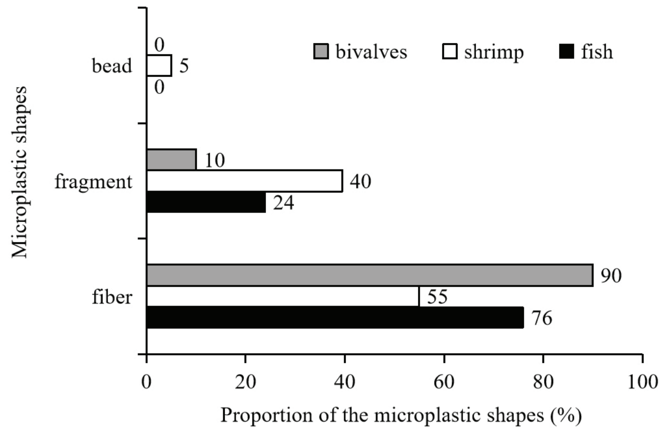

Fig. 2. Proportion of the microplastic shapes in the seafood from Vietnam.

Generally, the observed MPs size in fish from Vietnamese seawater ranged from approximately 100 to 5,000 µm, whereas in shrimp, it ranged from 100 to 1,000 µm. However, the observed MPs size in bivalves mostly varied from 300 to 5,000 µm (Table 1). Exceptionally, the MPs size in the mussel *P. viridis* ranged between 15 and 2,377 µm [25, 33, 43, 44]. The variation in MPs size among marine organisms along the Vietnamese coast could be closely related to several biological and ecological characteristics of the marine animals and the methods employed in the studies, such as (i) different habitats, such as pelagic or benthic environments for fish, shrimp, and bivalves; (ii) variations in the feeding behaviour and food size selection of the studied organisms; (iii) differences in the capacity of fish, shrimp, and bivalves to ingest, egest, excrete, and bioaccumulate microparticles; and (iv) the intentional setting of recorded MPs sizes in studies [1, 31, 32, 39-41]. To date, there has been no standardised method for MPs investigations internationally, and different researchers and laboratories have employed various modified MPs extraction methods, observation techniques, and enumeration means for their studies (Table 1). This lack of standardisation may interfere with the outcomes or accuracy of MPs studies among different marine groups, species, and even within the same species from different locations.

Previous studies in Vietnam revealed several colours of MPs in seafood, including white/translucent, green, blue, grey/black, red, and yellow. In fish, white and black MPs were dominant, comprising 50-60% of the total colours, while blue and red were present in lower proportions (15-18%), followed by yellow (9-15%) [29, 30]. In bivalves, blue, white, or black represented the majority of the total MPs proportion, depending on the species [31, 32]. Four colours-white/translucent, blue, black, and red MPs were found in shrimp along the coast of Vietnam [29]. Generally, the observed MPs colours in Vietnamese seafood align with the reported MPs colours in marine organisms worldwide. In fish from Asia, nine different MPs colours were observed [10], with blue (22%) and black (22%) being the dominant colours, followed by transparent (17%), green (13%), red (10%), white (7%), yellow (4%), grey (2%), brown (2%), and purple (1%). In sedentary (mussels and oysters) and sand-burrowing (clams) bivalves, several MPs colours were observed, including blue, red, brown, white, translucent, grey, green, yellow, and purple [45-48]. In shrimp, the dominant MPs colours were black or grey, with blue and green also noted in the study by S. Abbasi, et al. (2018) [8], while another investigation reported them as white/translucent (dominant), blue, and black [9].

More than ten polymers and plastic additives in the MPs were identified in seafood from Vietnam (Table 1). Most of these were recorded from bivalves, including alkyd, polyethylene terephthalate (PET), polypropylene (PP), polyethylene (PE), polyamide (PA), polyester, polystyrene (PS), polyethersulfone, phenol-formaldehyde, polycyclic aromatic hydrocarbons, nylon, and rayon, among others [18, 25-27, 30-32, 49]. In fish, the detected MPs polymers included PE, polyvinyl ether, polymethacrylate, polydichloroethylene, polydivinyl ester, polyester, and polyfluoroethylene [34]. In shrimp, the identified MPs polymers were PE, PET, PA, PS, and polyacrylic [29]. Marine fish in Asia were found to ingest and accumulate MPs with polymers such as PE (22%), PP (13%), PET (12%), PA (11%), PS (7%), poly 4-tert-butylstyrene (3%), low-density polyethylene (3%), cellulose (2%), ethylene-vinyl acetate (1%), high-density PE (1%), polyvinyl chloride (PVC, 1%), polyvinylidene fluoride (0.98%), polyvinyl fluoride (0.98%), polytetrafluoride (0.98%), and polytetrafluoroethylene (0.97%) [10]. In marine bivalves worldwide, various MPs polymers have been recorded, including PET, PA, PP, PS, PVC, polyester, rayon, polyacrylonitrile, acrylic, cellophane, polymethyl methacrylate, nylon, polyolefins, polyphthalamide, and polyarylamide [5], with PET, PS, and PP being the most common. In shrimp, M. Keshavarzifard, et al. (2021) [9] found MPs polymers of PET (46%), PP (27%), and PS (27%). Therefore, the observed MPs polymers in Vietnamese seafood are consistent with those reported globally. The high and dominant proportions of PET, PS, and PP in marine fish, shrimp, and bivalves are likely related to the major production and prevalence of these polymers in marine environments [5]. Different polymers can pose varying potential toxicity to predators, thereby presenting ecological risks [37]. However, the lack of detailed information on the proportions of polymers in each seafood group from publications in Vietnam (but see V.M. Do, et al. (2024) [33]) likely underestimates the health risks for local ecosystems.

4. Risk to consumers

Although this review compiles all available data on MPs items in seafood from Vietnam, the data are limited, and the seafood species are not very diverse or abundant. Consequently, data were pooled for all fish into one group, and this method was similarly applied to shrimp. Given the numerous bivalve species identified in several studies, we selected four main and most common groups of bivalve species, including (i) *Anadara* spp., (ii) *Crassostrea* spp., (iii) *Meretrix* spp., and (iv) *Perna* spp., along with (v) other bivalves (e.g. *Ensidens* sp., *Mactra grandis, Paratapes undulatus*). In a previous study, the average fish consumption by one local person was approximately 19.1 g ww per day, equating to 6,996 g ww per year [34]. For the hard clam *M. lyrata*, the average amount of clam tissue consumed by one Vietnamese person in a year was 665 g ww [31]. However, information is not available regarding the average annual consumption of other seafood groups by Vietnamese individuals, including shrimp and other bivalves (*Anadara, Crassostrea, Perna*, and others). Therefore, it was assumed that the annual intake of shrimp and each of the other bivalve groups is similar to that of the clam *Meretrix lyrata*, estimated at 665 g ww per year or 1.82 g ww per day. The estimated plastic daily intake (pEDI) and the total MPs items ingested in one year by one Vietnamese person are shown in Table 2. The pEDI values varied from 0.02 (oysters) to 0.78 (fish), with the pEDI of each seafood group being less than 1, indicating low MPs intake by Vietnamese consumers. The higher pEDI value for fish compared to other groups is attributed to the significantly higher daily consumption of fish in Vietnam. Consequently, the total MPs items ingested annually were highest from fish, amounting to 17,064 (Table 2). In the remaining groups, the number of MPs items detected in contaminated seafood ascended in the following order: *Anadara* spp. > *Perna* spp. > *Meretrix* spp. > other bivalves > shrimp. It is important to note that each year, one Vietnamese person may consume multiple seafood groups listed in Table 1. Therefore, the total MPs from seafood that one can ingest could be up to 22,876 MPs items annually; however, this figure remains significantly lower than the estimated range of ingested MPs worldwide, which is between 74,000 and 121,000 items per capita [38]. Furthermore, the pEDI calculation and total annual MPs ingestion estimation in the present review (Table 2) do not account for the high potential MPs contamination from food, drinks, body care products, and air that Vietnamese individuals encounter in their daily lives. MPs contamination in salts, body care and cosmetic products, and the air environment in Vietnam has been reported recently [21, 50-52]. Therefore, a higher MPs intake by Vietnamese individuals through food, drink, air, and other sources necessitates further study.

Table 2. The plastic estimated daily intake and annual accumulating microplastic ingestion in men from seafood in Vietnam. Other bivalves include species of *Ensis, Mactra*, and *Paratapes*.

Group of seafood	Pi (items/g)	RI (g)	pEDI	Total annual item ingestion
Fish	2.44	19.1	0.78	17,064
Shrimp	0.73	1.82	0.02	485
Bivalves				
Anadara spp.	2.69	1.82	0.08	1,787
Crassostrea spp.	0.76	1.82	0.02	505
Meretrix spp.	1.36	1.82	0.04	903
Perna spp.	2.34	1.82	0.07	1,554
Other bivalves	0.87	1.82	0.03	578
Total			1.04	22,876

Pi is the MPs abundance in seafood tissue; RI is the average amount of seafood consumed daily by an adult, and BW is the average body weight of an adult (60 kg); pEDI is the plastic estimated daily intake.

Once in human cells and tissues, MPs can cause various negative physical, chemical, and biological effects. This is due to the potential sharp edges of the MPs items, the chemicals added to the surface of plastic products (e.g. phthalates, bisphenol A, flame retardants, Pb, Cd), the absorption of pollutants from surrounding environments onto the plastic surface (e.g. persistent organic pollutants including polychlorinated biphenyls, polycyclic aromatic hydrocarbons, organochlorine pesticides, and heavy metals), and biofouling with pathogenic bacteria [1, 5, 10, 13]. Each type of polymer can also pose a certain hazard, hence a potential health risk to consumers. For example, the hazard scores of PET, PE, PS, and PVC can be 4, 11, 30, and 1,450 times more potent compared to that of PP, respectively [33]. Different pollutants and polymers have varying impacts on cells, tissues, and organs, and the combined effects may lead to unpredictable serious impairments in human health. Although not fully understood, the potential adverse influences of MPs and their associated pollutants could include oxidative stress, cellular damage, impaired physiological function, and disruption of hormone regulation and reproductive function [10]. Furthermore, MPs in the human body could cause lipid digestion issues in the gastrointestinal system, potential cytotoxicity, neurotoxicity, fluctuations in energy equilibrium, blood cell coagulation, haemolysis, high blood pressure, increased porosity of the cell membrane, bone loss, and immune system disruption [10, 14, 15]. To date, the potential health risks faced by Vietnamese individuals due to exposure from food consumption, drinking water, and inhaled air have not been studied, suggesting an underestimation of exposure.

The presence of MPs in organisms in Vietnam has been reported (Table 1). However, the sources and emissions of MPs have not been quantitatively studied or estimated for the entire country. The use of MPs, especially single-use plastics, has been socially encouraged, but related regulations to ban or limit MPs discharge have not been issued or effectively applied in Vietnam. Investigations into MPs treatment in the environment are ongoing. Therefore, MPs pollution prevention and treatment remain among the most significant challenges for researchers, managers, and industries in Vietnam.

5. Conclusions and perspectives

Microplastics are commonly found in marine fish (six species), shrimp (four species), and bivalves (eleven species) collected along the coast of Vietnam. The abundance of MPs in fish, shrimp, and bivalves varied significantly depending on the species, their sizes, feeding behaviours, and their surrounding environments. The minimum and maximum MPs values recorded were 0.25 (for the clam *M. lyrata*) and 87 items per individual (for the fish *D. maruadsi*), respectively. MPs abundance was highest in fish and lowest in shrimp tissues, with fibres being the most common shape of MPs found in seafood from Vietnam. Various MPs colours were observed in the seafood, with white and black being dominant in fish, while blue, white, and black were predominant in bivalves. More than ten different MPs polymers were identified in the marine fish, shrimp, and bivalves from Vietnam. The estimated plastic daily intake was highest from fish (0.78), but still less than 1, indicating low MPs intake by Vietnamese consumers. However, when considering all studied seafood, the intake increased to 1.04, suggesting a higher MPs intake by Vietnamese consumers. The data on MPs from fish and shrimp were quite limited, necessitating further studies on both species, their spatial distribution along the coast of Vietnam, and their consumption patterns. A national monitoring programme for MPs studies in seafood throughout Vietnam would significantly enhance knowledge and understanding of the potential human health risks associated with MPs exposure. Further quantitative studies of MPs in other types of food, spices, drinks, and outdoor air in Vietnam are essential for a comprehensive assessment of human MPs exposure. Lastly, a similar methodology for MPs investigation in seafood is needed in Vietnam to optimise data exploitation, assessment, and management issues.

CRediT author statement

Trung-Hau Nguyen: Methodology, Data curation, Visualisation, Writing original draft, Reviewing and Editing; To Thi Hien: Visualisation, Writing original draft, Reviewing and Editing; Thanh-Son Dao: Supervision, Conceptualisation, Visualisation, Reviewing and Editing.

ACKNOWLEDGEMENTS

We acknowledge the support of time and facilities from Ho Chi Minh City University of Technology (HCMUT), VNU-HCM for this study.

COMPETING INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this article.

REFERENCES

[1] H.S. Auta, C.U. Emenike, S.H. Fauziah (2017), "Distribution and importance of microplastics in the marine environment: A review of the sources, fate, effects, and potential solutions", *Environment International*, **102**, pp.165-176, DOI: 10.1016/j.envint.2017.02.013.

[2] N.N. Phuong, T.T. Duong, T.P.Q. Le, et al. (2022), "Microplastics in Asian freshwater ecosystems: Current knowledge and perspectives", *Science of The Total Environment*, **808**, DOI: 10.1016/j.scitotenv.2021.151989.

[3] X. Li, X. Shen, W. Jiang, et al. (2024), "Comprehensive review of emerging contaminants: Detection technologies, environmental impact, and management strategies", *Ecotoxicology and Environmental Safety*, **278**, DOI: 10.1016/j.ecoenv.2024.116420.

[4] N.H.S. Le, A.D. Pham, T.T. Hien, et al. (2024), "First report on microplastics in a freshwater clam, *Corbicula baudoni*, in Vietnam", *IOP Conf. Ser.: Earth Environ. Sci.*, **1349(1)**, DOI: 10.1088/1755-1315/1349/1/012011.

[5] Z. Xu, L. Huang, P. Xu, et al. (2024), "Microplastic pollution in commercially important edible marine bivalves: A comprehensive review", *Food Chemistry: X*, **23**, DOI: 10.1016/j.fochx.2024.101647.

[6] L. Lahens, E. Strady, T.C. Kieu-Le, et al. (2018), "Macroplastic and microplastic contamination assessment of a tropical river (Saigon river, Vietnam) transversed by a developing megacity", *Environmental Pollution,* **236**, pp.661-671, DOI: 10.1016/j.envpol.2018.02.005.

[7] United Nations Environmental Programme (UNEP) (2022), "Plastic treaty progress puts spotlight on circular economy", https://www.unep.org/news-and-stories/story/ plastic-treaty-progress-puts-spotlight-circular-economy, accessed 20 January 2024.

[8] S. Abbasi, N. Soltani, B. Keshsvarzi, et al. (2018), "Microplastics in different tissues of fish and prawn from the Musa Estuary, Persian Gulf", *Chemosphere,* **205**, pp.80-87, DOI: 10.1016/j.chemosphere.2018.04.076.

[9] M. Keshavarzifard, A. Vazirzadeh, M. Sharifinia (2021), "Occurrence and characterization of microplastics in white shrimp, *Metapenaeus affinis*, living in a habitat highly affected by anthropogenic pressures, northwest Persian Gulf", *Marine Pollution Bulletin*, **169**, DOI: 10.1016/j.marpolbul.2021.112581.

[10] J. Oza, V. Rabari, V.K. Yadav, et al. (2024), "A systematic review on microplastic contamination in fishes of Asia: Polymeric risk assessment and future prospectives", *Environmental Toxicology and Chemistry*, **43(4)**, pp.671-685, DOI: 10.1002/etc.5821.

[11] J.W.M. Wijsman, K. Troost, J. Fang, et al. (2019), "Global production of marine bivalves: Trends and challenges", *Goods and Services of Marine Bivalves*, Springer, pp.7-26, DOI: 10.1007/978-3-319-96776-9_2.

[12] H. Villarreal (2023), "Shrimp farming advances, challenges, and opportunities", *World Aquaculture Society*, **54(5)**, pp.1092-1095.

[13] N.S. Maghes, K.V. Ajith (2024), "Microplastics contamination and risk assessment in bivalves of economic importance from Beypore estuary, Southern India", *Environmental Research*, **261**, DOI: 10.1016/j.envres.2024.119711.

[14] H. Tan, T. Yue, Y. Xu, et al. (2020), "Microplastics reduce lipid digestion in simulated human gastrointestinal system", *Environmental Science & Technology*, **54(19)**, pp.12285-12294, DOI: 10.1021/acs.est.0c02608.

[15] M.S. Bhuyan (2022), "Effects of microplastics on fish and in human health", *Frontiers in Marine Science*, **10**, DOI: 10.3389/fenvs.2022.827289.

[16] Q.A. Tran-Nguyen, H.N.Y. Nguyen, E. Strady, et al. (2020), "Characteristics of microplastics in shoreline sediments from a tropical and urbanized beach (Da Nang, Vietnam)", *Marine Pollution Bulletin*, **161**, DOI: 10.1016/j.marpolbul.2020.111768.

[17] E. Strady, T.H. Dang, T.D. Dao, et al. (2021), "Baseline assessment of microplastic concentrations in marine and freshwater environments of a developing Southeast Asian country, Viet Nam", *Marine Pollution Bulletin*, **162**, DOI: 10.1016/j.marpolbul.2020.111870.

[18] N.T. Nguyen, N.T.T. Nhon, H.T.N. Hai, et al. (2022), "Characteristics of microplastics and their affiliated PAHs in surface water in Ho Chi Minh City, Vietnam", *Polymers*, **14(12)**, DOI: 10.3390/polym14122450.

[19] T.C. Kieu-Le, Q.T. Thuong, N.T.S. Truong, et al. (2023), "Baseline concentration of microplastics in surface water and sediment of the northern branches of the Mekong river delta, Vietnam", *Marine Pollution Bulletin*, **187**, DOI: 10.1016/j.marpolbul.2023.114605.

[20] N.T.T. Nhon, T.N. Nguyen, H.T.N. Hai, et al. (2024), "Microplastic pollution in coastal surface seawater of southern Vietnam", *Environmental Monitoring and Assessment*, **196**, DOI: 10.1007/s10661-024-13243-4.

[21] N.T.S. Truong, E. Strady, T.C. Kieu-Le, et al. (2021), "Microplastic in atmospheric fallout of a developing Southeast Asian megacity under tropical climate", *Chemosphere*, **272**, DOI: 10.1016/j.chemosphere.2021.129874.

[22] N.T.T. Nhon, T.N. Nguyen, H.T.N. Hai, et al. (2022), "Distribution of microplastics in beach sand on the Can Gio coast, Ho Chi Minh City, Vietnam", *Water,* **14(18)**, DOI: 10.3390/w14182779.

[23] M.K. Nguyen, C. Lin, N.T.Q. Hung, et al. (2022), "Occurrence and distribution of microplastics in peatland areas: A case study in Long An province of the Mekong delta, Vietnam", *Science of the Total Environment*, **844**, DOI: 10.1016/j.scitotenv.2022.157066.

[24] S. Yukioka, S. Tanaka, Y. Nabetani, et al. (2020), "Occurrence and characteristics of microplastics in surface road dust in Kusatsu (Japan), Da Nang (Vietnam), and Kathmandu (Nepal)", *Environmental Pollution*, **256**, DOI: 10.1016/j.envpol.2019.113447.

[25] N.N. Phuong, Q.T. Pham, T.T. Duong, et al. (2019), "Contamination of microplastic in bivalve: First evaluation in Vietnam", *Vietnam Journal of Earth Sciences*, **41(3)**, pp.252-258, DOI: 10.15625/0866-7187/41/3/13925.

[26] H.T.T. Hue, L.K. Dong, T.T. Hien, et al. (2021), "Assessment of microplastics contamination in commercial clams in the coastal zone of Vietnam", *Applied Ecology and Environmental Research*, **19(6)**, pp.4977-4991, DOI: 10.15666/aeer/1906_49774991.

[27] D.V. Manh, D.T. Thom, L.X.T. Thao, et al. (2022), "Microplastics accumulation in pacific oysters from Danang bay, Vietnam", *Vietnam Journal of Science and Technology*, **60(3)**, pp.499-512, DOI: 10.15625/2525-2518/16374.

[28] T.T.A. My, N.D. Dat, H.T. Long, et al. (2022), "Occurrence of microdebris in muscle of round scad (*Decapterus maruadsi*) collected from central Vietnam", *EnvironmentAsia*, **15(3)**, pp.38-47, DOI: 10.14456/ea.2022.46.

[29] T.T.A. My, N.D. Dat, N.Q. Hung (2023a), "Occurrence and characteristics of microplastics in wild and farmed shrimps collected from Cau Hai lagoon, Central Vietnam", *Molecules*, **28(12)**, DOI: 10.3390/molecules28124634.

[30] T.T.A. My, N.D. Dat, N.Q. Hung, et al. (2023b), "Preliminary determination of microplastics in bivalves collected from Phu Yen, Central Vietnam", *Vietnam Journal of Science and Technology*, **61(3)**, pp.480-490, DOI: 10.15625/2525-2518/17032.

[31] T.S. Dao, D.M.T. Lai, Q.H. Nguyen, et al. (2023a), "Investigation on microplastics in some bivalves at Binh Dien market in Ho Chi Minh city, Vietnam", *IOP Conf. Ser.: Earth Environ. Sci*., **1278**, DOI: 10.1088/1755-1315/1278/1/012029.

[32] T.S. Dao, T.C. Kieu-Le, X.T. La, et al. (2023b), "Microplastic accumulation in oysters: Insights from aquaculture and laboratory conditions", *Regional Studies in Marine Science*, **68**, DOI: 10.1016/j.rsma.2023.103251.

[33] V.M. Do, V.T. Trinh, X.T.T. Le, et al. (2024), "Evaluation of microplastic bioaccumulation capacity of mussel (*Perna viridis*) and surrounding environment in the North coast of Vietnam", *Marine Pollution Bulletin*, **199**, DOI: 10.1016/j.marpolbul.2023.115987.

[34] S.T. Tran, H.V. Nguyen, T.C. Hoang (2024), "Ingestion and accumulation of microplastics in small marine fish and potential human exposure: Case study of Binh Dinh, Vietnam", *Human and Ecological Risk Assessment: An International Journal*, **30(1-2)**, pp.1-21, DOI: 10.1080/10807039.2023.2268208.

[35] N.N. Tri, N.P.C. Tu, D.T. Nhan, et al. (2021), "An overview of aquaculture development in Vietnam", *Proceedings of The International Conference on Fisheries and Aquaculture*, **7(1)**, pp.53-71, DOI: 10.17501/23861282.2021.7105.

[36] T.Q. Ho, H.L. Do, H. Eggert (2025), "Shrimp farming industry in Vietnam: An aquaculture performance indicators approach", *Aquaculture Economics & Management*, **29(2)**, pp.207-230, DOI: 10.1080/13657305.2024.2449410.

[37] C.E. Enyoh, W. Qingyue, A.W. Verla, et al. (2022), "Index models for ecological and health risks assessment of environmental micro- and nano-sized plastics", *Environmental Science*, **9(1)**, pp.51-65, DOI: 10.3934/environsci.2022004.

[38] K. Kannan, K. Vimalkumar (2021), "A review of human exposure to microplastics and insights into microplastics as obesogens", *Frontiers in Endocrinology*, **12**, DOI: 10.3389/fendo.2021.724989.

[39] V.V. Chi, V.T.N. Quyen (2022), "Microplastic contamination in blood cockle (*Anadara granosa*) distributed in Thi Nai lagoon, Binh Dinh province", *Journal of Science and Technology - Da Nang University*, **20(1)**, pp.21-25 (in Vietnamese).

[40] T.O. Doan, T.T. Duong, L.A. Pham, et al. (2023), "Microplastic accumulation in bivalves collected from different coastal areas of Vietnam and an assessment of potential risks", *Environmental Monitoring and Assessment*, **195(12)**, DOI: 10.1007/s10661-023-12087-8.

[41] P.D. Thanh, T.D. Thao, T.B. Son (2022), "Microplastic in sediments and clam (*Meretrix lyrata*) and oyster (*Crassostrea rivularis*)", *Journal of Science, Technology and Food*, **22(1)**, pp.65-73 (in Vietnamese).

[42] N.T.G. Hang, D.T.K. Nhi, T.T.A. Dao, et al. (2021), "Microplastic pollution in clam (*Meretrix lyrata* Sowerby, 1851) at Mekong delta river, Vietnam", *Science & Technology Development Journal - Natural Sciences*, **5(4)**, pp.1443-1454, DOI: 10.32508/stdjns.v5i3.949.

[43] N.D. Thanh, V.A. Thu, D.T. Thom, et al. (2022), "Investigation of microplastics existence in mussel (*Perna viridis*) from Ha Long bay, Vietnam", *Vietnam Journal of Science and Technology,* **60(5B)**, pp.1-10.

[44] N.N. Phuong, Q.T. Pham, T.X.T. Ngo, et al. (2024), "Occurrence of microplastics in bivalves from the northern coast of Vietnam", *Regional Studies in Marine Science*, **78**, DOI: 10.1016/j.rsma.2024.103731.

[45] N.N. Phuong, L. Poirier, Q.T. Pham, et al. (2018), "Factors influencing the microplastic contamination of bivalves from the French Atlantic coast: Location, season and/or mode of life?", *Marine Pollution Bulletin*, **129(2)**, pp.664-674, DOI: 10.1016/j.marpolbul.2017.10.054.

[46] J. Ding, C. Sun, C. He, et al. (2021), "Microplastics in four bivalve species and basis for using bivalves as bioindicators of microplastic pollution", *Science of The Total Environment*, **782**, DOI: 10.1016/j.scitotenv.2021.146830.

[47] C.P. Liao, C.C. Chiu, H.W. Huang (2021), "Assessment of microplastics in oysters in coastal areas of Taiwan", *Environmental Pollution*, **286**, DOI: 10.1016/j.envpol.2021.117437.

[48] F. Marques, C. Vale, A. Rudnitskaya, et al. (2021), "Major characteristics of microplastics in mussels from the Portuguese coast", *Environmental Research*, **197**, DOI: 10.1016/j.envres.2021.110993.

[49] A.Q. Tran-Nguyen, T.Q. Nguyen, T.L.T. Phan, et al. (2023), "Abundance of microplastics in two venus clams (*Meretrix lyrata* and *Paratapes undulatus*) from estuaries in central Vietnam", *Water*, **15(7)**, DOI: 10.3390/w15071312.

[50] D.T. Ha (2021), "Microplastic contamination in commercial sea salt of Vietnam", *Vietnam Journal of Science and Technology*, **59(3)**, pp.333-344, DOI: 10.15625/2525-2518/59/3/15718.

[51] T.T.T. Dung, H.N. Ngoc, N.N. Trinh (2024), "Microbeads in exfoliating products: Occurrence, abundance, and potential for water contamination in Ho Chi Minh City, Vietnam", *Discover Environment*, **2**, DOI: 10.1007/s44274-024-00120-7.

[52] N.T. Nguyen, L.T.K. Oanh, N.D.T. Chi (2024), "The presence of microplastics in personal care and cosmetic products (PCCPs) commonly used in Ho Chi Minh City", *IOP Conf. Ser.: Earth Environ. Sci.*, **1349**, DOI: 10.1088/1755-1315/1349/1/012012.