EnvironmentAsia
The international journal by the Thai Society of Higher Education Institutes on Environment

EnvironmentAsia 15(3) 2022 25-37
DOI 10.14456/ea.2022.45
ISSN 1906-1714; ONLINE ISSN: 2586-8861

Accumulation of Microplastics in the Freshwater Shrimp, *Macrobrachium lanchesteri*, from Khwae Noi Watershed in Western Thailand

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Received: February 9, 2022; Revised: July 18, 2022; Accepted: August 2, 2022

Abstract

Microplastics (MPs) have been considered as an environmental pollutant, which disperses and accumulates in the environment, including in aquatic organisms. In this study, MPs accumulation in the freshwater shrimp, *Macrobrachuim lanchesteri*, sampled from headstream, midstream and downstream of the Khwae Noi watershed in western Thailand was investigated. A total of 300 individuals from 30 sites were sampled with dip nets. MPs accumulation in the shrimp was found to be only the filamentous type in approximately 19.0% of frequency occurrence, with the lengths varying from > 50 to 300 µm and an average of 0.46 ± 1.64 piece/individual (n = 300). Sorensen Distance of 70% similar index was classified into three groups of MPs accumulation in the shrimp. The first was no MPs accumulation, the second showed an average of 0.32 ± 1.2 piece/individual (n = 100), and the third exhibited an average of 0.72 ± 0.4 piece/individual (n = 100). Fourier-transform infrared analysis illustrated four types of MPs accumulation: polydimethylsiloxane, polyamide, polyester and polymethyl methacrylate. All MPs types found in the shrimp were linked with those found in water and sediment, indicating that MPs were in the food chain in the freshwater ecosystem. Principal Correspondence Analysis demonstrated the MPs accumulation correlated with eight environmental factors.

Keywords: Freshwater shrimp; Ecosystem; Environmental pollutant; FT-IR; Plastic debris

1. Introduction

Microplastics (MPs) are usually defined as plastic debris with smaller than 5 mm (generally 50 to 5000 µm) in diameter (Wang *et al.,* 2020). They result from the direct disposal of small plastic particles from anthropogenic activities, called "primary MPs", typically found in facial cleansers and cosmetics (Zitko and Hanlon, 1991), or hand cleansers and facial micro-scrubbers or micro-beads (Fendall and Swell, 2009), and from the fragmentation of plastic objects, called "secondary MPs", caused by physical, biological and chemical processes (Browne *et al.,* 2007). MPs are considered to be an environmental pollutant (Thompson *et al.,* 2004) found in the atmosphere, hydrosphere, lithosphere and biosphere, called the environmental compartments (Pachana *et al.,* 2010).

In the biosphere, many aquatic organisms have been vastly studied for MPs accumulation comprising fish (44%), crustacean (21%), molluscs (14%), and annelid worms (6%), as well as other organism groups (de Sa *et al.,* 2018). Particularly, freshwater shrimps are decapod crustaceans belonging to the family Palaemonidae, genus Macrobrachium (Bate, 1868). This genus was taxonomically identified to report about 240 species recorded in the world (Chen *et al.,* 2009), and 26 species (Cai and Vidthayanon, 2016) defined as 10.8 % are presented in Thailand. The most economically important species for Thailand include *Macrobrachuim dienbienphuense, M. niphanae, M. lanchesteri, M. sintangense* and *M. rosenbergii decqueti* (de Man, 1898).

M. lanchesteri is a small freshwater shrimp widely distributed in Asia and found in Thailand, Malaysia, Singapore, Lao PDR and Brunei (de Grave *et al.,* 2018). Its morphology is translucent with distinctive features of a straight rostrum (Cai and Vidthayanon, 2016). It is well adapted to a variety of habitats in both running and standing water ecosystems including lakes, rivers, wetlands, and manmade ponds including paddy fields. It is commonly abundant and has a high commercial value in Thailand, as well as in other Southeast Asian countries.

In all the regions of Thailand, *M. lanchesteri* is an important economic resource for local people, especially in rural areas. It is eaten as local food in many forms, e.g. shrimp paste (Pongsetkul, *et al.,* 2019), crispy shrimp, Koi Kung, Kung Jom, as well as fresh popular food called Kung Ten (Thongkao and Sudjaroen, 2020; Rattanapradap, 2013). Furthermore, it plays an important role in the food chain of freshwater ecosystems. It is routinely captured from natural water sources because of minimal support in developing aquaculture farms (Jongyotha, *et al.,* 2015).

Pollution in rivers has been gradually increasing owning to anthropogenic activities, e.g. agriculture, industry, commerce, municipal discharge (wastewater, solid waste and leachate), etc. These activities create small-sized plastic debris as MPs contaminating these rivers and accumulating in aquatic organisms. MPs may then affect aquatic organisms, including freshwater shrimp, on their genetics, reproduction, population and abundance, and may cause a risk to human health.

To the best of our knowledge, there have been no studies on MPs accumulation in any local commercial shrimps in Thailand and on the correlation of MPs accumulation with environmental factors. In this study, MPs abundance, shapes, sizes, colors and types found in the freshwater shrimp, *M. lanchesteri*, as well as in water and sediment in the headstream, midstream and downstream areas of the Khwae Noi watershed, which is one of the most important rivers in Thailand, were investigated. In addition, the MPs accumulation and its correlation with environmental factors were studied. This shrimp, *M. lanchesteri,* might be useful as a bio-indicator of MPs contamination in freshwater ecosystem.

2. Materials and Methods

2.1 Study area

Khwae Noi (from 15° 13’ 30.37’’ N, 98° 26’ 46.01’’ E to 13º 58’ 29.94’’ N, 99º 30’ 32.03’’ E) is a main river in western Thailand with a watershed area of approximately 353 km² (220,625 rai in Thai unit). This watershed originates the Tenasserim Hills (Ta Nao Sri) in Myanmar on the border with Thailand. The Khwae Noi watershed is comprised of tributaries, from 1st-5th order streams, which provide habitats for the freshwater shrimp, *M. lanchesteri* (Figure 1). *M. lanchesteri* is abundant and widely distributed in headstream to downstream areas, and is important for trophic levels of river (Hayden *et al.,* 2021). Headstream areas are composed of relatively pristine mountains with national parks and wildlife sanctuaries together with very few small industrial activities, rarely agricultural areas, and few local villages with sparse populations. Midstream areas consist of middle scale of agricultural areas with more local villages and larger populations, and few small industries. Lastly, downstream areas have large-scale agricultural areas, and many anthropogenic activities, including more small industries and municipal discharge.

Geographical Information Systems (GISs) with 1:50000 map was used to derive land uses covering all the sampling sites using ArcGIS program (ArcMap 10.8 version). Hydrological data were processed using the Spatial Tools for the Analysis of River Systems, which were allowed to calculate cumulative areas of land covering contributing sub-catchments of downstream to headstream of sampling sites.

2.2 Microplastics samplings and processing

2.2.1 Shrimp

Shrimps were collected at 30 sampling sites in tributaries of the Khwae Noi watershed with 1st-5th order streams (Figure 2).Each sampling site was recorded by Global Positioning System (GPS) (SD ± 5 m). The shrimps were randomly sampled within an area of 100 m^2 at each site, covering headstream, midstream and downstream. Headstream (15º 22' 35'' N, 98º 43' 13'' E and 14º 39' 57.53'' N, 98º 23' 6.61'' E, n = 10 sites) comprises mostly 1st order streams. Midstream (14º 41' 55'' N, 98º 50' 14'' E, and 14º 09' 6.58'' N, 98º 58' 24.58'' E, n = 10 sites) and downstream (14º 09' 19'' N, 99º 37' 31'' E and 13º 53' 23.5'' N, 99º 22' 15'' E, n = 10 sites) consist of 2nd and 3rd order streams and 3rd and 4th order streams, respectively.

Shrimps were collected with a shrimp dip net with 0.03 cm mesh size, 50 cm diameter, or hand net with 0.05 - 1 cm mesh size, 30 cm diameter during August 2020 to April 2021, which these time periods presented no different abundance of shrimps in wet and dry seasons. They were transported in 4.0 ºC iceboxes to the freshwater laboratory, and were stored at −20 °C until analysis. Then, each specimen was washed gently with filtered (0.70 µm) distilled water. Each shrimp was weighed by calibrated balance (± SD 0.03 mg) and total length was measured by calibrated Vernier calipers (± SD 0.01 mm). Whole body shrimp was washed gently with filtered (0.70 µm) distilled water to dislodge any possible MPs on their exoskeletons.

Whole body shrimp samples were placed in 50 ml Erlenmeyer flasks. 10% KOH and 30% H_2O_2 were used to digest tissues and organic matter, respectively (Avio *et al.,* 2015; Lusher *et al.,* 2017), which H_2O_2 is also effective to digest biogenic materials (Avio *et al.,* 2015). The samples were placed in an incubator at 65 ºC for 24 h. A saturated NaCl solution, 300 g/L concentration, was filtered and added into the flasks to separate MPs by flotation. The saline solution was kept at 20-25 ºC room temperature for 12 h, and the supernatant was then pipetted, filtered through a glass microfiber filter (Whatman GF/C 1.2 µm pore size)

Figure 1. *Macrobrachium lanchesteri* studied for MPs accumulation in the Khwae Noi watershed

and placed on 60 mm x 15 mm Petri-dish size after incubated at 60 ºC for 48 h.

For quality control of the experiment, special care was taken to avoid any contamination. All glassware and essential equipment, e.g. metal scissors, tweezers and scalpel, were first cleaned with a non-ionic detergent, then cleaned with 70% alcohol, and later rinsed three times with filtered (0.70 µm) distilled water. Then, essential equipment was enveloped with aluminum foil, then oven-dried at 40 ºC. At the laboratory room, the workstation was carefully cleaned before and after the analysis of all the samples. Also, whole body shrimps were rinsed with filtered distilled water, and then placed under laminar flow and then in glass Petri dishes, covered with aluminum foil.

2.2.2 Water

MPs in water were investigated for their diversity and accumulation in the shrimp. Ten liters of surface water were collected using 20 µm plankton net, 30 cm diameter mouthed with a 150 ml bottle glass container. Before sampling, the plankton net was cleaned first with drinking water and rinsed 5 times using river water at the sampling site. MPs in water were collected with a horizontal method for 5 replications and pooled in each site, with the plankton net about 45 cm depth from the surface. Water sampling was conducted at the margin and center of rivers for predicting MPs diversity in the river. Water samples were preserved in 4 ºC in insulated boxes (Leslie *et al.,* 2017).

From each 500 ml of samples, 300 mL were taken for duplicate measurements to ensure no MPs left in all the used containers. For each MPs separation in a water sample, 300 mL of water was filtered using Whatman GF/C (Glass microfiber filter 1.2 µm) paper (Barrows *et al.,* 2017), and then used to identify MPs types in the water.

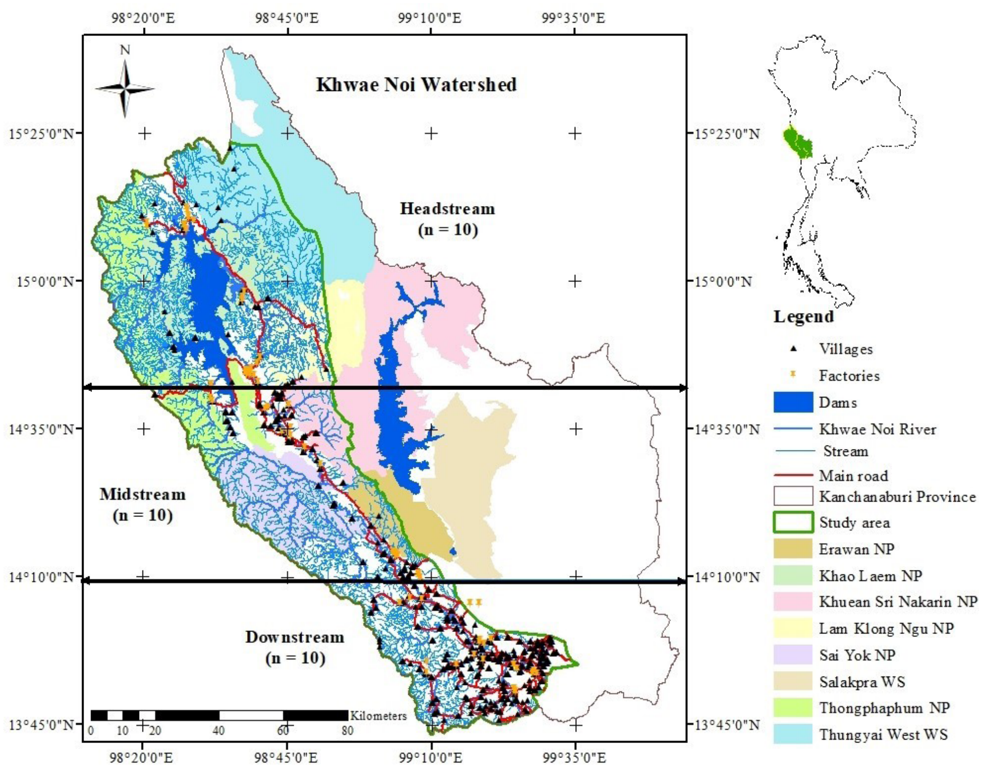

Figure 2. Locations of sampling sites within the Khwae Noi watershed, demonstrating headstream, midstream, and downstream associated to conservation areas and human activities

2.2.3 Sediment

MPs in sediments were also investigated to predict MPs diversity associated with their accumulation in the shrimp. Sediment samples were collected using Ekman grab sampler (T.Science, GS - 600 model) on depth-large river sediments and with shovels or spoons for lower sedimentary river conditions. Sediments were taken at the right-left coastal river margin and middle location of the river. The collected sediments were then placed into a 0.5 L glass container. For each site, sediment was collected for 3 replications. The obtained sediment samples were then preserved at 4 ºC iceboxes (Lusher *et al.,* 2017).

All the sediment samples were processed according to Wang *et al.* (2017) and Peng *et al.* (2017). One kg of each sample in wet weight was dried in the oven at 100 ºC for 48 h. The dried sediments were thoroughly mixed and then taken about ≤ 100 g of duplication and then dissolved with a NaCl 30% solution of 400 mL. Next, the mixture was stirred for 2 min using a stirring spoon. After stirred, they were waited for settling as long as no more visible material floats between the supernatant. The floating material in the supernatant was filtered using a vacuum pump on Whatman GF/C (Glass microfiber filter 1.2 mm) filter paper (Zhang *et al.,* 2016), and then used to identify MPs types in the sediment.

2.3 Microplastics analysis

In this study, whole body shrimp (n = 300) was used to analyze for MPs because its whole body is normally eaten as traditional Thai food and cooking. The supernatant of shrimp samples was used to investigate the numbers of MPs particles and colors using the filter paper placed on 60 mm x 15 mm Petri-dish size after incubated at 60 ºC for 48 h. And, their physical characteristics were visually examined and divided into filaments (fibers), rods, fragments and pellets under a stereomicroscope. MPs found were photographed with a camera (Dino-Lite Pro AM423) incorporated to the stereomicroscope. MPs sizes were measured for their longest dimension under the camera program (DinoCapture 2.0, 1.5.43 version). Their sizes in this study were classified into eight categories: ≤ 50 µm (very small MPs), > 50 – 500 µm (small MPs), > 500 – 1000 µm (relatively small MPs), > 1000 – 2000 µm (medium size MPs), > 2000 – 3000 µm (relatively large MPs), > 3000 – 4000 µm (large MPs), and > 4000 – 5000 µm (very large MPs), and > 5000 µm (plastic waste), respectively.

Fourier-transform infrared (FT-IR) spectrometer (Shimadzu, FTIR-8900) with a NaCl cell measurement technique was used to identify chemical compositions and IR bands (cm^{-1}) for classifying MPs diversities and types in the shrimp, water and sediment supernatant samples, as described by Khuyen *et al.* (2021). For FT-IR analysis, more than 60 % subsampled filamentous MPs (Chinfak *et al.,* 2021) were pooled as three replications to analyze their compositions of functional chemistry groups.

2.4 Statistical analysis

Frequency occurrence of MPs in shrimp was calculated by dividing of individual shrimp contaminated with MPs by the total samples of shrimp (n = 300) multiplied by 100. Numbers of MPs pieces in the shrimps from headstream, midstream and downstream were analyzed by Principal Correspondence Analysis (PCA), PCoA-Plot technique and percent similarity index by Sorensen Distance for Identification using PC-ORD program (MjM Software Design, USA, version 4.17).. This technique was used to analyze the environmental factors corresponded to MPs accumulation. The environmental factors taken into account included headstream, midstream, downstream, elevation, pristine area, land-used area, MPs in water and MPs in sediment.

3. Results and Discussion

3.1 Microplastics abundance and frequency occurrences in shapes, sizes and colors

Body weights of the shrimp, *M. lanchesteri,* were in the range of 0.5 to 3.5 mg with an average approximately 3.2 ± 1.5 mg, and total lengths were in the range of 2.1 to 5.1 cm with an average of 3.5 ± 0.3 cm. Their body weight and total length were not significantly correlated to abundance of MPs accumulation in *M. lanchesteri* ($p \geq 0.05$). In this study, only filament type of MPs, called filamentous MPs (Figure 3), was found in the shrimp. Abundance of filamentous MPs were various from 0.0 to 9.0 piece/individual with a total of 422 pieces and an average of 0.46 ± 1.64 piece/individual (n = 300). Frequency occurrence of filamentous MPs in the shrimp samples was approximately 19% of 300 individual samples from 30 sampling sites in the Khwae Noi watershed. The abundance is consistent with the study of Nan *et al.* (2020) who found MPs in shrimps, *Paratya australiensis*, at an average of 0.52 ± 0.55 piece/individual.

Besides, colors of filamentous MPs accumulation found were 47.3%, 31.9% and 20.8% for blue, green, and black colors (Figure 4A). Lengths of filamentous MPs were in the range of > 50 to 300 µm, classified to the relatively small MPs group between >50-500 µm, with approximately 6.0 % (1.21 ± 2.5 pieces/individual, 51 - 100 µm), 13.0% (0.11 ± 0.68 pieces/individual, 101-200 µm), and 3.0% (0.06 ± 0.42 pieces/individual, 201 - 300 µm) of occurrence (Figure 3), respectively.

This study is correspondent to the studies of Nan *et al.* (2020) and Yan *et al.* (2021), who reported that filamentous MPs were the most frequent shape and the highest amount in shrimps. And, lengths of filamentous MPs at ≤ 500 µm were accounted to the highest proportion in shrimps. Additionally, blue color was the most color overserved in filamentous MPs accumulation in shrimps, e.g. and *Nephrops norvegicus* and *Litopenaeus vannamei* (Cau *et al.,* 2019; Yan *et al.,* 2021), which Nan *et al.* (2020) also reported that the most filamentous MPs found in shrimps were blue, consistent with our results. The MPs found in the shrimp were consistent with the diets of the shrimps, genus *Macrobrachium* sp. and *M. lanchesteri,* which prefer to eat blue-green algae, filamentous algae, pennate diatom with sizes ranging from 20 to 200 µm, and plant fragment (Collins and Paggi, 1997; Wongrat, 1999; Lawal-Are and Owolabi, 2012; Melo and Nakagaki, 2013; Bakhtiyar *et al.,* 2014) that are resemble in MPs shapes, sizes and colors according to our results.

Frequency occurrence of filamentous MPs in the shrimp samples from the headstream (n = 100) was not found, while those in midstream and downstream were found at 22.0% and 35.0% of frequency occurrence, respectively (Figure 4B). Abundance of filamentous MPs in the shrimps from three zones was significantly different at $p \leq 0.05$. The abundance of MPs in the shrimp samples from headstream was not found, while they were increased at midstream and downstream with increasing numbers of 0.64 ± 1.72 and 0.75 ± 2.2 piece/individual, respectively.

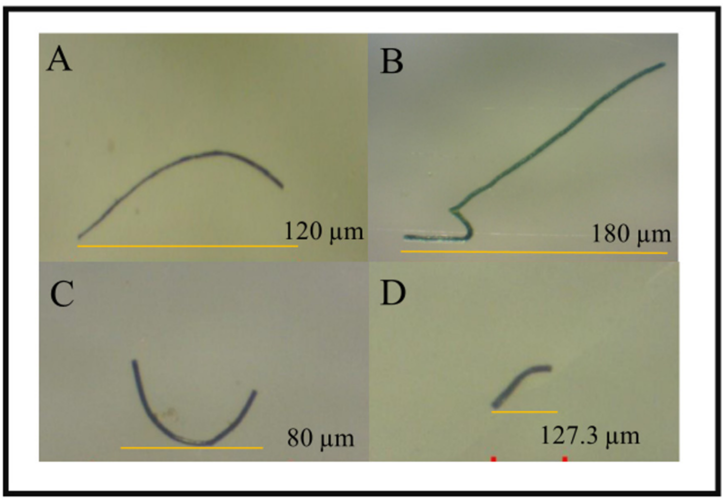

Figure 3. Filamentous microplastics found in *M. lanchesteri*: A) blue, B) green, and C-D) black colors.

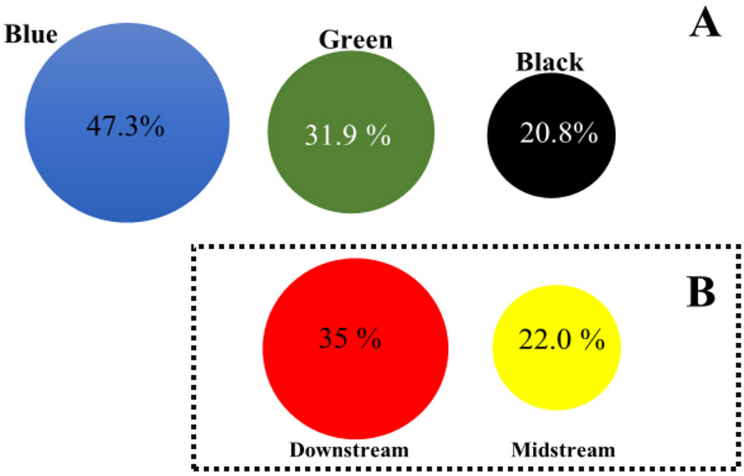

Figure 4. Percent of frequency occurrences of filamentous microplastics found: A) colors: 47.3% blue, 31.6% green, and 20.8% black, accumulated in *M. lanchesteri*; and B) frequencies: 35% downstream (n=100), 22.2% midstream (n = 100), and not found in headstream (n = 100)

3.2 Microplastics diversities and types

From FT-IR analysis, bond assignments and IR bands (cm^{-1}) of functional chemical compositions were identified to 10 types of MPs in water and sediment from the Khwae Noi watershed where shrimps were sampled (Figure 5, Table 1), which four MPs types found to accumulate in the shrimps were Polydimethylsiloxane (PDMS), Polyamide (PA), Polyester (PES), and Polymethyl Methacrylate (PMMA). In this study, MPs types were not significantly differed between water and sediment (t-test, $p < 0.05$). Frequency occurrences of MPs types in water and sediment were presented to accumulate in the shrimps in the Khwae Noi watershed as well.

Many studies have investigated MPs accumulation in shrimps. For example, Yan *et al.* (2021) found cellulose, Polyethylene (PE), acrylic, Polypropylene (PP), PA, Polyethylene terephthalate (PET) and cotton in shrimps, and Nan *et al.* (2020) found rayon, PE, PA, PES, PP, pigment, acrylic, PMMA, coating and elastane. Most of the MPs types found in our study were generally found according to other studies depending on surrounding anthropogenic activities. Apparently, all the MPs types found in the shrimp were linked with those found in water and sediment, which this result might indicate that MPs were in the food chain in the freshwater ecosystem.

3.3 Environmental factors corresponded to microplastics accumulation

The percent similarity index by Sorensen Distance was used to classify the accumulation of MPs in the shrimp, being classified into three groups by Sorensen Distance of 70% of similar index as the followings (Figure 6). The first group consisted of shrimps in headstream, high elevation at ≥ 300 m, high pristine area (protected areas with lowest village number and population). The second group comprised shrimps in midstream with medium elevation at 150 - 200 m, having MPs at 0.32 ± 1.2 piece/individual, having medium disturbance areas with increasing land-used area. The third group clearly comprised land-used areas, having high abundance of MPs in water and sediments related to high accumulation of MPs in downstream shrimps at 0.72 ± 0.4 piece/individual with low elevation at ≤ 150 m.

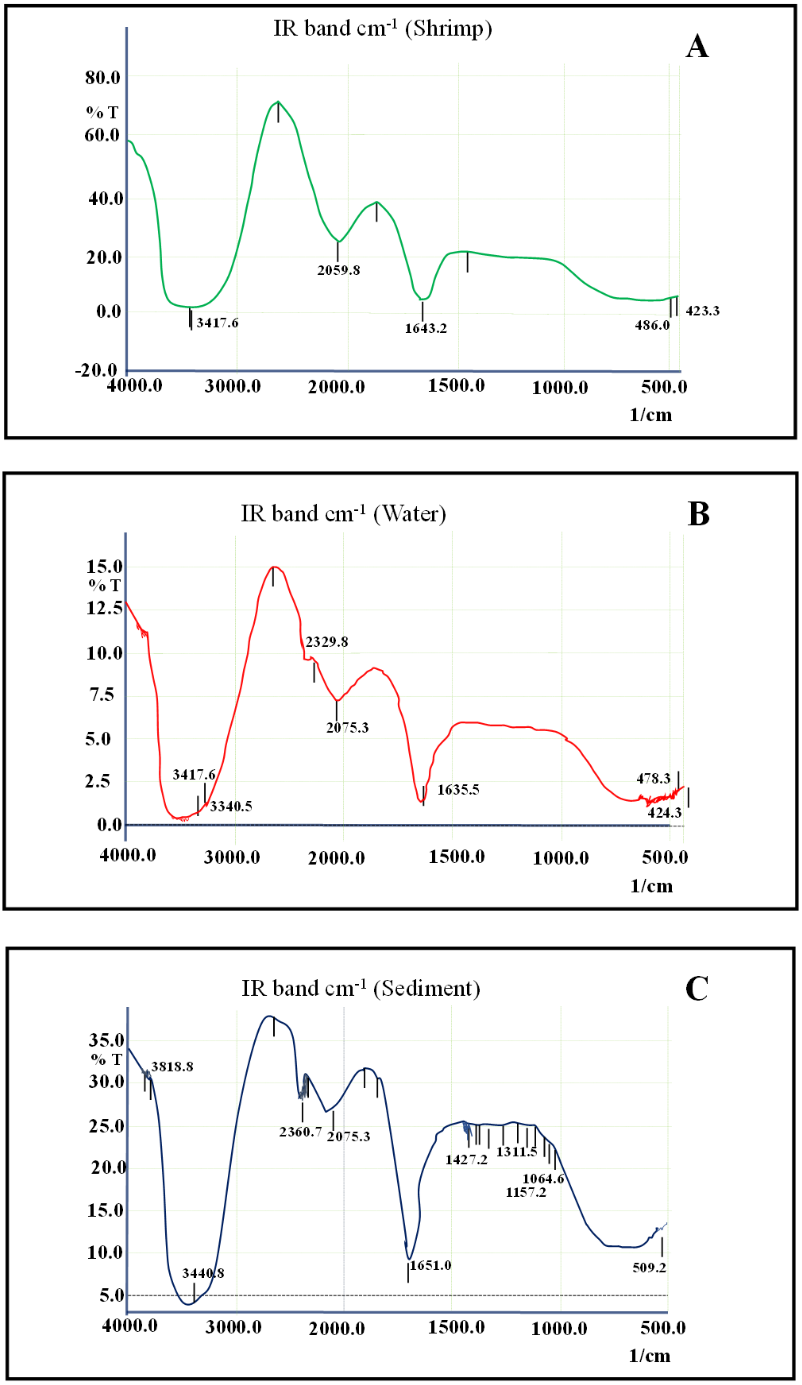

Figure 5. FT-IR spectrum of microplastics types found in: A) freshwater shrimp, B) water, and C) sediment from the Khwae Noi watershed

Table 1. Microplastics types found in water and sediment, ≥ 60% pooled samples, and classified by chemical compositions of bond assignment and IR band by FT-IR

Environment	IR Band (cm^{-1})	Bond Assignment	Microplastic types
Water	3417.6	N - H, C - H, O - H	Polypropylene (PP), Polyethylene (PE), Polyethylene terephthalate (PET), Polyvinyl chloride (PVC), Polydimethylsiloxane (dimethicone) (PDMS), Polyamide (nylon) (PA), Polyester (PES), Polyurethane (PU), Polystyrene (PS), Polymethyl Methacrylate (acrylic) (PMMA)
	3340.5	C - H, CH_2, CH_3, N - H	
	2329.8	C = C, C ≡ C, C ≡ N	
	2075.3	Silicon compounds	
	1635.5	C = C, C = O, N - H, Aromatics	
	478.3	Alkyl halides	
	424.3	Alkyl halides	
Sediment	3818.8	O - H	PP, PE, PET, PVC, PDMS, PA, PES, PU, PS, PMMA
	3440.8	N - H, C - H, O - H	
	2360.7	C = C, C ≡ C, C ≡ N	
	2075.3	Silicon compounds	
	1651.0	C = C, C = O, N - H, Aromatics	
	1427.2	CH_2, C - F, C = C, Aromatics	
	1311.5	CH_3, C - N, C - F	
	1157.2	C - O	
	1064.6	C - C	
	509.2	C - Cl, C - I, C - Br	

Accordingly, Principal Correspondence Analysis (PCA) as Pearson Correlation demonstrated abundance of filamentous MPs correlated with eight environmental factors comprising: headstream, midstream, downstream, elevation, pristine area, land-used area, MPs in water and MPs in sediment as illustrated in Figure 5 ($p < 0.05$, $r^2 = 0.78$). PCA indicated that the first group is clearly positively correlated with high elevation and relatively pristine area, which MPs accumulation was not found in headstream shrimps, and is negatively correlated with land-used area and high abundance of MPs in water and sediment. For the second group comprising only midstream shrimps, its position is tended to the right of diagram defined as medium disturbance area according to the presence of 0.32 ± 1.2 piece/individual of MPs accumulation. Third group is positively correlated with land-used area, relatively high abundance of MPs in water and sediment contributing to present the highest accumulation of MPs in downstream shrimps (0.72 ± 0.4 pieces/individual). Land-used area was the highest significant factor that supported the contamination of MPs in the environmental compartments especially in water and sediment, and contributed to accumulate MPs in the shrimp in the Khwae Noi watershed based on relatively high anthropogenic activities in downstream as a deteriorated habitat, respectively (Tongnunui *et al.,* 2016).

Presently, MPs have been accumulated in terrestrial (Rillig and Lehmann, 2020) and aquatic ecosystems (Tang *et al.,* 2021), linked with anthropogenic activities, and in return have negative consequence on humans (Boyle and Örmeci, 2020). Our findings are worth noticing that small filamentous MPs with the sizes between > 50 – 300 µm in *M. lanchesteri*, even with a very small quantity, were detected in Kanchanaburi Province in Thailand.

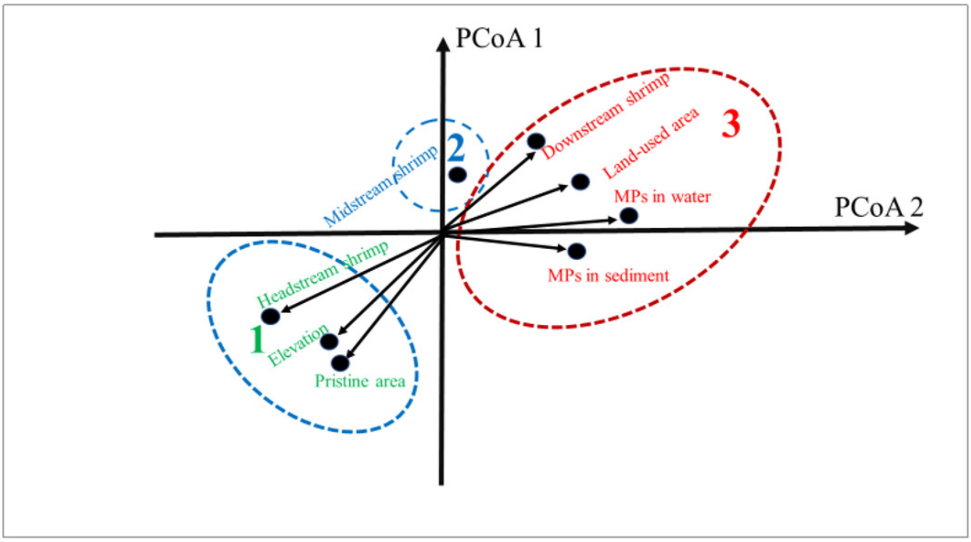

Figure 6. 70% similarity index by Sorensen Distance and Principal Correspondence Analysis of the three groups of microplastics accumulation in the shrimp, being significantly related to 8 factors for each group (Pearson correlation, $p \leq 0.05$, $r^2 = 0.78$)

Due to a limitation of our method, MPs smaller than 50 µm including nanoplastics could not be detected. With this limitation, this study could not certain that, even with a relatively low MPs abundance in the shrimp, it would not be threatened by nanoplastics. The nanoplastics was reported on its toxic effects on phytoplankton (Larue *et al.* 2021). And, the smaller the shrimp is, the higher chance of ingesting relatively smaller MPs and nanoplastics (Nan *et al.* 2020).

This study therefore concerns about health implication of shrimp survival from gastrointestinal tract obstruction, possibly leading to starvation and injuries. Toxic monomers from plastics can also cause abnormal reproduction system and cancer, potentially leading to death (Boyle and Örmeci, 2020). MPs presence in *M. lanchesteri* may imply the quality of ecological health of the Khwae Noi watershed because *M. lanchesteri* is abundant, widely distributed, and important for trophic levels of river (Hayden *et al.,* 2021), then provides ecosystem functions, and subsistent foods and economic value for local communities.

To reduce influx of MPs in the Khwae Noi watershed, a policy with strategies of single use plastic management, especially reuse, reduce, recycle (3R), and promotion for using biodegradable plastics, is required through education, campaign and public awareness creation to safeguard the environment and food safety.

Additionally, this study is worth to be discussed for implementing to the United Nations (UN) Sustainable Development Goals (SDGs), which governments, corporations, organizations and communities put an effort to enhance the sustainability. The issues of this study related to MPs accumulation in the shrimp, *M. lanchesteri*, and its environmental factors are under: Goal 2 (End hunger, achieve food security and improved nutrition, and promote agriculture) because the shrimp is served as a local food; Goal 3 (Ensure healthy lives, and promote well-being for all at all ages) because MPs are accumulated in the shrimp, threatening an impact on human health; Goal 6: (Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation) because biodegradable plastics are alternatives to contribute a circular economy and decrease MPs in the environmental compartments; Goal 11 (Make cities inclusive, safe, resilient, and sustainable) because disposals of plastics with inadequate waste management systems lead to environmental problems including MPs; and Goal 15:

(Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss) because the environmental factors are related to MPs accumulations in some study areas of the Khwae Noi watershed comprising national parks and wildlife sanctuaries.

4. Conclusions

This study first reported microplastics (MPs) accumulation in the freshwater shrimp, *Macrobrachium lanchesteri*, that is a local commercial shrimp generally eaten by Thai people. It was sampled from headstream, midstream and downstream areas of the Khwae Noi watershed in western Thailand. The results found that MPs accumulation in the shrimp correlated with eight environmental factors comprising: headstream, midstream, downstream, elevation, pristine area, land-used area, MPs in water and MPs in sediment. Headstream together with elevation and pristine area did not have MPs accumulation in the shrimp, but the numbers of their accumulations consecutively increased with higher numbers of land-used area, MPs in water and MPs in sediment in midstream and downstream, which all the MPs types found in the shrimp were also found in water and sediment. These factors cause notable effects on the shrimp with MPs accumulation. Then, anthropogenic activities inevitably caused the MPs accumulations in the shrimp.

Acknowledgements

This study was financially supported under Research and Innovation Grant 2020 by National Research Council of Thailand. The authors wish to acknowledge Conservation Biology Program, Mahidol University, and Applied Science and Science Center, Surindra Rajabhat University for providing convenient equipment and laboratories. The authors would like to thank Department of National Parks, Wildlife and Plant Conservation and Department of Fisheries, Ministry of Natural Resources and Environment, Thailand, for providing the permissions to sample aquatic animals. Finally, thank Dr. Lawrence M. Page, University of Florida, for comments of the manuscript. The animal care and use license for scientific research Kasetsart University was ACKU63-ETC-001.

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