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Microplastics occurrence in the commercial Southeast Asian seafood and its impact on food safety and security: A review

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Abstract. Microplastics are plastic particle with size less than 5 mm and omnipresent in the aquatic environment. The occurrence of microplastics in marine environments has been reported in many studies and recently extended to the freshwater ecosystem. To date, the increasing incidence of microplastic ingestion by various edible aquatic species has raised concern about its potential impact on food safety, food security, and human health. Therefore, this paper overviews the current knowledge on the occurrence of microplastics in edible fish and shellfish in the Southeast Asian region. The review also discussed the research findings on the adverse effects of contaminated seafood with microplastics to human health.

1. Introduction

Fisheries are one of the main sectors in most countries as it generates income, increase regional economy and sustain food security of the nation. In general, there are three main subsectors of fisheries, namely aquaculture, marine fisheries, and inland fisheries to fulfil the seafood demand. In Southeast Asian region, the fisheries industry plays a significant role as a major supplier of animal protein to the people. Based on the Southeast Asian Fisheries Development Center (SEAFDEC) statistics, in 2015, Southeast Asia region contributes about 22% of the world total fishery production. It shows that many countries in this region are among the major producers of seafood worldwide. The production increased from 33.6 million ton from 2011 to 44.0 million ton in 2015.

To date, many studies have reported on seafood contamination with plastic. It is noting that plastic debris in aquatic environments derived from anthropogenic activities, such as plastic production, agriculture and landfills. Various waste-management strategies have introduced as another option of the conventional way of disposal like landfilling. For example, downgauging, incineration, reuse and recycles plastic products, where recycling is more green strategy. Recycling method is introduced in the 1970s as it can reduce impact in the environment and efficiently increase resource concurrently [1]. In many countries, serious efforts are undertaken to create awareness to consumers in practising ‘reduce’, ‘reuse’, and ‘recycle’ (3R) campaign. Nevertheless, this campaign not entirely captured the consumers perspective in Southeast Asian countries. It shows that the recycling rate in this region much lower compared to others worldwide. Among Southeast Asian countries, Thailand has the highest recycling rate at 14%, followed by Singapore (11%) and Malaysia (5%). These considered lower compared to Japan and Germany at 40% and 52.8%, respectively [2]. The top 10 countries worldwide that mismanage plastic waste (e.g. uncontrolled landfills and disposal in dumps or open) mostly among the countries in the Southeast Asia region. In general, the low recycling rate and mismanaged plastic waste will indeed increase the risk of plastic pollution in the aquatic biome [3]. Besides, the comprehensive understanding of its source, deposition and decomposition processes in the environment are still deficient [4]. Hence, due to its impact and ubiquity in ecosystems, the scientific community in recent years begins to propose plastic pollutant as a potential planetary boundary candidate [5].

The main problem of plastic waste is that it can generate smaller plastic particles known as microplastics. Microplastics are plastic particles with a size of less than 5 mm. This pollutant is always reported greater in the highest population density. In freshwater ecosystems, streams and rivers are regarded as the major pathways of microplastics to the ocean. Microplastics are omnipresent in both marine and freshwater environments. To date, the occurrence of microplastics in different compartments (i.e. water, sediment, and biota) has been reported in numerous studies. Nonetheless, the investigation on microplastic ingestion by the freshwater animal is still scarce compared to marine animals.

Several studies have also remarkably reported on the occurrence of microplastics in a variety of food products such as dried fish, canned seafood, table salt and drinking water. It shows that the impact of microplastics does not affect aquatic animals only but also human health. More recently, it has trigger global concerns over the food safety [6]. Thus, the present study overviews the occurrence of microplastics in edible aquatic species among the Southeast Asian countries and assess the impact of microplastics on food safety and security.

2. Methodology

Literature retrieval was performed using the ISI Web of Knowledge, Scopus, and Google Scholar. The topic of search keywords are “microplastics”, “occurrence”, “commercial seafood”, and “southeast asia”. The topics were searched from 1970 to 2021. The assessment includes the articles that define the microplastic occurrence in the environment and provide a comprehensive explanation of the topics such as captured fish from both inland and marine fisheries as well as aquaculture sector in Malaysia. Articles related to commentary, reviews, and chapter in books were excluded. A preliminary screen of the searched articles was carried out for the relevance of the title and subject discipline before the full-text screening. A total of 19 articles were retrieved in this paper.

3. Results and Discussion

Table 1 shows that only 50% of the Southeast Asian countries investigate the occurrence of microplastics in edible aquatic animals from both marine and freshwater environments such as Indonesia, Malaysia, Phillippines, Thailand, Vietnam and Singapore. Of these, Thailand reported a higher number of edible aquatic animals species followed by Malaysia and Indonesia. Overall, the approximate number of documented edible aquatic animals in this region were 60 fish and eight shellfish species. The review indicates that the unit of microplastic concentration and its identification procedure is not uniform across the countries.

Most of the microplastic particles were found in gastrointestinal (GI) tract of the fish and only Sembiring et al. [7] studied on its edible part such as flesh. It is worthy of note that the GI tract/stomach is the commonly used tissue sample to investigate microplastic occurrence in aquatic animals. For instance, almost 93% of the previous study have utilized the GI tract/stomach of freshwater fish worldwide [8]. Meanwhile, all studied shellfish animals such as bivalve (i.e. mussel and Ark shell), gastropod, and crustacean (i.e. prawns) species in the present review ingested microplastics in the natural environment. Almost 74% of the articles investigate on the occurrence of microplastics in fish species compared with shellfish at only 26%.

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Table 1. Occurrence of microplastics in seafood among Southeast Asian countries. Asterisk* indicates ingestion based on different unit.

Country	Sampling site	No. of species	No. of Sample	*Ingestion	Dominant				Reference
					Shape	Colour	Size (mm)*	Polymer	
Indonesia	Bengkalis Waters, Riau	3 fish species	36	62.96 particle/fish	Film	White	0.1-0.5	NA	[9]
	Kodingareng Lompo Island	4 fish species	46	up to 40%	Line	Blue	NA	LDPE	[10]
	Citarum River downstream area	1 fish species (*Chanos chanos*)	6	1.33 ± 0.58 – 2.6 ± 2.23 particle/fish (gills & guts); 1.11 ± 0.84 -1.17 ± 0.98 particle/fish (tissue)	Fragment	Black	0.5-1.0	PP & PE	[7]
	Pantai Baron, Yogyakarta	4 fish species	80	78 97.5% (45.60 ± 44.31 particle/fish)	Fibre	Black	0.05-0.1	PA	[11]
	Pangandaran Bay	2 fish species	18	NA	Fragment	varied	varied	NA	[12]
	Talisayan Harbor, East Kalimantan	1 fish species (Stolephorus spp.)	15	366 ± 3.51 particle/fish	Film	NA	0.05-0.5	varied	[13]
	East Lombok Harbour, Lombok Island	1 fish species (Stolephorus spp.)	15	88 ± 2.89 particle/fish	Fibre	NA	0.05-0.6	varied	[14]
	Pantai Indah Kapuk	9 fish species	174	97.13%	Fibre	Transparent	0.06-0.08	NA	[15]
Malaysia	Klang River estuary	3 gastropod species	95	0.5 – 1.75 particle/g w.w	Fibre	Black	0.3-1.0	PE-PDM	[16]
	Skudai River, Johor	6 fish species	60	up to 100%	varied	Blue	varied	NA	[17]
	Seri Kembangan Market, Selangor	11 fish species	110	up to 100%	Fragment	NA	NA	PE	[18]

Table 1. continued.

Country	Sampling site	No. of species	No. of Sample	*Ingestion	Dominant				Reference
					Shape	Colour	Size (mm)*	Polymer	
Malaysia	Setiu Wetlands, Terengganu	1 fish species (*Lates calcarifer*)	4	Total of 4498 particles	Line	Black	< 0.015	PA and PVA	[19]
	Setiu Wetland, Terengganu	1 bivalve species (*Scapharca cornea*)	NA	up to 557.98 particle/g d.w	Filament	Transparent	NA	PE and PA	[20]
Phillipines	Negros Oriental	1 fish species (*Siganus fuscescens*)	120	46.70%	Fibre	NA	1.8 ± 0.13	PP	[21]
	Sineguelasan Seafood Terminal	1 bivalve species (*Perna viridis*)	5	NA	varied	varied	< 1	NA	[22]
Thailand	Chi River	8 fish species	107	72.90%	Fibre	Blue	0.5	NA	[23]
	Gulf of Thailand	24 fish species	110	66.67%	Fibre and Fragment	Blue and Green	varied	NA	[24]
Vietnam	Tinh Gia, Thanh Hoa	1 bivalve species (*Perna viridis*)	5	0.29 ± 0.14 particle/g w.w	NA	NA	NA	PP	[25]
Singapore	Supermarkets	3 crustacean species (shrimps)	93	13 ± 1 to 7050 ± 418 particle/g w.w	Film and Sphere	Blue and Pink	NA	NA	[26]

The number of studied aquatic animals in this region varied because most of the articles only reported a preliminary investigation on the microplastics occurrence. Human often consume cleaned seafood as most of the GI tract of the fish is removed from the edible part. Indeed this will reduce the exposure of microplastic pollutant to human. Nevertheless, the occurrence of microplastics in fish tissue has also been reported in this region. For example, microplastics were reported in milkfish, *C. chanos* tissue with the average from 1.11 ± 0.84 to 1.17 ± 0.98 particles per fish [7].

There is also certain seafood wholly consumed by human, for example, mussels, anchovies, and prawns. Curren *et al.* [26] have recently studied on the commercial shrimps such as *Litopenaeus vannamei*, *Pleoticus muelleri*, and *Fenneropenaeus indicus* from the local supermarkets in Singapore. The study segregates the prawns based on the origin country such as *L. vannamei* imported from Malaysia and other regions such as Ecuador (*L. vannamei*), the Indian Ocean (*F. indicus*), and Argentina Southwest Atlantic (*P. muelleri*). On average, their study found that *P. muelleri* contained the highest microplastics at 7050 ± 418 particles/g wet weight, followed by *F. indicus* (5570 ± 100 particles/g wet weight). Meanwhile, *L. vannamei* from Malaysia and Ecuador ingested about 20.8 ± 3.57 and 13.4 ± 1.42 particles/g wet weight, respectively. On the other hand, anchovies, Stolephorus spp. from different Indonesian coastal have also been reported to ingest microplastics within a range from 88 ± 2.89 to 366 ± 3.51 particle per fish [13,14].

The review also shows that, fibre/line was the most dominant shape found in seafood. In general, fibres/line have been widely reported in various freshwater and marine aquatic animals stomach, especially the edible ones. Fibres derived from clothes can remain for a longer time in environment and also found mixed in sediments. It is more pliant and much lighter compared to other microplastics shapes (i.e. hard plastic fragment and film). It has been reported that the invertebrate species such as bivalve and gastropod are likely ingested fibres since most of these species inhabit and scavenging at the seabed. Thus, microplastics have the potential to biomagnify in the food web where it ends at apex predator animals (i.e. fish). Besides, the smaller particles can also be regularly ingested by fish during drinking water to sustain homeostasis [27].

Microplastic ingestion based on colours varies among aquatic animals. Fish has several numbers of sensory organs which can affect their feeding behaviour. These specialized organs are highly developed in most fishes, where vision and chemoreceptive systems often used to detect preys. Fish may initially use chemical cues via sense of chemoreceptors to determine preys before using their vision for final attack [28]. Previous studies have also reported on the preference of food items by fish based on different colours during feeding experiment. Meanwhile, in natural environment, Herrera *et al.* [29] reported high concentration of blue microplastics in Atlantic chub mackerel (*Scomber colias*) as the colour resembles blue copepods. Overall, microplastic ingestion based on chemical cues and visions are more complex matter and warrant in-depth investigations [8].

The occurrence of microplastics in aquatic animals have been widely reported. The gut microplastics burden significantly varied according to species, feeding habits and trophic transfer [30]. Of these, the investigation of microplastic ingestion based on feeding habits and trophic transfer is still limited. It is noting that aquatic ecosystems have a very complex food web. The first level contains producers where green plants are the food source of herbivorous fish in the natural environment. Herbivorous fish have no true stomach which makes them eat more often on plants, algae, and fruits. For instance, tilapia often consume duckweed as their primary food. However, a recent study has demonstrated the rapid adsorbed of polyethylene microplastics to all surfaces of duckweed under laboratory experiment [31]. Other interaction of microplastics with aquatic vascular plants was also reported by previous studies where the adsorbed microplastics on plant tissue can be easily ingested by herbivores [32]. Besides plants, many bivalve and fish species also feed on zooplankton as their nutritional resource, especially in marine ecosystems. Zooplankton is often found and feed on surface water where microplastics abundantly reported. As of today, microplastic ingestion by zooplankton have been reported by numerous studies [33]. It shows the severity and persistence of microplastics in aquatic ecosystems, especially in the edible fish and shellfish. Thus, it could lead to the accumulation of microplastics in apex predator via trophic level transfer in the food web. Remarkably, both fish and shellfish in higher trophic levels are served as delicacies and may affect human health. Other studies have also found microplastics in a variety of processed seafood products.

To eliminate microplastics from the environment is not viable due to their small size and continuous degradation of larger debris. The reduction of input of debris is recognised as the most effective measures. But, it is not sufficient enough to stop the increment of microplastic concentrations in environments. This is because the existence of present debris in environments would be the legacy inputs of microplastic particles [34]. The occurrence of microplastics in different tissues of commercial seafood have been reported in many regions worldwide. The main concern arises when the persistent organic pollutants or metals sorbed onto microplastics' surface could be transferred to edible tissues. Besides, translocation of microplastics to internal tissues of aquatic animal have also raised concerns among researchers [35].

The study on toxicity effects of microplastics and the carried pollutants on its surface in seafood as well as its impact on human health is continuously in progress. There are several studies which demonstrated the effect of microplastics based on different sizes, shapes and polymers of plastic particles. Watts et al. [36] demonstrated the significant reduction of feeding activity in crab, *Carcinas maenas* after four weeks of exposure to polypropylene fibres. The result showed this feeding reduction affects the energy used for their growth. Meanwhile, the exposure of polyethylene and polystyrene particles less than 100 μm contaminated with pyrene to the mussel, *Mytillus galloprovincialis* in 7 days shows cellular and molecular effects such as the alteration of immunological response and changes in DNA expression [37]. Other studies investigating the retention time of microplastics in the GI tract shows its accumulation was not significant.

4. Conclusion and perspective

Microplastics occurrence in edible fish and shellfish in the Southeast Asian region are still limited compared to other areas. The interaction of microplastics with aquatic organisms and the risk related to human that consume organisms had ingested microplastics remain unknown. The toxicity of microplastics and other chemical pollutants in the environment and its implication to aquatic organisms and human health is still in its infancy and need additional research investigations.

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