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Risk of aquaculture-derived microplastics in aquaculture areas: An overlooked issue or a non-issue?

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Plastic equipment such as fishing nets and foam buoys has been widely used in aquaculture. This kind of equipment would gradually decompose while being subject to the long-term effects of physical, chemical, and biological degradation processes, leading to the release of large amounts of microplastics (MPs) into the local marine environment and the generation of aquaculture-derived MPs (AD-MPs). The rapid growth of aquaculture has resulted in an explosion of AD-MPs with various environmental consequences. The accumulation of MPs in aquatic products was found closely related to the abundance of environmental MPs, suggesting the importance of determining whether AD-MPs increase the risk of MP ingestion by aquatic products and thus endanger aquatic food safety. In this short communication, the ecological and health risks of AD-MPs were discussed and perspectives were proposed for future studies.

KEYWORDS

aquaculture, microplastics, occurrence, bioaccumulation, ecological risk

Highlights

- Plastic gears for aquaculture generate aquaculture-derived microplastics (AD-MPs)
- AD-MPs have become a major source of MP pollution in aquaculture
- Ecological and health risks of AD-MPs in aquaculture areas were discussed
- Key environmental perspectives on AD-MPs research were proposed

Introduction

As emerging pollutants, microplastics (MPs) have attracted worldwide attention and recently become a research focus in aquatic environmental science. Previous studies considered terrigenous input as the main source of MP pollution (Cole et al., 2011). However, recent studies have shown that the contribution of aquaculture activities to the abundance of MPs in coastal waters, especially the aquaculture areas, could be substantially underestimated (Zhang et al., 2021b). Fishing nets, foam buoys and other plastic products have been widely used in aquaculture (**Table 1**). They can gradually break and finally release a large number of MPs into local water environment under long-term ultraviolet radiation and wind-wave action (Lusher et al., 2017) (**Figure 1**). Aquaculture activities such as feeding, treatments, and packaging can also lead to the release of MPs into the water environment (Lusher et al., 2017) (**Figure 1**). All these released MPs are defined as aquaculture-derived MPs (AD-MPs). Currently, a large number of AD-MPs have been detected in different coastal waters, and their proportion can be even up to 99.00% of the total MPs at some aquaculture areas (**Table S1**). What's more, AD-MPs have also been detected in different tissues of various aquatic economical organisms in both freshwater and marine aquacultures (Zhang et al., 2020; Zhang et al., 2021a). All these results raise concern that the increasing AD-MPs pollution at aquaculture areas may cause adverse effects on the farmed species, and finally pose threats to human health *via* food chain. Since aquaculture has become one of the main production modes of aquatic products for its efficiency (Chen et al., 2018), it is important to determine whether AD-MPs increase the risk of MP ingestion by aquatic products and thus endanger aquatic food safety. The aim of this communication thus is to identify the sources and occurrences of AD-MPs, and discuss their ecological and health risks in aquaculture areas by comparing differences in content, chemical composition, color, and shape of MPs between farmed and wild aquatic products. Potential risk of AD-MPs' being carriers of complex contaminants was also discussed. Key environmental perspectives on AD-MPs research were finally proposed.

Sources and occurrences of AD-MPs in aquaculture areas

Sources of AD-MPs in aquaculture areas include several pathways (**Figure 1**): (i) sunlight driven decomposition, seawater corrosion, wave friction and abrasion can cause the breakdown of the plastics in use (e.g., buoys, net cages, packaging) as well as the abandoned, lost, or discarded fishing gears (ALDFGs) and form AD-MPs (Lusher et al., 2017; Chen et al., 2018); (ii) Removing biofouling organisms can lead to the release of fibrous AD-MPs from aquaculture equipment such as fishing nets and ropes (Davidson, 2012); and (iii) AD-MPs contained in the feed or adsorbed on the surface of fish medicine can enter the aquatic environment during aquaculture (Yao et al., 2021).

Aquaculture activities and the associated equipment should be an important local contributor to the plastic pollution in aquaculture areas. Recent studies have shown a large number of AD-MPs in different aquaculture areas, such as Sanggou Bay (AD-MPs/MPs = 57.72%) (Sui et al., 2020b), Longjiao Bay (AD-MPs/MPs = 83.10%) (Chen et al., 2020), Xiangshan Bay (AD-MPs/MPs = 55.70%) (Chen et al., 2018), and Geoje Island (AD-MPs/MPs = 99.00%) (Lee et al., 2013) (**Table S1**). In some regions (e.g., Longjiao Bay and Geoje Island), even over 50% of the total MPs are AD-MPs (Lee et al., 2013; Sui et al., 2020a; Xue et al., 2020) (**Table S1**). This would lead to a higher abundance of MPs in aquaculture areas than that in the open ocean (Chen et al., 2018), indicating that the pollution of AD-MPs should not be neglected.

Ecological and health risks of AD-MPs

MPs can enter and, accumulate in aquatic products through gill respiration or ingestion behavior, which has been detected in the gastrointestinal tract, gill or circulatory system of aquatic organisms (Brillant and MacDonald, 2002; Browne et al., 2008; von Moos et al., 2012; Zhang et al., 2021a). However, the accumulation and potential risk of MPs varies in different tissues. For example, it showed that MPs accumulation in non-cleansed crayfish was more likely to occur in their digestive system compared with the respiratory organs, accounting for 77.3-91.2% of the total accumulated MPs (Zhang et al., 2021a). In general, larger MPs tend to accumulate in the digestive tract and be excreted more quickly, while smaller ones can be transported through the digestive tract to the circulatory system and more likely to remain in the aquatic products (Brillant and MacDonald, 2002; Browne et al., 2008; Kaposi et al., 2014). What's more, the abundance of MPs in aquatic products may be closely related to their feeding habits and habitats (Guven et al., 2017; Baalkhuyur et al., 2018). Aquatic organisms are susceptible to accidental ingestion of MPs with a color similar to their prey or those mixed with their food sources (Zhang et al., 2021a). In addition to feeding habits, the MP abundance in specific habitat can also significantly affect the accumulation of MPs in aquatic products. For example, since sediments are considered a sink for MPs, demersal species are at relatively high risk of MP exposure and ingestion compared to pelagic species (Van Cauwenberghe et al., 2015; Wang et al., 2019a; Zhu et al., 2019; Zhang et al., 2020).

TABLE 1 Names, shapes, materials and purposes of common plastic equipment used in aquaculture.

Name	Shape	Material*	Purpose	Reference
Meshes		PP, PE, LDPE, PET and PA	Made into fishing net and net cage	(Lusher et al., 2017; Chen et al., 2018; Wang et al., 2019b)
Fiber Rope, Film Rope		PP, PET, PA, PE and LDPE	Made into fishing rope	(Lusher et al., 2017; Chen et al., 2018; Wang et al., 2019b)
Plastic Film		PE, PET and HDPE	Made into impervious membrane, blackout film, shed film and pond liner	(Lusher et al., 2017; Chen et al., 2020)
Plastic Pipe		PVC and HDPE	Made into cage collar and drain-pipe	(Lusher et al., 2017)
Buoy		EPS, PS, PVC, ABS and PE	Made into buoyant raft and positioning buoy	(Lusher et al., 2017; Chen et al., 2018; Wang et al., 2019b)
Plastic Box		PP, PE and LLDPE	Seedling-raising	(Lusher et al., 2017)
Foam Box		PS and EPS	Packaging and transportation	(Wang et al., 2019b)
Woven Bag		PA, PP and PE	Made into feedbag and sandbag	(Lusher et al., 2017)
Sponge		PU	Made into positioning buoy	(Zhou et al., 2018)
Scrap Rubber Tire		BR, SBR, IR and EPR	As a habitat and shelter for aquatic products	(Chen et al., 2018)

*ABS, Acrylonitrile Butadiene Styrene Plastic; BR, Cis-1,4-Polybutadiene Rubber; EPR, Ethylene Propylene Rubber; EPS, Expanded Polystyrene; HDPE, High Density; Polyethylene; IR, Polyisoprene Rubber; LDPE, Low Density Polyethylene; LLDPE, Linear Low-Density Polyethylene; PA, Nylon; PE, Polyethylene; PET, Polyethylene Terephthalate; PP, Polypropylene; PS, Polystyrene; PU, Polyurethane; PVC, Polyvinyl Chloride; SBR, Polymerized Styrene Butadiene Rubber. The AD-MPs derived from abandoned, lost or discarded plastic equipment is considered to be the main source of plastic waste from the equipment.

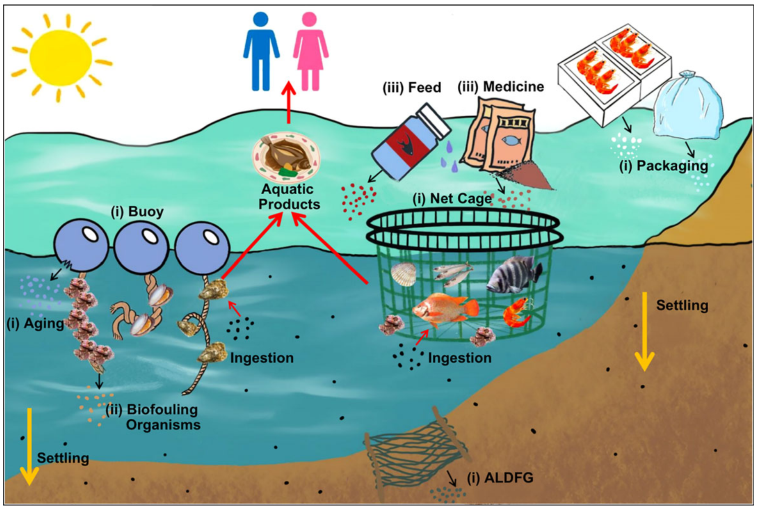

FIGURE 1
Schematic diagram of the sources and migration of AD-MPs.

Given that the accumulation of MPs in aquatic products is closely related to the abundance of environmental MPs in their habitats, along with the higher MP abundance (presented as AD-MPs) in aquaculture areas than that in the open ocean, more MPs would be accumulated in aquatic products than in wild animals. In other words, AD-MPs could increase the risk of MP ingestion and accumulation in aquatic products. This has been proved in several studies that aquaculture activities (with high AD-MPs release) could generate large amounts of AD-MPs to which aquatic products would be exposed, significantly increase the risk of MP ingestion by the organisms (Mathalon and Hill, 2014; Li et al., 2018) and finally cause higher MPs accumulation (Davidson and Dudas, 2016). Nevertheless, there were also a few field surveys showing that the MP abundance in farmed aquatic products was comparable to or even lower than that in wild organisms (Li et al., 2016; Birnstiel et al., 2019). Whether AD-MPs would increase the risk of ingesting MPs in aquatic products and jeopardize aquatic food safety seems to be controversial. However, further analyses suggest the contrary results could be explained by the phenomenon that the living environment of wild aquatic products is generally affected by frequent human activities such as tourism and shipping (Birnstiel et al., 2019; Li et al., 2016). Therefore, the wildlife collection sites should be far away enough from human activities to prevent additional disturbances when comparing the MP accumulation between farmed and wild aquatic products.

The differences in chemical composition, color, and shape of MPs in farmed and wild aquatic products also support the above findings. Most of the fibrous MPs detected in farmed aquatic products originated from netting, while those detected in wild aquatic products originated from the discharge of municipal domestic sewage (Browne et al., 2011; Witte et al., 2014; Li et al., 2018). The average diameter of the fibrous MPs released from fishing gear was usually at the millimeter levels, which is significantly higher than that of the fibrous MPs in the wash wastewater (<0.07 mm) (Chen et al., 2018a; Frias et al., 2010). There are also differences in chemical composition and color of MPs between farmed and wild aquatic products. Farmed organisms tend to be more susceptible to ingesting polypropylene (PP) and grey MPs (Davidson and Dudas, 2016; Li et al., 2018). This could be attributed to the locally used aquaculture plastic equipment. For example, PP MPs were mainly found in farmed UK mussels, but were hardly detected in wild mussels (Li et al., 2018). This was likely because the farmed mussels lived on PP ropes and thus ingest more PP MPs while the wild environment lacked sources of PP contamination.

Therefore, by comparing the differences in content, chemical composition, color, and shape of MPs between farmed and wild aquatic products, we further confirmed that accumulation of MPs in aquatic products is influenced by AD-MPs (**Figure S1**). The results also imply that the large number of AD-MPs released from farming facilities can not only increase the risk of MP ingestion but also influence the types and characteristics of MPs in aquatic products (**Figure S1**). The probability of adverse reactions in aquatic products may be increased as well and ultimately affect the ecological health of aquaculture areas.

Moreover, AD-MPs are complex contaminants composed of various monomers and additives; their hydrophobic surfaces can adsorb different types of toxic and hazardous substances from the aqueous environment and become carriers of contaminants including PAHs, PCBs, and organochlorine pesticides

(Rochman, 2015). Thus, ingestion of AD-MPs by organisms may be accompanied by the ingestion of the associated contaminants (**Figure S1**), leading to a series of adverse effects even causing the death of the organism (Gardon et al., 2020). In addition to the direct effects of AD-MPs on aquatic products, these particles released from aquaculture plastics such as foam buoys, fishing nets, and plastic pipes can also affect the microbial community in the marine environment. They can provide colonization sites for microorganisms enhancing the survival of potential bacterial pathogens, and act as vectors spreading pathogens to aquatic products or the ecosystems (Hou et al., 2021) (**Figure S1**). Microbial-induced diseases are a major problem faced by aquaculture industry today. To sum up, AD-MPs could be an important reason to increase the morbidity rate of aquatic products, raising food safety concerns for aquatic products.

Perspectives

The development of aquaculture has increased the abundance of AD-MPs in the aquatic environment. Existing findings indicate that the ecological and health risks of AD-MPs cannot be neglected. To effectively assess the potential risks of AD-MPs, the following suggestions are proposed: 1) more studies are needed in the global pollution and spatial-temporal distribution of AD-MPs. These studies should evaluate the abundance, materials, and sizes of AD-MPs in the aquatic environment and organisms around the world. 2) A scientific source identification method of MPs should be established to pinpoint the source of MPs in the aquaculture environment and ensure the comparability between different investigations. 3) A comprehensive ecological and health risk assessment method is needed for AD-MPs. The regulation of aquaculture plastic products should be strengthened according to the risk levels. 4) The dynamics of AD-MPs in the aquatic environment should be studied to evaluate the migration patterns of AD-MPs among different areas, which could be conducted in conjunction with physical oceanography. The feasibility of using ocean remote sensing to monitor MPs pollution in aquaculture farms can be considered. 5) Since large amounts of AD-MPs are produced during aquaculture, farmed aquatic products would be more susceptible to MPs than wildlife, posing potential risks to human health *via* consumption of the contaminated seafood. Given the continuous demand for protein and the flourishment of aquaculture, understanding the ecological and health risks caused by AD-MPs is the next critical step to study the health and sustainability of aquaculture.

Author contributions

LL constructed and wrote this paper. CC and KP reviewed and edited the article. XZ and XX devised the idea and revised the manuscript. All authors contributed to the article and approved the submitted version.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2022.923471/full#supplementary-material

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