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Original Article

Environmental Health Risk of Microplastics Due to Consumption of Fish and Shellfish in the Coastal Area

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Abstract

Background: The increasing accumulation of plastic waste is the most serious threat to the marine ecosystem. People who still have the habit of disposing of solid waste, especially plastic-type waste, in the marine environment have led to the discovery of microplastic content in various marine biota such as fish and shellfish. We aimed to assess the environmental health risks of microplastics due to consumption of marine life in the coastal area.

Methods: We used an observational method with the Environmental Health Risk Assessment (EHRA) design to analyze the health risks of humans consuming fish and shellfish containing microplastics. This research was conducted in the coastal area of Takalar Regency, Indonesia in 2022. The samples used consisted of human (n = 30) and marine biota (fish, n=20; shellfish, n=20) samples. The data were obtained from observations, physical measurements of biota, laboratory tests, polymer type identification by Fourier Transform Infrared (FTIR) spectroscopy, and microscopy.

Results: The average concentration of microplastics containing styrene compounds in shellfish was 2.01 mg/kg. The abundance of MPs in the fish and shellfish samples was 0.01 particles/g or 10 particles/kg in fish and 7 particles/individual in shellfish. The MPs were found in line, fragment, film, and pellet forms, with different size and color variations. The average MPs exposure risk level (RQ value) for both fish and shellfish was 0.02.

Conclusion: All samples had RQ values < 1, which means that the microplastic-containing tofu shellfish were still safe for consumption by people living in the Takalar coastal area.

Keywords: Health risk; Microplastic; Fourier transform infrared; Fish; Shellfish

Introduction

Everyday items such as clothing, furnishings, automobiles, and cleaning supplies are now made of plastic (1). Plastics have infinite uses since they are affordable, strong, light, and pliable. Because of this, the environmental damages brought on by the overabundance of plastic garbage are obvious. Waters contain the majority of the microplastic (MP) abundance (2). One of the biggest challenges to the marine environment today is plastic garbage. Microplastics are one of the plastic wastes that should be of particular concern due to their small size (3). Marine biota and public health may be negatively impacted by the lack of equipment to detect the smallest microplastics in the environment (4).

Microplastics have been discovered in salt, beer, honey, bottled water, and drinking water (5). With a mean value of 103 particles/Lt, the reported particle concentrations in drinking water samples ranged from 0 to more than 104 particles/Lt. The number of microplastic particles in drinking water from the soil was greater than 103/Lt. Microparticles (microplastics) come in various shapes in fresh water, including fragments, fibers, films, foams, and pellets. Microplastics were present in honey at concentrations of 0.009 fragments/g and 0.116 fibers/g, with sizes ranging from 10 to 9,000 micrometers. Beer was found to contain 0.025 particles/ml and 0.033 fragments/ml of microplastics (3).

Many different kinds of plastics are produced worldwide, but five plastic polymers—polyethylene, polypropylene, polyvinyl chloride, polystyrene, and polyethylene terephthalate—generally account for the majority of production (6). Today's commonly used plastic polymers are extremely resistant to deterioration, added with complicated and persistent chemicals, and hazardous to human health and the environment (7).

Microplastic contamination has spread throughout the marine ecosystem due to human activities (8). Microplastics settle in sediments due to widespread pollution, and many marine organisms, including fish and shellfish, consume them (9) (Fig. 1). A remote marine reserve on the open coast of California, the USA, is surrounded by microplastic debris. There were 36.59 plastic particles per liter in water, and in sediments, there were 0.227 to 0.135 plastic particles per gram of dry material. *Tegula funebralis*, a herbivorous snail, has the greatest microplastic density of 9.91 ± 6.31 particles/g dry weight of tissue (10).

A small number of microplastic particles can enter the bodies of fish and other marine forms of life. A food chain system will emerge from this condition (aquatic food chain) (11). Microplastics' detrimental effects on human health are raised by their presence in marine biota species consumed by humans, such as fish and shellfish (12).

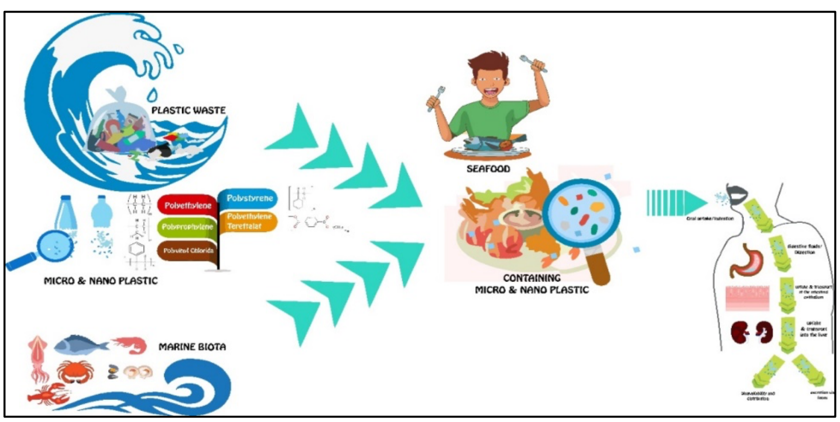

Fig. 1: The mechanism of entry of microplastics into the human body
Source: Authors' elaboration

Pollution of the aquatic environment by microplastics is one of the most serious environmental issues worldwide, which has raised many concerns about their availability and hazards for aquatic biota (13). The pollution of the Takalar coast and sea is proven by a research study, which investigated the presence of garbage in three beaches that served as research sites around the marine and water areas of Takalar Regency. Solid waste was dominated by plastic. Therefore, it is necessary to determine the level of health risk of consuming microplastic-containing marine biota (14). Therefore, in this study, evidence of marine biota being contaminated with microplastics will be reviewed, and the level of risk of microplastics in the marine ecosystem to human health will be determined. We aimed to assess the environmental health risks of microplastics due to consumption of marine life in the coastal area.

Materials and Methods

Sample Collection

This study was approved and carried out in conformity with ethical guidelines under grant number [11966/UN4.14.1/TP.01.02/2022].

This research was conducted in the coastal area of Takalar Regency in 2022. Takalar Regency is a coastal area famous for producing seafood such as fish and shellfish. The research location is a residential area in the coastal area, which is close to the fish auction site, so it can be ensured that people consume shellfish from the fish auction site. The human population was all people living in the Takalar Regency's coastal area, Indonesia and the environmental/marine biota population was all fish and shellfish in the Beba Fish Landing Place, Takalar Regency. The human samples consisted of 30 people who consumed seashells. The environmental samples consisted of 20 fish and 20 seashells, which were selected by random sampling according to the type consumed by the people of Pa'lalakkang Village in Takalar Regency.

Sample preparation

Before use, all equipment was cleansed with 10% nitric acid and rinsed with aquabidest to prevent equipment contamination. For the test sample, 1,000 ml of refill drinking water was prepared, two droplets of 0.1% Nile Red dye solution were added, and the sample was incubated for 30 minutes. The Nile Red dye solution would be adsorbed on the surface of microplastics but not on the majority of natural materials, allowing it to be observed with microscope magnifications of 100x to 400x. Prior to the FTIR (Fourier transform infrared) analysis, the test sample was filtered through a cellulose nitrate filter with a pore size of 0.45 m and a known weight. The residual mass could be calculated, so that the microplastic concentration could be quantitatively determined using aquabidest as a standard blank.

Determination of microplastics' mass and concentration

Initially, blank aquabidest was filtered through 0.45-m-sized filter paper, which was then desiccated in a desiccator for 24 hours. The filter paper was weighed, and its mass was recorded after drying. Filter paper was then used to filter the water sample. After filtration was complete, the filter paper was desiccated for another 24 hours in a desiccator. After the filter paper was dried, its mass was re-measured and recorded. The difference between the mass of the filter paper before and after filtration was the mass of the microplastics that the filter paper could accommodate. This microplastic mass represented the microplastic concentration in each liter of filtered water.

Characterization of the number of microplastics

FTIR characterization is a chemical analysis technique that is used to determine the identity of a sample's component. It is possible to determine the identity of a compound based on its functional groups, i.e., the types of bonds between various atoms, which distinguish one compound from another. This FTIR characterization can identify functional groups in compounds by detecting infrared light signals transmitted by compounds in samples; this occurs in the FTIR instrument used for this purpose (15).

FTIR Microscopy

The spatial resolution of an FTIR microscope is only 10–20 μm, but it is wavelength-dependent and constrained by a well-established diffraction limitation. For FTIR to function correctly, a sample should ideally be stored on an IR-transparent substrate with a minimum thickness of around 150 nm. Due to this limitation, FTIR is most effective for particulates larger than 20 µm. Still, examination of aggregates or films of finer particles are possible (17). Micro-FTIR spectroscopy (micro-FTIR) is an excellent method for identifying microplastics in the air because it detects particles as small as 20 µm with greater efficiency than other methods.

Human Health Risk Assessment

We used a quantitative method with an observational approach to design (Cross-sectional Study and Human Health Risk Assessment) (Fig. 2). In this design, simultaneous analyses of both environmental and human factors are carried out.

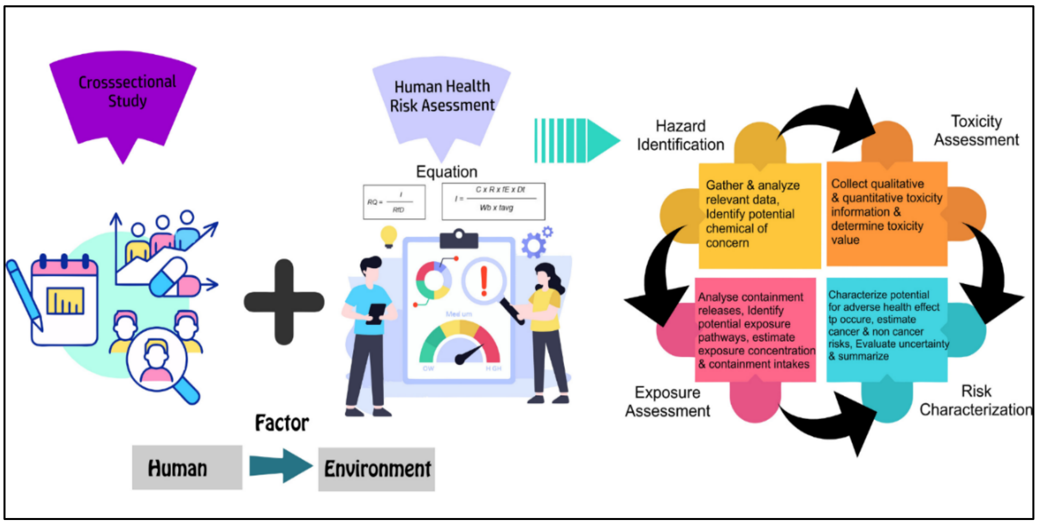

Fig. 2: Human Health Risk Assessment
Source: Authors' elaboration

The method starts with the stage of identifying hazards, response dose determines the reference dose (RfD) or reference concentration (RfC) or slope factor (SF) of the risk agent, dose-response, risk characterization to determine the level of risk.

$$\text{ADD intake} = \frac{C \times EF \times ED \times ET}{BW \times AT} \ldots\ldots\ldots\ldots\ldots\ldots [1]$$

$$\text{HQ} = \frac{ADD_{intake}}{RfC} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [2]$$

Results

Microplastic Abundance

Figure 3 shows that fish and shellfish contained microplastics in various colors such as blue, green, and purple. The color that each microplastic particle was in would depend on the source of plastic contamination. The microplastics often found in the body of an organism are in a striking color similar to the organism's prey. Color diversity occurs due to anthropological activities in different areas of primary and secondary sources of microplastics.

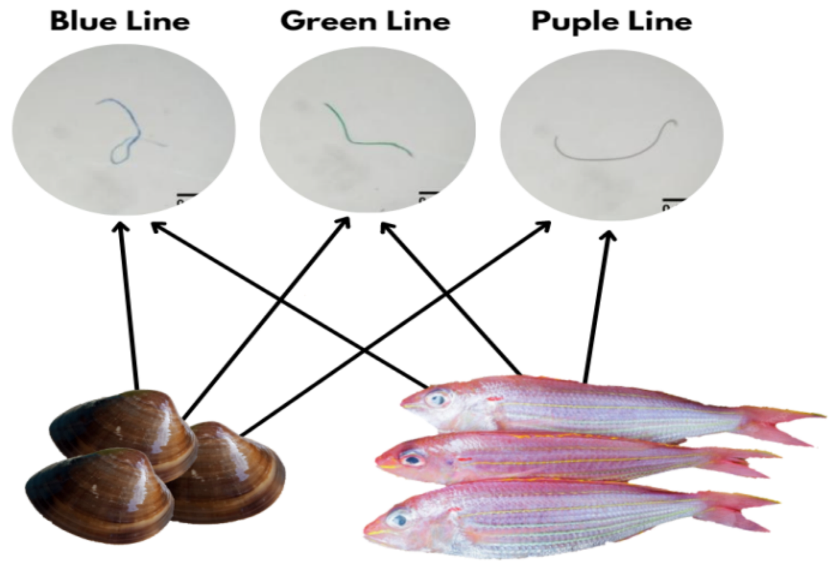

Fig. 3: Microplastic in Marine Biota

The gastrointestinal tract of a large number of fish species has been investigated for the presence of microplastics. A small number of particles are often found, andgenerally far from all of the specimens of a species investigated contain plastic in the GI tract. For example, of the 76 whole fish (11 species) from a fish market in Indonesia 28% were found to contain plastic debris in the GI tract (19). Of the 64 individual fish (12 species) purchased in California, 25% were found to contain microplastics. The average MP abundance found in fish and shellfish marine biota samples can be seen in Table 1.

Table 1: Microplastic Abundance Data (MPs) on Marine Biota

	Abundance	Minimum	Maximum	Average ± SD
Fish	Abundance (items/g)	0	0.04	0.01±0.008
	Abundance (items/kg)	0	40	10 ± 8
	Quantity (item/individual)	0	4	1.1±0.85
Shell	Weight of mussel meat (g)	0	10	6.9±1.119
	MP abundance (mg/kg)	0	15	6.7±3.62
	MP average concentration			6.7±3.599

Source: Primary Data, 2022

Table 1 shows the average abundance of MPs found in the marine biota samples of fish and shellfish (0.01 particles/g or 10 particles/kg in fish and 7 particles/individual in shellfish). Of the 20 shellfish samples, the average meat weight was 7 g/shellfish. Based on the results of the identification using a Euromex Stereo Blue Stereo microscope, the highest microplastic concentration was 15 mg/kg, and the lowest was 1 mg/kg, with an average of 6.7 mg/kg. The microplastics found in tofu shellfish (100%) were in the forms of lines. Furthermore, based on measurements using ImageJ software, the minimum length of microplastic was 0.247 mm, and the maximum was 4.982 mm.

Table 2: Study Microplastics in marine biota

Species	*Amount of Microplastic*	*Area*	*Reference*
M. edulis	1.1-6.4 items/individual	U.K. coast	(18)
Mytilus galloprovincialis	3-12.4/individual	Italy coast	(19)
Mytillus galloprovincialis	1.2-2.0/individual	Greece	(20)
Dicentrarchus labrax, Diplodus vulgaris, Platichthys flesus	1.67 ± 0.27/individual	Portugal	(21)
Perna perna	31.2/individual	Brazil	(22)
Girella laevifrons	0,01g/individual	Valparaiso Region, Chile	(23)
Perna viridis	39 particles/gram.	Jakarta, Indonesia	(24)
Pinctada fucata	1.95 ± 1.43/individual	Japan	(25)
Marine biota (fish and shellfish)	0.01 items/gram or 10 items/kg in fish and 7 g/individual in shellfish	Makassar, Indonesia	Present study

Table 2 highlights significant global variations in microplastic contamination among marine species, with the highest concentrations observed in *Perna perna* from Brazil and *Perna viridis* from Jakarta, indicating a pressing need to address this widespread environmental issue. If microplastic contaminated fish are consumed by coastal communities, it will bring the microplastics into the human body and potentially cause health problems if the intensity of exposure is high (12). The spectrum in Fig. 4 shows the polystyrene (PS) polymer type in the microplastic samples found in marine biota. A total of 5 microplastic samples in the form of lines were subjected to the FTIR test, and the same type of polymer was found. This spectrum is representative of several microplastic samples tested.

Microplastic Intake Rate

Table 3 shows that the average daily non-carcinogenic intake of 30 respondents was 0.005 mg/kg/day, while the average daily carcinogenic intake was 0.002 mg/kg/day. The average intake level of people who consumed shellfish was 91 g/day, the minimum was 75 g/day, the maximum was 100 g/day, and the standard deviation was 12.253 g/day. The respondents' intake rates were known based on their doses of shellfish intake, with portion sizes of 75 g and 100 g, from which the respondents chose themselves.

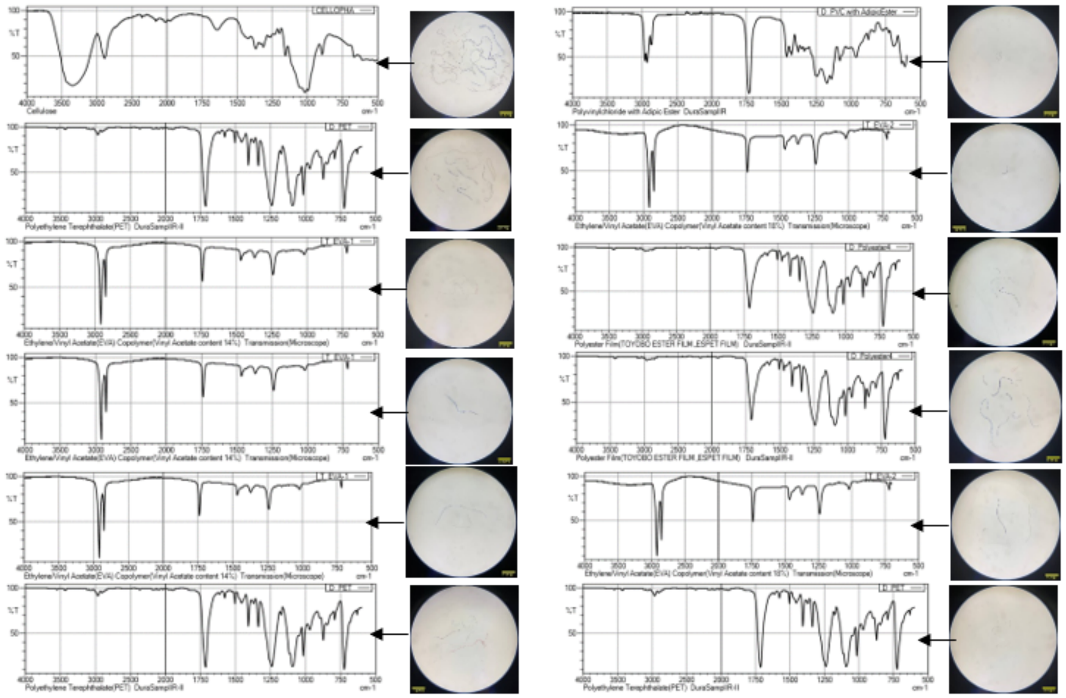

Fig. 4: FTIR Spectrum Results of Identification of Polystyrene Polymer in Microplastics in Marine Biota

Microplastic Intake Rate

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Table 3: Distribution of Intake Rate (R) of Fish and Shellfish in Society

Type of Biota	*Intake Rate (g/day)*		
Fish	Minimum	Maximum	Average ± SD
	0.04	0.32	0.15±0.06
Shell	Minimum	Maximum	Average ± SD
	75	100	91±12,253

Exposure Frequency

Table 4 shows that the average frequency of exposure of people who consumed fish was 190 days/year, where the maximum frequency of exposure was 260 days/year, the minimum was 104 days/year, and the standard deviation was 43.8 days/year. In comparison, the average frequency of exposure of people who consumed shellfish was 93 days/year, where the maximum frequency of exposure was 96 days/year, the minimum was 48 days/year, and the standard deviation was 12.178 days/year.

Table 4: Distribution of Exposure Frequency (FE) Consumption of Fish and Shellfish in the Community

Type of Biota	*Exposure Frequency (days/year)*		
Fish	Minimum	Maximum	Average ± SD
	104	260	190±43.8
Shell	Minimum	Maximum	Average ± SD
	48	96	93±12,178

Risk Level

Table 5 shows that the average level of risk of exposure to MPs in both fish and shells was 0.02. It is said that there is No Risk if the RQ value is 1, and it is said to be Risky if the RQ value is 1. As the RQ value of 0.02 is < 1, it means that there was No Risk. It was estimated that the risk level (RQ) of the average consumption of tofu shellfish containing microplastics of the styrene compound type for an exposure duration (Dt) of 30 years was less than 1 (RQ < 1).

Table 5: Interpretation of the Calculation of the Risk Level for Microplastic Exposure (MPs)

Risk Level (RQ)	*Minimum*	*Maximum*	*Average ± SD*
MPs on Fish	0.005	0.046	0.02±0.01
MPs on Shells	0.008	0.019	0.02±0.012

Discussion

Microplastics in marine biota, such as fish and shellfish, come from coastal marine pollution, and so is true on the coast of Takalar Regency. Based on the survey results at the research sites, coastal communities dispose of their waste into the open sea, especially during fish auction activities in Takalar Regency, which further exacerbates contamination from the plastic waste disposed. Currents will carry away this plastic waste into the middle of the sea, which is then degraded by sunlight, so that it breaks down into small pieces, which are then consumed by marine biota. This is in line with the statement of (13) that microplastics could contaminate marine biota through loaded seawater that contains microplastics and food from other organisms in the food chain (23).

The abundance of MPs found in marine biota samples of fish and shellfish was measured at 0.01 particles/g or 10 particles/kg in fish and 7 particles/individual in shellfish. The microplastics were only found in the line form. A research conducted (34) showed that in mackerel, flying fish, herring, Carangidae fish, and Baronang fish, microplastics were found in an average number of microplastics of 5.9 ± 5.1/fish (24). The microplastics found in the digestive tract of these fish were in the forms of fragments, films, styrofoam, and monofilaments. Additionally, it was discovered that there were 1.53 1.08 particles per g and 1.96 1.12 particles per individual microplastics in fish stomach samples (25) Meanwhile, researchers discovered an average abundance of microplastics in fish bodies of 1.5 particles/individual (26).

The average concentration of microplastics found in the tofu shellfish from the Takalar Sea was 6.7 mg/kg (particles/shellfish). This result is similar to the result of the research conducted in coastal of China, which identified that the average microplastic content in the *Mytilus edulis* shellfish was 7.6 particles/shellfish (27). Similar results were also obtained from the research conducted in Tambak Loro, Semarang, where the average numbers of microplastics in *Anadara granosa* shellfish at two different collection times were 5.1 particles/shellfish and 5.3 particles/shellfish (26).

Organisms at the lowest level are the first gateway through which microplastics enter the food chain. Their small size is the main factor causing microplastics to enter the food chain (28). Microplastics greatly affect small marine organisms that occupy low trophic levels, such as zooplankton. If the filter feeder consumes microplastics, it will have an impact on organisms at higher trophic levels through the bioaccumulation process (31). In addition, the colors of microplastics that bear similarities with the food of marine organisms also have the potential to contribute to the microplastic entrance into the food chain (28). Because of these similarities, some types of zooplankton-feeding fish and shellfish can eat microplastics.

The intake rate referred to in this study is the weight of marine biota that hads been processed multiplied by the amount of marine biota consumed by the respondent in a day. The result of this calculation indicates each respondent's intake rate in the unit of kg/day. The value of the intake rate will affect the level of risk, the chance of experiencing health problems.

The risk level indicates the danger of exposure to microplastic contamination in humans. The calculation results showed no risk if humans consume fish containing microplastics, even if the value is very far below the standard. However, it should not be concluded that microplastic contamination in the human body is harmless because the accumulation of microplastics in the human body does not only come from fish.

The amount of risk expressed in numbers without units is a calculation of the ratio of intake to reference dose/concentration of a non-carcinogenic risk agent. It can result in the interpretation of a safe/unsafe risk agent for organisms, systems, or sub/populations (28).

A risk level with an RQ value > 1 indicates that a marine organism is in the unsafe category for consumption by the public because it risk causing health problems. On the other hand, an RQ value < 1 indicates that a marine life does not pose any risk to public health. Based on the health risk analysis calculation in this study, the RQ value obtained was 0.129 or < 1, leading to the conclusion that the tofu shellfish is in the safe category for consumption by people in the coastal area of Takalar Regency.

The consumption of microplastic particles can not only cause physical harm such as mechanical injury and inflammatory responses to aquatic organisms, but also transfer toxicants (including internal plastic additives, organic contaminants adsorbed from the surrounding media and pathogens, etc.) to their bodies, which may accumulate in the food chain. Moreover, the ingestion of microplastics by humans who consume aquatic organisms such as fish and bivalves pose risks to food safety and human health.

This study has limitations in that individual variations in body weight, diet, and lifestyle were not fully accounted for, and the assumed duration of non-carcinogenic exposure of 30 years may not be universally applicable. This study did not evaluate potential carcinogenic effects, relied on general assumptions regarding frequency of exposure, and did not control for external factors.

Conclusion

Significant variations in microplastic contamination in marine organisms such as fish and shellfish were found across different regions and species. The microplastics detected were mostly fibrous and often made of polystyrene, indicating widespread pollution. Despite the levels of microplastics detected, risk assessments suggest that consuming these marine organisms, with measured non-carcinogenic and carcinogenic risks, remains within safe limits for human consumption. These findings underscore the need for continuous monitoring and mitigation efforts to manage and reduce microplastic pollution in the marine environment.

Journalism Ethics considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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Conflict of interest

The authors declare no conflict of interest.

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