EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology, 2025, 26(2), 280–291
https://doi.org/10.12912/27197050/199386
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Received: 2024.11.13
Accepted: 2024.12.20
Published: 2025.01.02

A systematic review and bibliometric analysis of the process of human health risk assessment to microplastics exposure through seafood consumption

Arif Atul Mahmuda Dullah[1], Anwar Daud[2, 3], Anwar Mallongi[3], Muhammad Zakir[4], Nurhaedar Jafar[5], Indar[6], Wahiduddin[7], Gurendro Putro[8], Agus Bintara Birawida[3]

[1] Doctoral School Program, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia
[2] Vision Center for Environemntal Studies, Hasanuddin University, Makassar, Indonesia
[3] Department of Environmental Health, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia
[4] Department of Chemistry, Hasanuddin University, Makassar, Indonesia
[5] Department of Nutrition Science, Faculty of Public Health, Hasanuddin University, Indonesia
[6] Department of Health Policy and Administration, Faculty of Public Health Hasanuddin University, Makassar
[7] Department of Epidemiology, Faculty of Public Health, Hasanuddin University, Indonesia
[8] National Research and Innovation Agency, Indonesia
* Corresponding author's e-mail: arifmahmudah.kesmasunhas@gmail.com

ABSTRACT

The variety of physical and chemical characteristics of microplastics in the environment has caused little research on assessing the health risks from exposure to microplastics. This article aims to review the steps for health risk assessment analysis of human health exposure to microplastics through the consumption of marine biota and provide an explanation of the extent to which health risk assessment research has been conducted. Article searches for this systematic review were conducted in three electronic databases: PubMed, Google Scholar, and Science Direct. The search term used was "health risk assessment for microplastics exposure" with three criteria: free full text, research article, and publication published in the years 2019–2023. Data base management was performed using Mendeley Desktop 1.19.8 and the articles were then analyzed bibliometrically using VOSviewer. A total of 203 articles were retrieved from the databases and 7 articles were eligible for the literature review. Risk assessments have not been widely conducted using health risk analysis procedures because there is no standard assessment of microplastic concentrations in biota. In addition, there is no specific reference dose for each microplastic polymer and the variety of physical characteristics, such as shape, color and size of microplastics, make it difficult to assess actual ingestion. A generally applicable approach to assessing human exposure to microplastics is needed. The approach should include a representative sampling procedure in the environment, a method to identify and calculate microplastic concentrations, a real-time ingestion assessment, and an assessment of specific health effects based on microplastic polymers.

Keywords: microplastics, health risk analysis, marine biota, ingetion.

INTRODUCTION

Plastic debris is estimated to be the most common type of pollutant found in waterways, accounting for approximately 62.31% (Hahladakis et al., 2018). It is estimated that up to 22 million tons of plastic are wasted into the environment (Glob. Plast. Outlook, 2022) and approximately 0.8–2.5 million tons of microplastics are dumped into the ocean every year (Friot et al., 2017).

In the environment, plastic particles are found in smaller sizes in the form of microplastics (MP) and nanoplastics (NP) (Thushari et al., 2020). Globally, microplastics account for up to 12%

of all plastic in the environment (Campanale et al., 2020). Microplastics are a diverse array of synthetic polymer particles that vary in chemical composition, size (from the micrometer scale to sizes between 1 nm and 5 mm), density, and shape (Eriksen et al., 2014) (Figure 1).

There are 12 types of secondary microplastics with 4 forms of microplastics, i.e. fibers, films, foams and fragments, and eight types of polymers, i.e. PES, PA, polypropylene (PP), low density polyethylene (LDPE), polyethylene terephthalate (PET), PU, polystyrene (PS) and polycarbonate (PC) (Lozano et al., 2021; Okunola et al., 2019). Various studies on waters and coastlines have shown microplastic contamination at varying levels in, for example, green mussels (Mawaddha et al. 2020), anchovies (Ningrum et al., 2022), tilapia (Bahri et al., 2020), milkfish (Amelinda et al., 2021), and sea urchins (Sawalman et al., 2021).

Plastic particles can threaten natural life because they can enter the food chain and potentially pose a risk to human health through the consumption of seafood that has been contaminated with plastic (Rai et al., 2021). The effects of microplastics on living organisms, including humans, are also linked to their role of microplastics as vectors for various chemicals (Sheng et al., 2021), organic matter (Polidoro et al., 2022) and metals (Liu et al., 2020).

Microplatics vary greatly in the combination of their physical composition (shape, size and color), their chemical composition and their role as vectors for various chemicals and microorganisms, so that in practice, risk assessment or characterization must take this diversity into account. Based on the EHRA paradigm, there are four frameworks for health risk assessment, namely hazard identification, dose response assessment, exposure assessment and risk characterization (Department of Health and Ageing, 2002) (Figure 2).

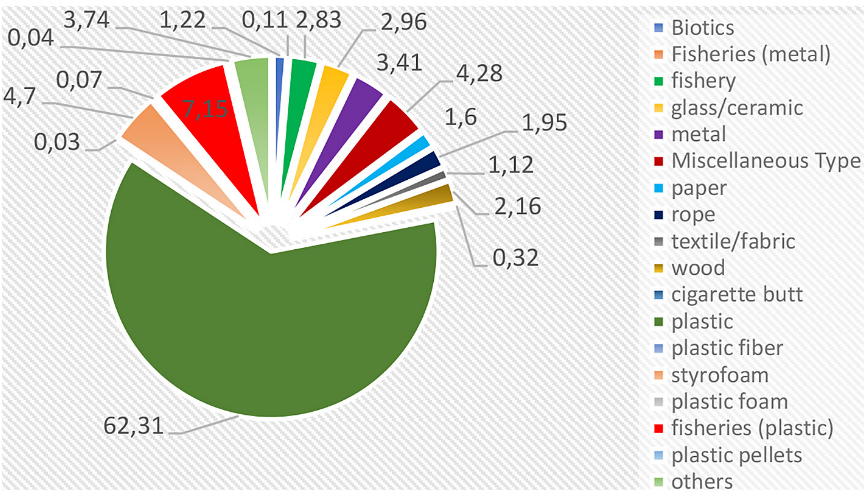

Figure 1. Estimates of the composition of global plastic waste (Hahladakis, 2020)

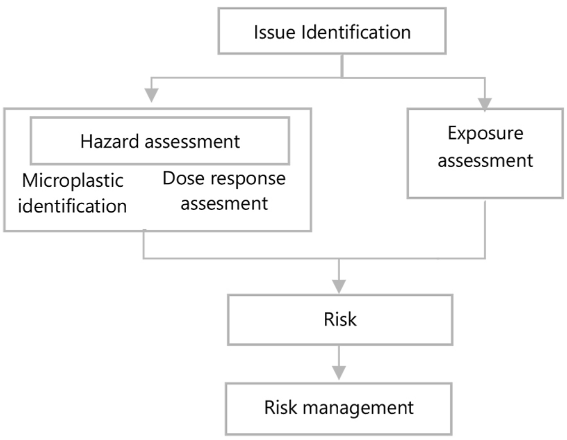

Figure 2. Health risk assesment paradigm for mikroplastics (Department of Health and Ageing, 2002)

In order to review the steps for assessing the health risk analysis of exposure to microplastics on human health through the consumption of marine biota which have been carried out throughout the 2019–2023 period and provide an explanation of the extent to which health risk assessment research has been carried out. This article aims to review the steps for health risk assessment analysis of human health exposure to microplastics through the consumption of marine biota and provide an explanation of the extent to which health risk assessment research has been conducted.

Microplastic identification in the biota employs diverse sampling methods, including direct collection from fishermen (Montero et al., 2023), net-caught samples (Lu et al., 2021), and market sourced samples (Barboza et al., 2020; Tanaviyutpakdee et al., 2023; Ziino et al., 2021). We found that health risk assessments have not been widely conducted using health risk analysis procedures because there is no standard assessment of microplastic concentrations in the biota. Microplastic concentrations are calculated based on counts in fish digestive tracts (Ziino et al., 2021), fish flesh (Simionov et al., 2023), or entire biota tissues (excluding bones) (Lu et al., 2021). There is no specific reference dose for each microplastic polymer and the variety of physical characteristics, such as shape, color and size of microplastics (Lu et al., 2021; Montero et al., 2023; Polidoro et al., 2022; Ziino et al., 2021), make it difficult to assess actual ingestion.

Currently, no standardized protocols exist for sampling microplastics to accurately represent environmental concentrations. Factor such as water dynamics affecting microplastic distribution in aquatic ecosystems and biota, varying concentrations among diverse species, and diverse microplastic characteristics (shape, size, color, and polymer type) hinder comprehensive health risk assessments.

METHODS

Article searches for this systematic review were conducted in three electronic databases: PubMed, Google Scholar, and Science Direct. Search terms were "health risk assessment for microplastic exposure". Three citeria were used in the literature search: free full text, research articles, and publication between 2019 and 2023. Database management was performed using Mendeley Desktop 1.19.8. The exclusion criteria were review and risk assessment by ingestion, and the inclusion criteria were articles with topics on ingestion, food, and human health risk assessment.

After removing duplicates, a total of 177 articles from the search results were bibliometrically analyzed using VOSviewer to determine the extent to which the risk assessment for exposure to microplastics had been carried out (see Figure 4 and Figure 5). Furthermore, seven articles that were eligible for the systematic review were analyzed to determine the state of the art in research specifically assessing the risk of microplastics from consumption of marine biota.

RESULTS

The search results yielded a total of 203 articles, consisting of 59 articles from Google Scholar, 33 articles from Science Direct and 111 articles from PubMed. From this total, seven journals were obtained that were eligible for the literature review process as presented in Figure 3.

Bibliometric analysis

To assess the progress of research and current theory regarding the mechanisms of the risk assessment process for exposure to microplastics from consumption of aquatic biota, 177 search result articles related to the mechanisms of health risk analysis assessment were evaluated (see Figure 4). Based on Figure 4, it appears that research on the relationship between microplastics and health risks is still very limited in number.

Figure 5 shows that studies examining microplastics have been related to assessing daily intake and food safety issues and have not directly assessed health risks. Figure 6 shows that during 2023, studies related to microplastics focused on assessing daily intake, especially of several microplastic polymers such as dibutyl phthalate (DBP), bisphenol-A, and bis (2-ethylhexyl) phthalate.

Identification of microplastics and polymers

Identification of microplastics was the first step taken to assess the potential for exposure to microplastics that may pose health risks to humans. The results of the article searches showed that microplastics in biota were identified by collecting environmental samples such as fish and

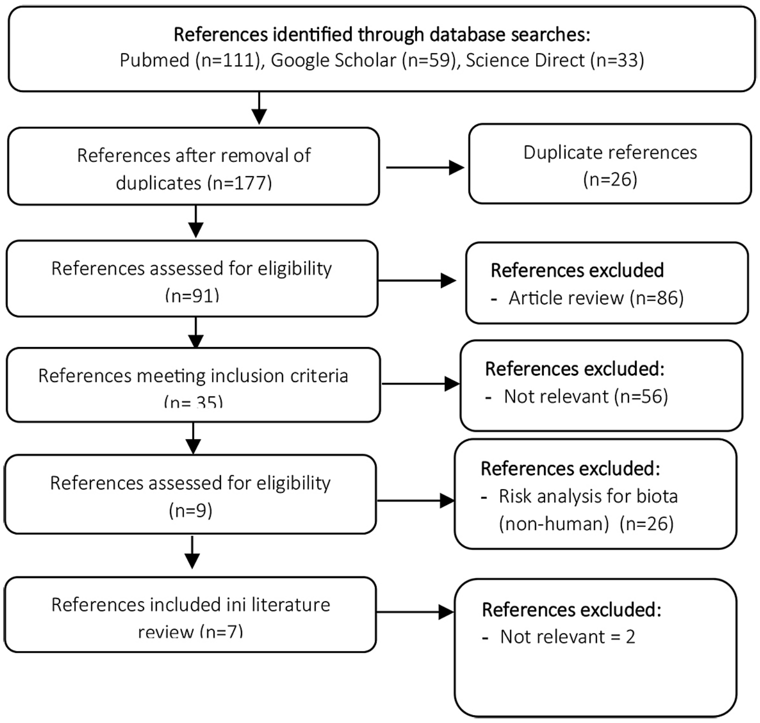

Figure 3. Systematic review prism chart

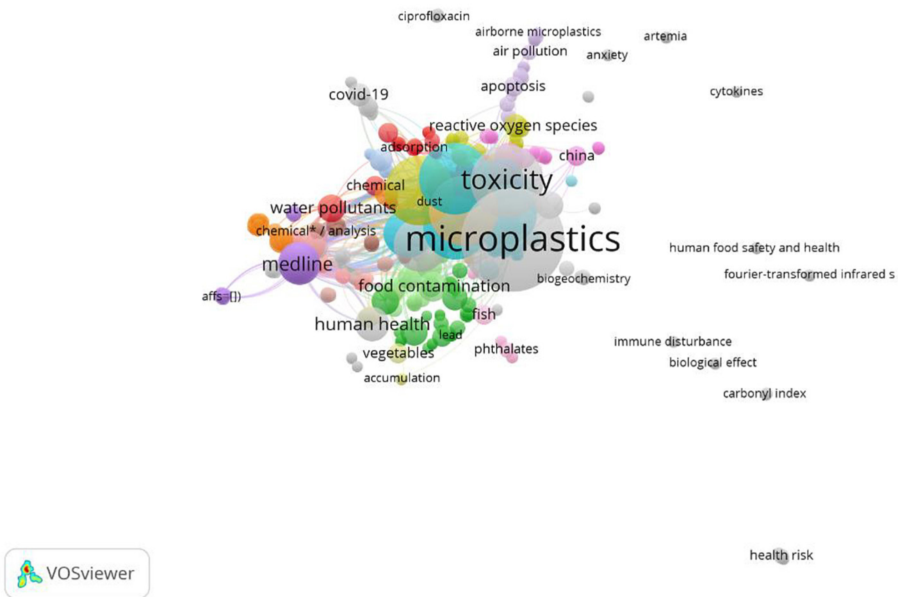

Figure 4. Network visualization for all journals

shellfish or mollusks collected directly from fishermen (Montero et al., 2023), caught using nets (Lu et al., 2021), or obtained from markets/retailers (Barboza et al., 2020; Tanaviyutpakdee et al., 2023; Ziino et al., 2021) Samples of marine biota were collected from multiple locations (Tanaviyutpakdee et al., 2023) or based on fish species (Barboza et al. 2020) or based on fishing season locations (Tanaviyutpakdee et al., 2023), with the aim of comparing the conditions of microplastic contamination in aquatic biota (Lu et al., 2021). The selection of fish species for sampling was based on the fish species most consumed by the community in the study area (Tanaviyutpakdee et al., 2023) (Table 1). Research and sampling sites were selected by considering the influence of water conditions on the biota, such as distance from the coast, tidal zone and estuary (Polidoro et al., 2022).

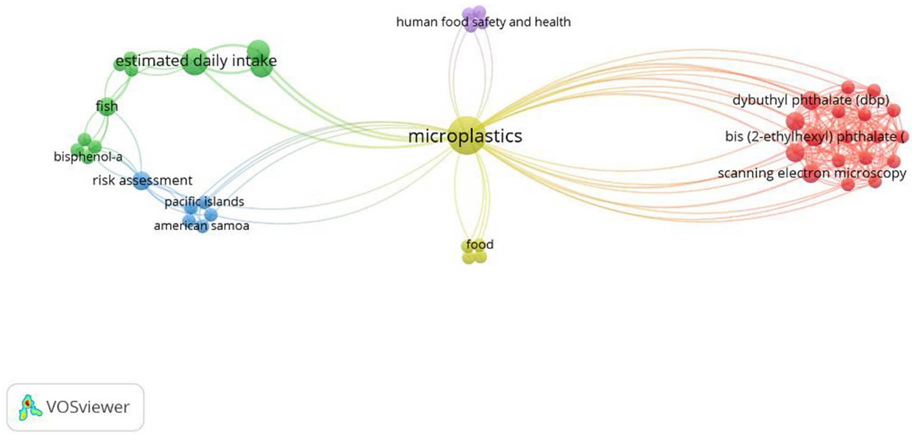

Figure 5. Network visualization journal eligible

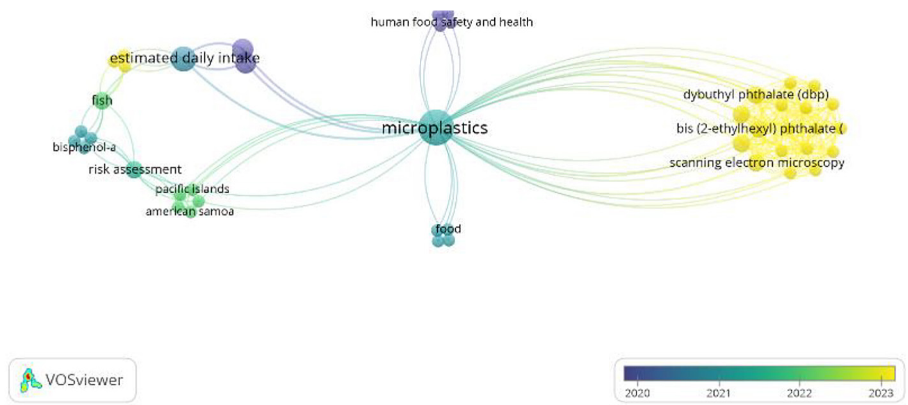

Figure 6. Overlay visualization journal eligible

Table 1. Sampling methods for aquatic biota to examine microplastics

Location	Biota	Sampling method	Reference
Calabria and Cicilia, Italia	Fish	Collected directly from the market	(Ziino et al. 2021)
Nicoya Bay, Costa Rica	Shellfish, fish and crustacean	Collected directly from fishermen	(Montero et al. 2023)
Lower Danube River Valley, Galati City, Romania	Fish	Collected from different retailers	(Simionov et al. 2023)
North Taiwan River Estuary	Fish	Caught with a fishing net	(Lu et al. 2021)
Gulf of Thailand	Shelfish	Collected from the five largest markets, random sampling with three samplings based on season	(Tanaviyutpakdee et al. 2023)
Northeast Atlantic Ocean	Fish	Samples were collected from three market locations. Fish are selected based on their species	(Barboza et al. 2020)
Tutuila, American Samoa	Gastropods and rock oysters	The sampling locations were the coastline, tidal zone and estuary	(Polidoro et al. 2022).

In the studies, microplastics abundance was assessed on the basis of items found in aquatic biota (Simionov et al., 2023; Ziino et al., 2021) or based on microplastic items per gram wet weight of biota (Montero et al., 2023; Ziino et al., 2021) or dry weight (Lu et al., 2021). The majority of polymer tests were performed using FTIR and Raman spectroscopy (Table 2). Differences in the size and weight of microplastics will affect their absorption capacity in marine biota (Ribba et al., 2022).

Microplastic exposure assessment

The results of the literature review showed that the assessment of human exposure to microplastics was calculated based on the results of

Table 2. Methods for identification of microplastics and microplastic polymers in biota

Biota	Body parts	Dominant physical characteristics	Microplastic abundance	Samples for polymer identification	Polymer identification methods	Dominant polymer	Reference
Fish	Soft tissue digestion	Line, blue, 201–500 µm	Mean 0.37 ± 0.288 g per weight	20% of the number of microplastics found	FT-IR	PP	(Ziino et al., 2021)
Shellfish, fish and crabs	-	Particle, purple. 30–500 µm	• Arched swimming crab 4.0 ± 1.0 MP/g • mangrove cockle 3.3 ± 2.9 MP/g; • Stolzmann's weakfish 2.4 ± 1.3 MP/g	30% of the number of microplastics found	Raman spectroscopy	DEHP	(Montero et al., 2023)
Fish	Muscle	Fiber, 3500 µm	1 item MP (only one fish found containing MP)	Filtering with a pore size of 1 µm and a diameter of 47 mm	FT-IR	PS	(Simionov et al., 2023)
Fish	All soft fish tissues (homogenized with a blender) except bones	-	• Mean 0.163 ± 0.305 ng/g d.w. (benthic fish) • Mean 2.40 ± 0.366 ng/g d.w. (pelagic fish) • Mean 0.0927 ± 0.135 ng/g d.w. (migratory fish)	Filtering, to obtain MP sizes of 5 mm–50 µm	FT-IR	DEP	(Lu et al., 2021)
Shellfish	Clams, mussels and cockles	Fiber, orange, > 100–500 µm	• Mean 0- 1.2 items//g w.w. • Mean 0-4.3 items/individual	-	-	-	(Tanaviyutpakdee et al., 2023)
Fish	Digestive tract, gills, meat	Fiber, blue, 501–500 µm (in gills)	• Digestive tract: mean 1.3 ± 2.5 item/individual • Gills: mean 0.8 ± 1.4 item/ individual • Dorsal: 0.4 ± 0.7 item/ individual	-	-	-	(Barboza et al., 2020)
Gastropods and rock oysters	Whole tissue	Fiber	15–17 particles per mollusk	10% of the number of microplastics found	Raman spectroscopy	PET	(Polidoro et al., 2022)

the identification of the amount of microplastics in biota (Tanaviyutpakdee et al., 2023). The assessment of microplastic intake refers to the MP content found in meat (muscle tissue), assuming that it is fish meat that is consumed by humans (Simionov et al., 2023). Another study showed that MP were most abundant in the gastrointestinal tract compared to those in gills and muscle (Barboza et al., 2020) (Table 3).

Studies to identify fish tissues to serve as a basis for exposure assessment showed no significant differences in microplastic findings in fish based on fish length and weight (Barboza et al., 2020). The digestive tract had the highest microplastic content compared to the gills and back of the fish. The microplastic content in the digestive tract was (mean) 1.2 ± 2.0 items/individual, in the gills (mean) 0.7 ± 1.2 items/individual and in the back was 0.54 ± 0.099 (Barboza et al., 2020). It is estimated that humans swallow 50.000 small pieces of plastic per year (Campanale et al., 2020). The amount of microplastics ingested by human through aquatic biota is influenced by geographic location of residence, lifestyle choices, and level of fish consumption (Barboza et al., 2020). Microplastics as small as 20 µm can enter organs, and microplastics as small as 10 µm can invade cells and penetrate cell membranes (Xu et al., 2019), the placenta (Grafmueller et al., 2015), muscles, and even the liver (Ogonowski et al., 2018; Stock et al., 2019; Verla et al., 2019; Yong et al., 2020). Physically, microplastics have the ability to pass through living cells into the spleen and human circulatory system (Kowalski et al., 2016).

Response assessment

Dose-response assessments have been used to estimate how exposure levels to different chemicals may affect the likelihood and severity

Table 3. Exposure and risk assessment methods

Biota	Types of polymers found	Exposure assessment method	Risk assessment methods	Reference
Shellfish, fish and crabs	DEHP, BPA and DBP	The dietary exposure per serving (µg/kg/bw/d) was calculated as the amount consumed (kg) multiplied by the concentration of MP (µg/kg) per body weight (mg/kg body weight/day)	The risk assessment was performed by comparing the proportion of microplastic consumption with the predetermined TDI	(Montero et al. 2023)
Fish	MP	EDI was calculated as the quotient of the product of exposure frequency, exposure duration, intake rate, concentration by body weight, and average exposure.	The level of non-carcinogenic risk was assessed by comparing the daily intake with a reference dose	(Simionov et al. 2023)
Fish	PAE, BPA, NP, and MP	Chronic daily intake (CDI) is calculated as the intake multiplied by the frequency of exposure per year (days/year) and the duration of exposure (years) divided by the average exposure (life expectancy/AT) times the number of days in a year (365 days)	The level of non-carcinogenic risk was assessed by comparing the daily chronic intake with a reference dose	(Lu et al. 2021)
Shellfish	MP	Exposure (item/person/day) was calculated as biota consumption multiplied by the number of microplastics	The risk could not be assessed because HBGV (health-based guidance value) was not yet available	(Tanaviyutpakdee et al. 2023)
Fish	MP	Intake was calculated as the average amount of microplastics in fish meat (microplastic items/gram) multiplied by the standard intake of fish per person (g)	-	(Barboza et al. 2020)
Gastropods and rock oysters	PET, phthalates, pesticides and PCBs	Intake was calculated as the average amount of microplastics in fish meat (microplastic items/gram) multiplied by the standard intake of fish per person (g)	The level of risk was assessed by comparing the intake with the reference dose (RfD)	(Polidoro et al. 2022)

of health effects. The dose-response relationship is often different for many chemicals that cause cancer than for those that cause other types of health problems (California Environmental Protection Agency, 2011).

In this literature review, the dose assessment of respondents' exposure to microplastics was performed by calculating the total daily intake (TDI) of microplastics. The results of the microplastic intake calculations were then compared with the intake standards set by authoritative institutions such as the BPA. There was no health risk assessment to determine the level of risk, as there is no reference dose for microplastic exposure (Table 4.)

Risk characterization for microplastic exposure

The exposure assessment of microplastics was done by estimating the amount of microplastics consumed by each age group, especially children and adults (Conti et al., 2020). Meanwhile, the risk characterization process has not been done because there is still no specific effect of microplastics on humans. Meanwhile, another approach was used to assess the cumulative exposure to various PTEs (potential toxic elements) in the form of heavy metals including microplastics (Simionov et al., 2023).

DISCUSSION

Environmental factors such as temperature, sunlight, degradation by microorganisms and hydrolysis influence the process of degradation of plastics in the environment to smaller sizes, both microplastics and nanoplastics (Hahladakis et al., 2018; Prata et al., 2020). Some microplastics are primary, meaning they are micro-sized from the manufacturing/production process, and some are secondary, meaning they come from the degradation of larger plastics (Prata et al., 2020; Rai et al., 2021). Plastic particles can enter the food chain or become contaminated with other substances and become vectors for various chemicals (Sheng et al., 2021), organic materials (Polidoro et al. 2022)., and metals (Liu et al., 2020), potentially posing a risk to human health (Rai et al., 2021) (Figure 7).

The process of identifying microplastics is the first step that must be taken to assess the potential health risks that may arise (Department of Health

Table 4. Dose reference levels used in health risk research on microplastic exposure

Biota	Polymer	Dose reference	Reference
Fish	Polipropylene	-	(Ziino et al. 2021)
Shellfish, fish and crustaceans	DEHP, BPA and DBP	TDI of BPA for pregnant women was 0.33 µg/kg/bw/d (ANSES, 2014) and 0.004 µg/kg/bw/d (EFSA); no TDI of DEHP and DBP was found for preganant women	(Montero et al. 2023)
Fish	MP	-	(Simionov et al. 2023)
Fish	PAE, BPA, NP and MP	Reference doses for DEP, DBP, DEHP, BPA, DIBP and DINP were 0.8, 0.1, 0.02, and 0.05, 0.100, 0.059 mg/kg/day, respectively. CSF for DEHP was 0.014 (oral exposure)	(Lu et al. 2021)
Shellfish	MP	-	(Tanaviyutpakdee et al. 2023)
Fish	MP	-	(Barboza et al. 2020)
Gastropods and rock oysters	PET, phthalates, pesticides and PCBs	Dibutyl phthahlate 0.1; diethyl phthalate 0.8; di-ethylhexyl phthalate (DEHP) 0.02; and PCBs 0.00002	(Polidoro et al. 2022)

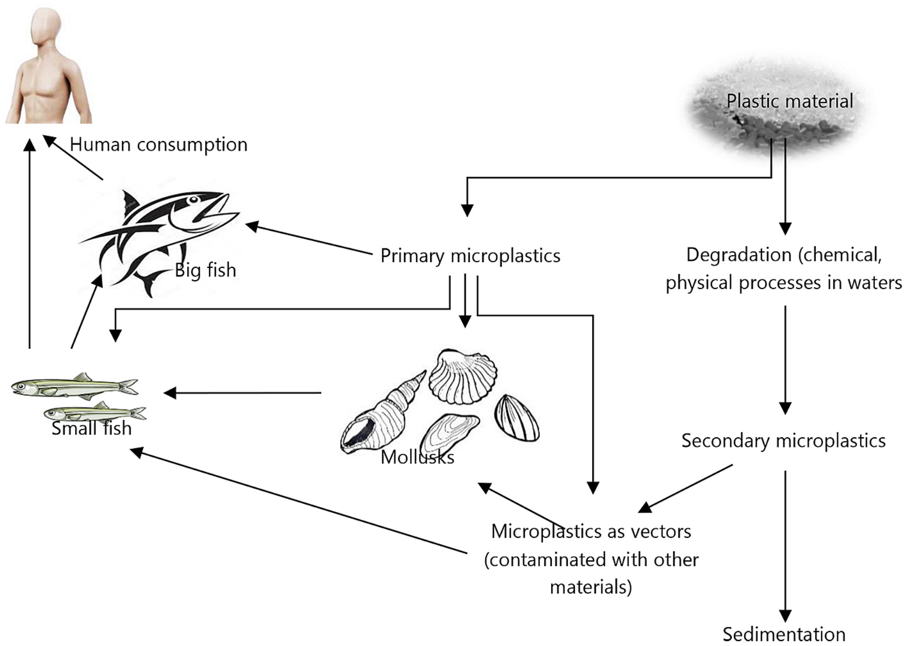

Figure 7. Transfer of microplastics in water

and Ageing, 2002). Considering the variety of microplastics in the environment, the sampling process of biota must consider environmental factors such as temperature and current patterns (Lu et al., 2021). Biomagnification of microplastics needs to be considered in the environmental sampling process in order to provide an explanation of the relationship between MP in the environment and in the body of aquatic biota (seawater, sediment, and MP in biota (Polidoro et al., 2022). Fish species that are active at the surface of the sea or water bodies, such as pelagic fish, have higher levels of microplastics compared to benthic and migratory fish (Lu et al., 2021), while shellfish are considered a good bioindicator of microplastic contamination in seawater (Simionov et al., 2023)

The process of identifying microplastic polymers is necessary to assess the potential for specific effects based on microplastics. Potential health risks to humans are related to dose, polymer type, size, chemical composition (liang Liao et al., 2020) and hydrophobicity (Campanale et al., 2020; Okunola et al., 2019; Smith et al., 2018). There are several techniques used to identify the presence of microplastics in the environment, one of the most common is to examine the IR spectrum with the FTIR test (Rakesh et al., 2014). The next step is to conduct an exposure assessment.

This includes assessing the duration of exposure, the rate of ingestion, and the concentration of microplastics ingested (Department of Health and Ageing, 2002). Dietary data are required for exposure assessment (Ziino et al., 2021). However, based on the human health risk analysis protocol (HHRAP), only food produced at the exposure site is contaminated by the substances or chemicals of the assessed substance. Food that was not produced at the exposure site is not considered to be contaminated and is not relevant to the assessment (Response et al., 2005). Duration of exposure is the length of time the receptor is exposed via a particular exposure pathway until the receptor is no longer exposed to the risk agent via the exposure pathway (Response et al., 2005).

The size, shape, and type of plastic are very important factors in explaining the effect of microplastics. Microplastics as small as 20 µm can enter organs, and only microplastics as small as 10 µm can enter cells and penetrate cell membranes (Schirinzi et al., 2017; Xu et al., 2019), penetrate the placenta (Grafmueller et al., 2015; Poulsen et al., 2015)· and potentially reach muscles and even the liver (Ogonowski et al., 2018; Stock et al., 2019; Verla et al., 2019; Yong et al., 2020). Physically, microplastics have the ability to pass through living cells into the spleen and the human circulatory system (Kowalski et al., 2016; US EPA, 2015). Only microplastics smaller than 150 µm can pass through the intestinal epithelium and cause systemic exposure.

The chemical toxicity of microplastics may result from the leaching or elimination process of monomeric components, endogenous additives, and adsorbed environmental contaminants (Lithner, 2011; World Health Organization, 2019; Wright et al., 2017). Meanwhile, from a physical perspective, exposure to microplastics has the potential to cause inflammation because they cannot be broken down in the body's metabolic processes and has the potential to increase the risk of neoplasia (De-la-Torre, 2020)

The results of an in vitro study to examine the effect of microplastic exposure in the digestive tract showed that the digestion process had increased the average size of PS-MP from 100 µm to 440.2 µm. The digestion process has also increased the zeta potential value for 50 µm size particles from 40.8 eV to 34.4 eV. For the 100 µm size, it increased from 31.4 eV to 39.1 eV, resulting in a decrease in LDH release and reduced intestinal transport damage. The bioavailability and toxicity of microplastics also decreased after processing in the gastrointestinal tract, increasing pro-inflammatory effects. This study also shows that the combined toxic effects of MP & Arsenic (As) can be reduced by processes in the digestive tract (Liu et al., 2020)**.**

CONCLUSIONS

The dynamics of marine waters must be of concern, especially in efforts to explain how microplastics spread in the environment and as a basis for determining representative sampling for the process of identifying microplastics in aquatic biota. Fish and shellfish meat is considered the most relevant part for assessing human intake of microplastics because of the meat consumed by humans.

In order to assess exposure to microplastics, it has been demonstrated that all fish body tissues were found to contain microplastics of different sizes and different chemical compositions with different contaminants. Therefore, it is necessary to consider conducting a comprehensive study of microplastic polymers in all biota tissues as well as to provide a basis for overall risk assessment, considering that microplastic components are very diverse both in terms of physical characteristics, chemical composition and the role of microplastics as vectors for other substances/materials.

Further research is needed on the exposure threshold for ingestion of microplastics to cause chemical and physical effects (simultaneously) from each type of polymer or from all microplastics ingested by humans through consumption of marine animals.

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