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Assessment of Microplastic Pollution in Fresh Fish and Pindang Fish and its Potential Health Hazards in Coastal Communities of Banyuwangi Regency, Indonesia

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ABSTRACT

This study aimed to analyze the microplastic contamination of fresh and pindang fish and its health impact on the coast of Muncar, Banyuwangi Regency, Indonesia. In this study, a total of 115 respondents participated, providing questionnaire data on their fish consumption habits and health problems. Subsequently, spearman's correlation coefficient, a non-parametric statistical test, was used to analyze the questionnaire data. This study also included 100 samples of marine fish, consisting of 89 fresh fish and 11 pindang fish from various types of marine species. The content of microplastic polymers detected through FTIR (Fourier-Transform Infrared Spectroscopy) was around 3-5 microplastic polymers/fish samples, and the most dominant were Polyethylene, Polyester, Polycaprolactam (Nylon 6) and Polyamide. This study showed that 94 percent of fish samples contained microplastics and only 6 percent of samples did not contain microplastics. The intensity of pindang fish consumption was positively correlated with respondents' health symptoms and problems. Subsequently, implementing effective waste management systems and educational programs in the coastal practices.

INTRODUCTION

Plastic is widely used in commercial products and is a significant pollutant in marine environments. According to Jambeck et al. (2015), 192 coastal countries produced 275 million metric tons (MT) of plastic waste in 2010, of which 4.8 to 12.7 million MT entered the sea. Typically, the types of waste found on coasts are made of Polyethylene (PE) materials, such as plastic bags, and polypropylene (PP) materials, for example, packaging products, textiles, and stationery.

Garbage, including plastic waste and microplastics, presents a significant challenge in Indonesia and other regions worldwide. This problem is caused by human activities and inadequate waste management practices. Pollution of marine environments from plastic waste can result from direct and indirect disposal of plastics into the sea, including activities such as oil rigs, fishing, cruises, and land-based activities, especially in densely populated areas where plastic can be transported into the sea by wind, water runoff, or direct discharge (Elizalde-Velázquez et al. 2021). There are two types of microplastics, depending on their source: primary microplastics, which can be associated with plastics produced in microscopic sizes, including scrubbers and pellets (Isobe et al. 2017), and secondary microplastics, resulting from the degradation of microplastics, such as fragments, fibers, or films (Zobkov et al. 2017).

Waste management systems face numerous challenges across different sectors, including Banyuwangi Regency, Indonesia. As the largest district in East Java (5,782.50 km²) with a population growth rate of about 0.44% (BPS 2021), the area has the potential to produce significant amounts of waste of varying quality. Despite its potential for beach and sea tourism, Banyuwangi Regency experiences environmentally unfriendly dumping of plastic waste into the sea. According to estimates, between 4.8 and 12.7 million tons of plastic waste end up in Indonesian waters (Jambeck et al. 2015).

A study was conducted by Johan et al. on microplastics in the digestive tract of 5 species of fresh fish in Segara Bay, Bengkulu (Johan et al. 2021). While Gunawan et al. studied the meat of 5 types of fresh and pindang fish in northern Bogor (Gunawan et al. 2021). Sawalman et al. conducted a study on the gills, digestive tract, and meat of 3 types of fish at Barranglompo Makassar (Sawalman et al. 2021), and Yona et al. focused on the gills and digestive tract of 12 coral reef fish caught from the waters of small and outer islands of Papua (Liki, Befondi, and Miossu Islands) (Yona et al. 2020). However, there is still limited knowledge on the presence of microplastics in fresh and pindang fish, with a greater number and variety of samples needed, especially along the Banyuwangi coast. Therefore, this study aims to analyze microplastic contamination in fresh and pindang fish and its impact on health on the Muncar coast, Banyuwangi Regency, Indonesia.

MATERIALS AND METHODS

This observational study examined the presence of microplastic contamination in fresh and pindang fish and their potential health hazards. The study was conducted in the coastal area of Muncar District, Banyuwangi Regency, East Java, Indonesia, from June to December 2022. The study population consisted of people working as fishermen in the coastal village of Tembokrejo, Muncar District, Banyuwangi Regency. A total of 115 respondents participated in the study, providing questionnaire data on their fish consumption habits

Table 1: Characteristics of respondents.

and health problems. The questionnaires asked respondents about their frequency of consuming fish (1-2 times per week, 2-3 times per week, 3-4 times per week, or every day), the types of fish they consumed in the past week (milkfish, cob, flying fish, semar, or others), and any health symptoms experienced, such as fatigue, cough, shortness of breath, high fever, pain in the mouth area, rashes, abdominal pain, chest pain, indigestion, respiratory problems, dizziness, nausea, and vomiting.

The questionnaire data was then analyzed using simple linear regression to look for the effect of the intensity of fish consumption on health complaints and symptoms. The study also included 100 marine fish samples, consisting of 89 fresh fish and 11 pindang fish from various types of marine fish, including Heteropriacanthus cruentatus, Sarda orientalis, Euthynnus affinis, Rastrelliger, Caesio erythrogaster, Epinephelus coioides, Sardinella lemuru, Crustacea, Helostoma temminckii, Trichiurus lepturus, and others. The fish samples were tested using the FTIR tool (Thermo Scientific Nicolet iS10) to detect microplastic polymers, in the Laboratory of the Material Institute of Technology Sepuluh Nopember Indonesia. This study has been approved by the ethics committee with certificate number 165/EA/KEPK/2022.

RESULTS

The research results are presented in Tables 1-4. Table 1 shows that the majority of respondents had a low level of education, with 33% not finishing graduation from elementary school and 31.3% having never attended school. Table 1 also indicates that respondents had low incomes, with about 64.3% earning between 1-1.5 million rupiahs per month.

Variable	Category	Frequency	Percentage (%)
Education	No school	36	31,3
	No graduation elementary school	38	33
	Graduation elementary school	23	20
	Graduation junior high school	12	10,4
	Graduation high school	6	5,2
Work	No work	88	76,5
	Work	27	23,5
Income (Rupiah)	< 1 million/month	6	5,2
	1-1,5 million/month	74	64,3
	1,5-2 million/month	33	28,7
	2-2,5 million/month	2	1,7



Table 2 shows that five parts were taken as samples, consisting of meat (30 samples), gills (26 samples), skin (26 samples), intestines (18 samples), and stomach (1 sample). The Table reveals that out of 100 fish samples analyzed for microplastics, 94 samples contained microplastics, while only 6 fish samples did not contain microplastics.

Table 3 shows the microplastic polymers detected in fish samples using FTIR. Fresh fish samples contained a variety of polymers, including polyester, polyethylene, polyamide, polyethylene terephthalate, low-density polyethylene, phenol formaldehyde, urea, melamine formaldehyde, and polycaprolactam. meanwhile, pindang fish samples were found to contain polyethylene, polyester, polyamide, and polycaprolactam polymers.

Table 4 shows a linear regression analysis conducted between the intensity of consumption and the type of fresh fish against the complaints and symptoms experienced. Table 4 shows that the value of sig>0.05 which means there is no

Table 2: Microplastics in fish.

No	Fish Part	Microplastic					
		Present	%	No Present	%	Total	%
1	Meat	29	29	1	1	30	30
2	Gill	26	26	0	0	26	26
3	Skin	23	23	3	3	26	26
4	Intestines	15	15	2	2	17	17
5	Stomach	1	1	0	0	1	1
	Sample Total	94	94	6	6	100	100

Table 3: The content of microplastic polymers in fresh fish and pindang fish.

	Kind of fish		
	Fresh fish	Pindang fish	
Number of samples	89 samples	11 samples	
Examined fish	Meat, gills, skin, intestines, stomach	Meat, skin	
Found polymers (frequency)	Polyester (63), Polyethylene (55) Polyamide (55) Polycaprolactam (30) Phenol formaldehyde (8) Urea & melamine formaldehyde (5) Polyethyelen Terephtalat (1)	Polyester (15) Polyethylene (6) Polyamide (2) Polycaprolactam (3)	
	Polyethylene Low-Density (1)		

Table 4: Linear regression analysis of fish consumption intensity to health complaints and symptoms.

Coefficients ^a						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		В	Std. Error	Beta	-	
1	(Constant)	.946	.206		4.594	.000
	Intensity of Fish Consumption	.026	.044	.056	.591	.556
	Types of fish consumed	.017	.024	.067	.709	.480
a. De	a. Dependent Variable: Health Complaints					
Coefficients ^a						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		В	Std. Error	Beta	-	
2	(Constant)	1.254	.275		4.562	.000
	Intensity of Fish Consumption	034	.059	054	571	.569
	Types of fish consumed	.005	.032	.015	.158	.875
b. Dependent Variable: Symptoms of the disease						

influence between the intensity of fish consumption and the type of fresh fish consumed on the health problems and symptoms experienced by the community.

DISCUSSION

The results of the study in Table 1 show that the majority of respondents have a low level of education. The level of education in a community can affect environmental protection measures, such as the use of clean water, energy, and waste management (Wulansari et al. 2020). Education can also influence an individual's mindset; those with higher education are often more involved in planning and implementing waste management activities that can reduce plastic waste pollution in the environment (Ivakdalam et al. 2022). The results in Table 1 also indicate that respondents had low incomes. Community income is a contributing factor to waste management, and other studies have shown that people's income levels affect the management of nonorganic waste in the community (Jayanti et al. 2017, Safitri et al. 2019).

The results of this study found 94 samples contained microplastics (Table 2), this research is in line with previous research which found that out of 75 pindang fish samples tested were contaminated with microplastics, while only 11 out of 25 fresh fish samples showed contamination (Gunawan et al. 2021). Other studies have also reported microplastics in various species of fish. For example, microplastics were found in all observed species and were most commonly detected in pelagic skipjack tuna (Neto et al. 2020). On the Colombian Caribbean coast, microplastics were found in the digestive tracts of 9 species of commercial fish (Garcés-Ordóñez et al. 2022). A study along the Finnish coast detected microplastics in the digestive tracts of 38 fish (Sainio et al. 2021), while a study in Japanese waters found microplastics in 39.1% of pelagic fish and 10.3% of demersal fish (Yagi et al. 2022). Wild fish in the Atlantic Ocean were also found to have high levels of microplastic contamination (Guilhermino et al. 2021). Similarly, a study in Guangdong, China, showed that freshwater fish commonly consumed by the public were contaminated with microplastics, with different abundances found in 52 tilapia and 24 mud carp samples from 25 locations (Sun et al. 2021). These findings demonstrate that microplastics have contaminated fresh and pindang fish in marine waters in various parts of the world. The results of the study (Table 2) also showed that as much as 26 percent of microplastics were found in the gills of fish and 15 percent in the intestines, these results were similar to a study by Guilhermino et al. showed that 89% of fish contained microplastics in their gastrointestinal tract and

27% in their gills, indicating high levels of consumption and gill contamination (Guilhermino et al. 2021).

The study results (Table 3) were similar to those reported in other studies, such as one that analyzed 69 microplastic items containing various polymers, including Polyamide, Polyurethane, Polypropylene, Polystyrene, and Polyethylene Terephthalate (Neto et al. 2020). Other studies have identified Polypropylene, Polyethylene, high-density Polyethylene, and Polyethylene as the most abundant microplastic polymers in surface water and sediments (Garcés-Ordóñez et al. 2022), while pelagic and demersal fish were found to contain polyethylene, polyester, polyolefin (PO), polypropylene, poly-perinapthalene (PPN), poly-pentaphenylene (PPP), polystyrene (PS), and polyvinyl chloride (PVC) (Yagi et al. 2022). In the mouth of the Minho River, 36 types of polymers were identified in microplastics found in fish, including polyester, polyethylene, polyacrylate, polypropylene, and cellulose acetate (Guilhermino et al. 2021). Furthermore, several studies have demonstrated the negative effects of polyethylene entering the plankton ecosystem, which can lead to a reduction in heart rate and plankton frequency (Pan et al. 2022).

The results showed that the polymer content of polyester, and polyethylene was the highest in both fresh and pindang fish. The results of this study were similar to a study in freshwater areas in southern Italy showing that Polyethylene, Polyethylene Terephthalate, Polystyrene, and Polypropylene are the most common microplastics Polymers reported in existing fish species, fish containing microplastics are the fish caught in the most polluted waters (Forgione et al. 2023). Other studies have shown that the polymers commonly reported in the digestive tract of fish are hight density polyethylene polymers, polypropylene-polyethylene copolymers, and ethylene vinyl acetate (Parvin et al. 2021). Furthermore, 48% of crustaceans, namely shrimp and crabs, contain microplastics, the most common of which are Polyester and Polyolefin (Ogunola et al. 2022).

Table 3 also shows that the results of microplastic polymer variations in fresh fish are more varied than in pindang fish. Pindang fish has been preserved by adding a lot of salt through a boiling or steaming process so that the microplastics in salted fish come from the raw material of the fish as well as from added salt. Gunawan et al. (2021) research stated that apart from being found in pindang fish, microplastics are also present in salt and boiled fish water. In addition, this study also shows that microplastic levels in pindang fish are higher than in raw fish. The pindang fish microplastic polymer in Table 3 contains more polyester and polyethylene polymers, in accordance with the research of



Gunawan et al which also shows that the dominant polymer in pindang fish is polyethylene (46 percent). So the microplastic polymer of pindang fish with a slight variation in types is probably due to the polymer being derived from the salt content added to the fish.

The consumption intensity and the type of fish chosen do not influence health complaints and symptoms (Table 4). Further research is still needed on health complaints and symptoms caused by microplastic exposure. Still, it does not rule out the possibility that microplastics can enter the human body through fish consumption and potentially cause potential risks to human health. One study showed that there is a strong relationship between the concentration of microplastics in fish, intake rate, frequency of exposure, duration of exposure, and body weight of the respondents (Daud et al. 2021). The amount of microplastics ingested by humans is estimated to be between 0.1-5 g microplastics per week, which is dependent on intake (Senathirajah et al. 2021). The potential contamination of humans by microplastics in fish depends on the amount of fish consumption, and estimates of microplastic intake may vary accordingly (Pan et al. 2022). Another study suggests that microplastics in shellfish pose a more direct threat when the shells are eaten whole, while microplastics in the digestion of fish have a fairly limited effect (Mahu et al. 2022). A research investigation conducted in Ghana revealed that exposure to microplastics in shellfish may be much higher in countries with high levels of consumption (Addo et al. 2022). Furthermore, microplastics and nanoplastics can reach the bloodstream and affect cells of the immune system and their distribution throughout the body (Domenech et al. 2021). A study showed that plastic particles were detected in human blood, with an average of 1.6 µg/mL of plastic particles measurable in blood (Leslie et al. 2022). Microplastics have the potential to carry heavy metals into the human body, which have the potential to cause severe health hazards such as birth defects, formation of Reactive Oxygen Species (ROS), cytotoxicity, severe cardiovascular, respiratory, hematological, gastrointestinal, kidney and liver damage, neurological, neurodegenerative and mental disorders, anemia, hypertension, miscarriage, infertility and carcinogenic effects on breast, liver, kidney, lung (Jadhav et al. 2021).

Exposure to microplastics has the potential to cause toxicity through oxidative stress, inflammatory lesions, and increased absorption or translocation, according to several studies showing the potential for metabolic disorders, neurotoxicity, and increased risk of cancer in humans (Rahman et al. 2021). Other studies have shown that the chemicals reported in microplastics in shellfish are categorized as harmful to human health (Masiá et al. 2022, Saha et al. 2021) and microplastics found in boiled and steamed shellfish products are less than those that are fried (Li et al. 2022).

The limitation of this study is that the health symptoms of the respondents are questionnaire data, so the results are subjective. The strength of the research is the number of samples and the types of fish studied along with an analysis of the differences in the polymer content of fresh fish and salted fish. This study recommends conducting education and a good waste management system in coastal areas so that it can minimize pollution of sea waters, especially due to plastic waste.

The majority of respondents in the coast village of Tembok Rejo, Muncar sub-district had low levels of education and monthly incomes of less than 2.5 million, which may affect waste management in the area and lead to environmental pollution. The results showed that 94 percent of the fish samples contained microplastics and only 6 percent of the fish samples did not contain microplastics. The intensity of pindang fish consumption is positively correlated with health symptoms and health complaints experienced by respondents. To minimize pollution of sea waters due to poor waste management, it is crucial to provide education and implement a proper waste management system in the coastal areas. Further study is necessary to investigate the toxic effects of microplastic exposure and consumption on human health, as well as to develop appropriate processing methods for fish that reduce the intake of microplastics into the human body.

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