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Risk Analysis of Heavy Metals in Fish Consumption and Its Implications for Human Health

Agna Silvina[1]

[1] Universitas Ngudi Waluyo, Ungaran, Indonesia

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Abstract

Fish is a nutrient-rich source of animal protein and plays a vital role in meeting human nutritional needs. However, the presence of heavy metals such as mercury (Hg), lead (Pb), and cadmium (Cd) in fish poses potential health risks. This study aims to analyze heavy metal contamination in fish and evaluate the risks of consumption to human health through a literature review. Data were collected from various online scientific sources published over the past five years and analyzed using a descriptive-comparative method. The results indicate that heavy metal contamination in fish is influenced by environmental and biological factors and tends to accumulate through the food chain. Although most heavy metal levels remain within safe limits, long-term exposure still has the potential to pose health risks. Risk assessment approaches such as Estimated Daily Intake and Target Hazard Quotient provide a more comprehensive picture regarding the safety of consumption. Therefore, continuous monitoring of aquatic environmental quality and increased public awareness regarding safe and balanced fish consumption are necessary.

1. Introduction

Food safety is a global issue that is gaining more attention along with the increasing consumption of fishery products in various parts of the world. Fish is known as a source of animal protein that has high nutritional value, especially because of the content of essential fatty acids such as omega-3 that are beneficial to human health. In recent decades, the demand for fish, including high-economic value species such as salmon, has increased significantly in line with population growth and public awareness of healthy diets (FAO, 2020). However, behind the benefits of these nutrients, there are potential risks related to the safety of fish consumption, especially related to the contamination of harmful substances.

One of the main issues in fishery-based food security is the presence of heavy metals in fish tissues. Heavy metals such as mercury (Hg), lead (Pb), and cadmium (Cd) are environmental contaminants that can enter aquatic ecosystems through industrial, agricultural, and natural processes. These metals are persistent, non-degradable, and can accumulate in the food chain through bioaccumulation and biomagnification processes (Ali et al., 2019). As a result, aquatic organisms, including fish consumed by humans, have the potential to be a medium of exposure to heavy metals that have an impact on health.

Exposure to heavy metals through fish consumption is a serious concern because of its toxic effects that can be acute or chronic. Several studies show that heavy metals can cause nervous system disorders, organ damage, as well as increase the risk of chronic diseases including cancer (Zaynab et al., 2022). Additionally, long-term consumption of foods contaminated with heavy metals in certain levels can

have significant health impacts even if exposure occurs in small but persistent amounts (Briffa et al., 2020). Therefore, evaluation of the level of safety of fish consumption is an important aspect in maintaining public health.

A number of studies have been conducted to identify the heavy metal content in different types of fish in different areas of waters. The results show that the level of heavy metal contamination can vary depending on environmental conditions, the source of pollution, as well as the biological characteristics of the fish species (Lounas et al., 2021). In addition, factors such as geographical location, water temperature, and human activities around the waters also affect the level of accumulation of heavy metals in the fish's bodies (Pavez et al., 2018). However, most of these studies still focus on measuring heavy metal levels without in-depth examining the risk implications for human health.

In this context, the risk assessment approach is very important to provide a more comprehensive picture of the impact of fish consumption on health. Risk assessments not only consider the content of contaminants in food, but also take into account the level of consumption, population characteristics, as well as the acceptable dose of exposure to the human body. This approach allows for a more accurate evaluation of the potential health risks that may arise from exposure to heavy metals through fish consumption (Zakir et al., 2021).

Although important, studies on heavy metal risk assessment in fishery products are still relatively limited compared to the study of contaminant content itself. This shows that there are research gaps that need to be filled, especially in efforts to integrate heavy metal content data with quantitative health risk analysis.

Thus, research is needed that not only identifies the presence of heavy metals, but also evaluates the level of risk posed to consumers.

Based on this background, this study aims to analyze the heavy metal content in fish and evaluate the level of risk of fish consumption to human health through a risk assessment approach. The results of the research are expected to contribute to the development of food safety policies and increase public awareness of the potential risks of consumption of fishery products.

2. Literature Review

2.1 Heavy Metal Contamination in Fish and Its Causative Factors

Heavy metal contamination in fish is one of the major issues in global food security, especially due to the persistent and easily accumulating nature of heavy metals in aquatic organisms. Metals such as mercury (Hg), lead (Pb), and cadmium (Cd) can enter the aquatic environment through a variety of sources, including industrial activities, domestic waste, and atmospheric deposition. After entering aquatic ecosystems, these heavy metals can undergo a process of bioaccumulation in the tissues of organisms and biomagnification along the food chain (Ali et al., 2019). As a result, fish as a medium to high-level consumer in the food chain has the potential to contain significant concentrations of heavy metals.

Several studies have shown that the level of heavy metal contamination in fish is influenced by a variety of environmental and biological factors. Environmental factors such as water quality, pollution levels, and sediment conditions have an important role in determining the concentration of heavy metals available in fish

habitats (Pavez et al., 2018). In addition, biological factors such as species, age, body size, and diet of fish also affect the level of accumulation of heavy metals in their body tissues (Copat et al., 2018). Predatory fish tend to have a higher content of heavy metals than herbivorous fish due to the biomagnification process.

In addition to these factors, changes in environmental conditions such as water temperature and pH can also affect the mobility and toxicity of heavy metals. This condition can increase the solubility of metals and facilitate their absorption by aquatic organisms. Other studies also highlight that increasingly intensified human activities in coastal areas and open waters have contributed to the increase in heavy metal contamination in marine ecosystems (Briffa et al., 2020). Therefore, monitoring heavy metal contamination in fish is important to ensure the safety of consumption and protect human health.

2.2 Health Risk Assessment Due to Contaminated Fish Consumption

Health risk assessment from the consumption of fish contaminated with heavy metals is an important approach in evaluating the impact of exposure on humans. This approach not only considers the levels of contaminants in the fish, but also takes into account the level of consumption, frequency of exposure, and characteristics of the population that consumes the fish. Risk assessment methods generally refer to frameworks developed by international agencies such as USEPA and WHO, which include hazard identification, dose-response assessment, exposure assessment, and risk characterization (Zakir et al., 2021).

In the context of fish consumption, one of the indicators that is often used is the Estimated Daily Intake (EDI) and Target Hazard Quotient (THQ), which are

used to assess whether exposure to heavy metals is within safe limits or potentially poses a health risk. A THQ value greater than one indicates a potential non-carcinogenic risk to consumers. In addition, risk assessment can also include estimating carcinogenic risk using parameters such as Cancer Risk (CR), especially for heavy metals that have carcinogenic properties such as cadmium (Gebreyohannes & Gebrekidan, 2018).

A number of studies have shown that although the heavy metal content in fish is often below the set maximum limit, the health risks still need to be comprehensively evaluated due to variations in people's consumption patterns. Long-term exposure in small amounts can still have a significant impact on human health (Diaconu et al., 2020). Therefore, the risk assessment approach is an effective tool in providing a more realistic picture of the safety of fish consumption and as a basis for policy-making related to food safety (WHO, 2021).

3. Methods

This study uses a qualitative approach with a literature review method which aims to comprehensively examine various research results related to heavy metal contamination in fish and its implications on human health. This method is carried out by collecting, selecting, and analyzing various sources of scientific data available online through academic platforms such as Google Scholar, ScienceDirect, ResearchGate, and official publications from international institutions. The main focus in data collection is scientific articles, reputable international journals, and

official reports published in the last five years to ensure the relevance and novelty of the information used in the research.

The data collection process is carried out using specific and relevant keywords, such as "heavy metals in fish", "food safety", "risk assessment of heavy metals", and "human health risk seafood", which are combined with Boolean operators to obtain more targeted search results. All literature obtained was then selected based on inclusion criteria, namely the suitability of the topic with the research, the availability of data that supports the analysis, and publication in scientific journals that have high credibility. Meanwhile, literature that is irrelevant, duplicate, or does not meet academic standards is eliminated from the analysis process.

After the selection stage, the data that has been collected is analyzed using descriptive-comparative analysis techniques. This analysis is carried out by identifying patterns, comparing research results between sources, and grouping information based on key themes, such as the level of heavy metal contamination, factors that affect metal accumulation, and risk assessment methods used. In addition, information synthesis was also carried out to link various research findings so that it can produce a more comprehensive understanding of the relationship between heavy metal contamination in fish and health risks to humans.

In the analysis process, the researcher also pays attention to the validity and reliability of the sources by reviewing the reputation of the journal, the research methods used in previous studies, and the consistency of the reported results. This approach aims to minimize bias as well as ensure that the conclusions generated are

based on strong scientific evidence. The results of this literature analysis are then used as a basis for compiling a discussion on the level of safety of fish consumption and potential health risks posed by exposure to heavy metals.

4. Results and Discussion

Based on the results of the literature review that has been conducted, it is known that heavy metal contamination in fish is a phenomenon that occurs widely in various waters around the world with varying degrees. Heavy metals such as mercury (Hg), lead (Pb), and cadmium (Cd) are found in fish tissues due to environmental exposure derived from anthropogenic activities and natural processes. The existence of these heavy metals cannot be ignored due to their persistent nature and tend to accumulate in the bodies of aquatic organisms through the process of bioaccumulation and biomagnification (Ali et al., 2019). This makes fish one of the main routes of heavy metal exposure for humans through seafood consumption.

The results of various studies show that the level of heavy metal contamination in fish is greatly influenced by the environmental conditions of the waters where the fish live. Factors such as industrial pollution, domestic waste, and mining activities contribute to the increase in heavy metal concentrations in the waters (Briffa et al., 2020). In addition, sediment characteristics and water quality also play a role in determining the level of availability of heavy metals that can be absorbed by aquatic organisms (Pavez et al., 2018). Under certain conditions, heavy

metals accumulated in sediments can re-dissolve into the water column and increase exposure to aquatic biota.

In addition to environmental factors, the biological characteristics of fish also affect the rate of accumulation of heavy metals. Fish with higher trophic positions, such as predatory fish, tend to have higher concentrations of heavy metals compared to herbivorous or omnivorous fish (Lounas et al., 2021). This is due to the process of biomagnification, in which the concentration of metals increases at each level of the food chain. Other factors such as age, body size, and diet of fish also determine the level of accumulation of heavy metals in their body tissues.

In the context of food safety, it is important to evaluate whether the heavy metal content in fish is within safe limits for human consumption. Some studies show that although the heavy metal content in fish is often below the maximum limit set by international standards, potential health risks are still worth considering, especially if consumption is carried out continuously over the long term (Micheline et al., 2019). This shows that it is not enough to evaluate food safety based only on contaminant levels, but must also consider people's consumption patterns.

The risk assessment approach is an important tool in assessing the impact of fish consumption on human health. One of the parameters used in risk assessment is the Estimated Daily Intake (EDI), which describes the amount of heavy metals that enter the body through food consumption. The EDI value is influenced by the concentration of metals in the fish as well as the individual's consumption levels. The higher the consumption of fish and its heavy metal content, the greater the exposure received by the body (Zakir et al., 2021).

In addition to EDI, another commonly used indicator is the Target Hazard Quotient (THQ), which is used to assess non-carcinogenic risks. A THQ value of less than one indicates that exposure is still within safe limits, while a value of more than one indicates a potential health risk. Based on various studies analyzed, most of the THQ values for heavy metals in fish are still below the threshold, so in general fish consumption is considered safe (Gebreyohannes & Gebrekidan, 2018). However, there are some cases where THQ values are close to or exceeding safe limits, especially in areas with high pollution levels.

In addition to non-carcinogenic risks, exposure to heavy metals can also pose carcinogenic risks, especially for metals such as cadmium. This risk is usually assessed using the Cancer Risk (CR) parameter, which indicates the probability of cancer occurring due to long-term exposure to carcinogenic substances. Studies show that CR values for fish consumption are generally still within an acceptable range, but still require attention due to the potential for long-term accumulation (Zaynab et al., 2022). This shows the importance of controlling heavy metal exposure from an early age.

From a public health perspective, fish consumption still has significant benefits, especially as a source of protein and essential fatty acids that are important for the body. Therefore, a balanced approach is needed in assessing the benefits and risks of fish consumption. FAO (2020) emphasizes that fish consumption is still recommended, but it must be accompanied by supervision of the quality and safety of fishery products. Thus, risk mitigation efforts need to be focused on controlling

pollution sources and improving the quality monitoring system of the aquatic environment.

Furthermore, WHO (2021) emphasized that food safety is a shared responsibility involving various parties, including government, industry, and society. Strengthening regulations related to the maximum limit of heavy metal contamination and increasing supervision of fishery products is an important step in protecting consumers. In addition, education to the public about safe consumption patterns is also needed to reduce the risk of exposure to heavy metals.

In the context of the study, there are still limitations in the availability of data that integrate heavy metal content and comprehensive risk analysis. Many studies have focused solely on measuring metal levels without linking them to health implications. Therefore, further research combining chemical analysis with risk assessment approaches is needed to produce a more accurate picture of the impact of fish consumption on human health (Briffa et al., 2020).

In addition, the development of analytical methods and technology also opens up opportunities to improve accuracy in detecting and evaluating heavy metal contamination. The use of more sensitive and specific methods can help in identifying the source of pollution as well as understanding the mechanisms of metal accumulation in aquatic organisms. Thus, the results of the research can be used as a basis for formulating more effective policies in food safety management.

Based on all the results of the study in this study, although fish has the potential to contain heavy metals, the level of risk posed to human health is generally still within acceptable limits, especially if consumed in moderation. However,

potential risks remain and need to be anticipated through strict supervision and increased public awareness. With the right approach, the benefits of fish consumption can still be obtained without neglecting the aspect of food safety.

5. Conclusion

Based on the results of the literature review conducted, it can be concluded that fish, as a food source, has high nutritional value and plays a crucial role in meeting human nutritional needs. However, the presence of heavy metals such as mercury, lead, and cadmium in fish is a major concern in terms of food safety. Heavy metal contamination in fish is influenced by various factors, including aquatic environmental conditions, human activities, and the biological characteristics of the fish themselves. Analysis results indicate that while heavy metal levels in fish generally remain within safe limits, potential health risks persist, particularly with excessive and long-term consumption.

Risk assessment approaches such as Estimated Daily Intake and Target Hazard Quotient provide a more comprehensive picture of the safety of fish consumption compared to simply looking at contaminant levels alone. Based on the research findings, fish consumption can still be categorized as safe and beneficial if practiced wisely and in moderation. Therefore, sustained efforts are needed in monitoring aquatic environmental quality, controlling pollution sources, and raising public awareness regarding safe consumption patterns. Thus, the benefits of fish consumption can be maintained without neglecting health and food safety aspects.

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