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Heavy Metal Exposure through Seafood Consumption and Its Impact on Human Health

Tiara Rahmadani[1]

[1] Poltekkes Kemenkes Palangka Raya, Palangka Raya, Indonesia

Abstract

Heavy metal pollution in aquatic environments is a growing public health issue resulting from anthropogenic activities. Heavy metals such as lead (Pb) are toxic and persistent, and they can accumulate in the food chain through bioaccumulation and biomagnification. This study aims to analyze the relationship between seafood consumption and heavy metal exposure, and to assess their impact on human health. The method used was a Systematic Literature Review (SLR) by examining scientific articles published in the last five years and obtained from the Google Scholar database. The results of the review indicate that consumption of contaminated seafood is one of the primary routes of heavy metal exposure in humans. Chronic exposure to heavy metals can cause disorders in the nervous, hematological, and reproductive systems. The level of exposure risk is influenced by consumption frequency, the type of seafood, and the environmental conditions of the water. Additionally, individual factors such as nutritional status also play a role in determining the level of vulnerability to exposure. Therefore, efforts to control environmental pollution and public education are needed to reduce the risk of heavy metal exposure and protect human health sustainably.

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1. Introduction

Environmental pollution is one of the public health issues that has received increasing global attention in recent decades. Anthropogenic activities such as industrialization, urbanization, and increased waste production have contributed to the accumulation of various pollutants in the environment, including heavy metals that are toxic and persistent. Heavy metals such as lead (Pb) have non-biodegradable characteristics so that they can survive in the environment for a long time and have the potential to have a serious impact on ecosystems and human health (Ali et al., 2019; Briffa et al., 2020).

In aquatic ecosystems, heavy metals can enter through various routes, such as industrial waste, mining activities, and runoff from land. Once they enter the waters, heavy metals undergo a process of bioaccumulation and biomagnification through the food chain. Low-level organisms such as phytoplankton absorb heavy metals from the water, which are then consumed by zooplankton and higher organisms, until they eventually reach humans as peak consumers (Isangedighi & David, 2019). This process causes heavy metal concentrations to increase at each trophic level, so organisms at the top of the food chain have a higher risk of exposure.

One of the main routes of exposure to heavy metals in humans is through the consumption of contaminated food, especially aquatic products such as fish, shellfish, and shrimp. Seafood is known to have a high potential in accumulating heavy metals because its habitat is directly exposed to polluted aquatic environments. Continuous consumption of contaminated seafood can lead to the accumulation of

heavy metals in the human body, which ultimately increases the risk of health problems (Eismann et al., 2020; Amqam et al., 2020).

Exposure to heavy metals, especially lead (Pb), has been linked to a variety of toxic effects on the human body. Lead can affect a variety of organ systems, including the nervous system, the hematological system, the reproductive system, as well as kidney function. In addition, chronic exposure to lead can interfere with hemoglobin synthesis, cause anemia, and negatively impact neurological development (Pirhadi et al., 2022; Ohiagu et al., 2022). These toxic effects can occur at both short-term and long-term exposures, with severity depending on the dose and duration of exposure.

A number of studies have shown a link between seafood consumption and increased levels of heavy metals in the human body. Epidemiological studies show that individuals with a high frequency of seafood consumption have a greater risk of experiencing heavy metal exposure compared to those who consume it infrequently (Pandion et al., 2022). In addition, other studies also confirm that exposure to heavy metals through food is one of the main contributors to toxic load in the human body, especially in areas with high levels of environmental pollution (Keshavarzi et al., 2018).

Although various studies have examined the impact of heavy metals on human health, there are still limitations in understanding the relationship between food consumption patterns and levels of heavy metal exposure in a comprehensive way. Most studies still focus on specific locations or populations, so generalizations

of research results are limited. In addition, variations in the research methods and indicators used are also a challenge in comparing results between studies.

Therefore, a more systematic study is needed to understand the relationship between seafood consumption and heavy metal exposure to human health. A comprehensive approach is expected to provide a clearer picture of the level of risk and the factors that influence it. This study aims to analyze the relationship between seafood consumption and heavy metal exposure and its implications on human health based on a review of relevant literature.

2. Literature Review

2.1 Heavy Metals and Bioaccumulation Mechanisms in the Food Chain

Heavy metals are chemical elements that have a high density and are toxic even in low concentrations. One of the main characteristics of heavy metals is their persistent nature in the environment as they cannot be biodegraded. This causes heavy metals to accumulate in environmental compartments such as water, sediment, and living organisms over long periods of time (Briffa et al., 2020). Heavy metals such as lead (Pb), cadmium (Cd), and mercury (Hg) are often found as major contaminants in aquatic ecosystems due to human activities.

In aquatic environments, heavy metals undergo the process of bioaccumulation and biomagnification. Bioaccumulation occurs when an organism absorbs heavy metals from its environment faster than the body's ability to eliminate them. Meanwhile, biomagnification is an increase in the concentration of heavy metals at each trophic level in the food chain. Low-level organisms such as

phytoplankton absorb heavy metals from the water, then consumed by zooplankton, small fish, and predatory fish that are at the highest trophic level (Isangedighi & David, 2019).

The process of biomagnification causes the concentration of heavy metals in the body of a high-level organism to be much greater than the concentration in the surrounding environment. This makes marine organisms, especially fish and shellfish, an important indicator in the monitoring of heavy metal pollution. In addition, environmental factors such as pH, temperature, and organic matter content also affect the level of heavy metal accumulation in organisms (Ali et al., 2019).

The impact of this bioaccumulation process is not only limited to the ecosystem, but also has direct implications for human health as the end consumer in the food chain. The consumption of organisms that have been contaminated with heavy metals can be the main route for the entry of these harmful substances into the human body. Therefore, understanding the mechanisms of bioaccumulation and biomagnification is important in identifying the health risks posed by heavy metal pollution (Collin et al., 2022).

2.2 Heavy Metal Exposure through Food Consumption and Health Impacts

Exposure to heavy metals in humans can occur through various pathways, one of which is through the consumption of contaminated food. Food products, particularly seafood such as fish, shellfish, and shrimp, are a major source of heavy metal exposure because these organisms live in aquatic environments that are susceptible to pollution. Repeated consumption of contaminated seafood can lead to the accumulation of heavy metals in the human body (Amqam et al., 2020).

Various studies show that exposure to heavy metals through food has a significant contribution to total exposure in the human body. The health risks posed depend largely on the type of metal, concentration, frequency of consumption, as well as the physiological condition of the individual. Studies show that individuals with high seafood consumption have greater levels of heavy metal exposure compared to individuals with low consumption (Eismann et al., 2020).

Lead (Pb) is one of the most dangerous heavy metals for human health. Lead exposure can affect a variety of organ systems, including the nervous system, the hematological system, as well as the reproductive system. Chronic exposure to lead can lead to neurological disorders, anemia, as well as decreased kidney function. In addition, long-term exposure can also increase the risk of developmental disorders in children as well as complications in pregnancy (Ohiagu et al., 2022).

Recent research has also shown that exposure to heavy metals through food can increase the risk of chronic diseases and metabolic disorders. This impact occurs not only in individuals with high exposure, but also in low exposures that last for long periods of time. Therefore, controlling pollution sources and monitoring food quality are important steps in protecting public health from the risk of exposure to heavy metals (Pirhadi et al., 2022).

3. Methods

This study uses the Systematic Literature Review (SLR) method which aims to identify, evaluate, and synthesize relevant research results in a systematic and structured manner. This method was chosen to gain a comprehensive understanding

of the relationship between seafood consumption, exposure to heavy metals, and their impact on human health. The research process began with the formulation of a research question that focused on how exposure to heavy metals through seafood consumption can affect human health.

The next stage is the determination of a literature search strategy which is carried out systematically using scientific databases, especially Google Scholar. Keywords used in the search process include a combination of terms such as "heavy metals", "lead (Pb)", "seafood consumption", "bioaccumulation", and "health effects". The inclusion criteria in this study include scientific articles published in the last five years, available in full-text form, using English, and having relevance to the research topic. Meanwhile, the exclusion criteria include articles that have not gone through a peer-review process, duplication of publications, as well as research that does not directly address the relationship between food consumption and heavy metal exposure.

Once the search process is done, the next stage is the selection of literature based on titles and abstracts to ensure its fit with the focus of the research. Articles that pass this stage are then further analyzed through thorough reading to assess the quality of the methodology, data validity, and relevance of the research results. The data extraction process is carried out by identifying important information from each article, such as the purpose of the research, the method used, the variables being studied, and the main findings.

The final stage in this SLR method is data synthesis, which is combining and comparing the results of various studies that have been selected to obtain broader

patterns, relationships, and conclusions. This approach allows researchers to identify consistency and differences in existing research results, as well as find research gaps that can be the basis for future research. Using the SLR method, it is hoped that this study can provide a comprehensive and systematic picture of the impact of seafood consumption on heavy metal exposure and its implications on human health.

4. Results and Discussion

The results of the literature review conducted show that heavy metal pollution, especially lead (Pb), is an environmental problem that has significant implications for human health. The various studies analyzed in this study consistently show that anthropogenic activity is a major factor contributing to the increase in heavy metal concentrations in the environment, especially in aquatic ecosystems. Poorly managed industrial activities, mining, and waste disposal lead to the accumulation of heavy metals that are persistent and difficult to degrade (Ali et al., 2019; Briffa et al., 2020).

Heavy metals that enter the waters not only settle in the water column, but are also distributed into sediments and living organisms. The process of bioaccumulation allows aquatic organisms to absorb heavy metals from their environment continuously. In the long term, this process is amplified by biomagnification, where the concentration of heavy metals increases at each trophic level in the food chain. High-level organisms such as predatory fish and shellfish are known to have higher concentrations of heavy metals than organisms at lower trophic levels (Isangedighi & David, 2019; Rahman & Singh, 2019).

Findings from various studies show that seafood is one of the main sources of heavy metal exposure in humans. This is due to the ability of marine organisms to accumulate heavy metals in their body tissues. Continuous consumption of contaminated seafood can lead to increased levels of heavy metals in the human body, especially if not balanced with adequate food quality monitoring (Amqam et al., 2020). In addition, research also shows that the level of exposure is greatly influenced by the frequency of consumption, the type of seafood, and the environmental conditions in which the organism lives (Eismann et al., 2020).

Exposure to heavy metals through food consumption has characteristics that are chronic, in which the effects are not always immediately noticeable, but accumulate in the body over a long period of time. Lead (Pb), as one of the most commonly found heavy metals, has extensive toxic properties and can affect a wide range of organ systems in the human body. Studies show that lead exposure can disrupt the central nervous system, cause cognitive impairment, as well as decrease neurological function, especially in vulnerable groups such as children and women (Ohiagu et al., 2022).

In addition, lead exposure also has an impact on the hematological system through impaired hemoglobin synthesis. This mechanism occurs because lead inhibits enzymes that play a role in the formation of heme, so it can lead to anemia. Another impact that is also frequently reported is disruption to the reproductive system, including decreased fertility as well as an increased risk of complications during pregnancy (Pirhadi et al., 2022). This suggests that exposure to heavy metals

not only impacts the health of individuals, but also has long-term implications for the health of the next generation.

The results of the study also showed a significant relationship between the frequency of seafood consumption and the level of exposure to heavy metals in the human body. Individuals who consume high amounts of seafood or with frequent frequency have a greater risk of developing heavy metal accumulation compared to individuals who consume it infrequently. These findings are supported by epidemiological studies showing that high consumption of fish and shellfish correlates with increased levels of heavy metals in the body's blood or tissues (Pandion et al., 2022).

In addition to consumption factors, environmental conditions also play an important role in determining the level of heavy metal contamination in seafood. Waters exposed to industrial waste or other human activities tend to have higher concentrations of heavy metals. This has a direct impact on the organisms that live in it, thereby increasing the risk of exposure for humans as end consumers (Keshavarzi et al., 2018). Thus, environmental quality is a key factor in determining food safety, especially aquatic products.

Furthermore, the results of the analysis showed that variations in heavy metal levels in seafood were also influenced by species type, organism size, and position in the food chain. Organisms that have a longer lifespan or are at higher trophic levels tend to have greater accumulation of heavy metals. This reinforces the concept of biomagnification which explains the increased concentration of toxic substances at each trophic level (Collin et al., 2022).

Nonetheless, not all studies show the same level of risk. Some studies report that the levels of heavy metals in seafood are still within safe limits set by international standards. This difference can be caused by variations in research locations, analysis methods, and levels of environmental pollution. Therefore, the interpretation of the results of the study must take into account the environmental context and characteristics of the population studied (Barone et al., 2018).

In addition, individual factors such as age, nutritional status, and health conditions also affect the level of vulnerability to heavy metal exposure. Individuals with good nutritional status, especially those who have adequate intake of minerals such as calcium and iron, tend to have a lower risk of heavy metal absorption in the body. Conversely, deficiencies in certain nutrients can increase the absorption of heavy metals and exacerbate their toxic effects (Liang et al., 2019).

The results of this study also highlight the importance of preventive approaches in reducing the risk of heavy metal exposure. Monitoring the quality of the environment, especially waters, is an important step in preventing seafood contamination. In addition, education to the public about safe and balanced consumption patterns is also needed to minimize the risk of exposure. Diversifying food consumption and limiting seafood consumption from potentially contaminated sources can be an effective strategy in reducing exposure to heavy metals.

Overall, the results and discussions in this study show that there is a complex relationship between environmental pollution, bioaccumulation of heavy metals, seafood consumption, and their impact on human health. Although the benefits of seafood consumption as a source of protein and nutrients remain recognized, the

risks of exposure to heavy metals cannot be ignored. Therefore, an integrated effort involving various parties, including the government, industry, and the community, is needed to maintain environmental quality and food safety.

Thus, this study reinforces previous findings that exposure to heavy metals through seafood consumption is an important public health issue to pay attention to. This evidence-based approach through this literature review provides a comprehensive picture of risk factors, exposure mechanisms, and health impacts. This is expected to be the basis for policy making and the development of effective intervention strategies in protecting public health from the risk of exposure to heavy metals.

5. Conclusion

Based on the results of the literature review conducted, it can be concluded that heavy metal pollution, particularly lead (Pb), is an environmental problem that has a significant impact on human health. Heavy metals entering aquatic ecosystems through various anthropogenic activities can undergo bioaccumulation and biomagnification within the food chain. This makes aquatic organisms, particularly fish and shellfish, a potential primary source of heavy metal exposure for humans. The continuous consumption of contaminated seafood has been shown to contribute to increased levels of heavy metals in the human body.

This exposure is chronic and can lead to various health disorders, such as neurological, hematological, and reproductive disorders. The level of exposure risk is influenced by various factors, including consumption frequency, type of seafood,

environmental conditions, and individual characteristics. Furthermore, the quality of the aquatic environment plays a crucial role in determining food safety levels, making pollution control efforts critically important. Preventive strategies include environmental quality monitoring, waste management, and public education on healthy and safe consumption patterns. Consequently, an integrated approach is necessary to minimize the risk of heavy metal exposure and sustainably protect public health.

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