Heavy Metal Contamination on Vannamei Shrimp Aquaculture in North Coast of Central Java

Fadil Apresia[1]*, Ambariyanto Ambariyanto[2], Bambang Yulianto[2], Carolyn Melissa Payus[3]

[1]*Magister of Marine Science Study Program, Faculty of Fisheries and Marine Science, Universitas Diponegoro*
[2]*Department of Marine Sciences Faculty of Fisheries and Marine Sciences, Universitas Diponegoro*
Jl. Prof. Jacub Rais, Tembalang Semarang Jawa Tengah 50275 Indonesia
[3]*Faculty of Science and Natural Resources Universiti Malaysia Sabah*
Kinabalu, Sabah, Malaysia
Email: fapresia@gmail.com

Abstract

The North Coast of Central Java receives consignments of waste containing heavy metal contamination from several sources, resulting in a decrease in water quality on the coast. Heavy metal contamination in water sources, such as Pb, Cd, and Cr that will be used in shrimp farming. The impact of Pb, Cd, and Cr can have several adverse effects, such as health risk, ecological imbalance, reduce shrimp growth and productivity, environment pollution. The research was conducted to analyze heavy metal contamination levels in ponds and vannamei shrimp yields on the northern coast of Central Java. The method involved collecting shrimp, water, and sediment samples at nine different locations (Dampyak; Suradadi; Kedongkelor; Danasari; Nyamplungsari; Pesantren; Depok; Wonokerto; Degayu). Heavy metal data were analyzed with SPSS. The mean lead concentrations were 0.52$\pm$0.19 mg.kg^{-1} in sediment, 0.66$\pm$0.11 mg.kg^{-1} in water, and 0.86$\pm$0.18 mg.kg^{-1} in shrimp. Cadmium levels were measured in soil (0.028$\pm$0.03 mg.kg^{-1}), water (0.027$\pm$0.021 mg.kg^{-1}), and shrimp (0.011$\pm$0.004 mg.kg^{-1}). The mean chromium concentrations were 0.51$\pm$0.25 mg.kg^{-1} in sediment, 0.93$\pm$0.40 mg.kg^{-1} in water, and 0.95$\pm$0.11 mg.kg^{-1} in shrimp. Based on the calculation of the average BAF x > 1.0, vannamei shrimp on the northern coast of Central Java have the capability of becoming bioaccumulation and bioindicators. The consumption of vannamei shrimp for 70 years has a lifetime risk of developing cancer due to the LCR value of x > 10^{-6} on the northern coast of Central Java.

Keywords: *Heavy Metal, Vannamei Shrimp Aquaculture, Bioaccumulation Factor, Lifetime Cancer Risk.*

Introduction

Indonesia's strategic location, abundant water resources, and favourable environmental conditions have positioned it as a prominent player in the shrimp industry in Southeast Asia (FAO, 2020). This significant presence of vannamei shrimp not only drives economic growth but also satisfies the demand of both domestic and international markets for this highly prized seafood commodity (FAO, 2020). The industrialization of fisheries has led to a focus on optimizing natural resources, including the aquaculture of vannamei shrimp (Litopenaeus vannamei) (FAO, 2020). On the northern coast of Central Java, the production of vannamei shrimp has reached a considerable level, with an annual total production of 26,791 tons.y^{-1} (BPS Jawa Tengah, 2019). The vicinity of vannamei shrimp ponds is susceptible to anthropogenic pollution, resulting in the presence of heavy metals in the surrounding environment (Hossain *et al*., 2022). Anthropogenic waste serves as the main contributor to heavy metal contamination in aquatic environments, presenting challenges in the transformation of these contaminants into elemental forms that can support the growth of aquatic organisms. The aquatic biota, starting from the benthic layer in coastal waters, plays a vital role in a complex food chain. Nonetheless, contaminants like cadmium and lead can have adverse effects on these organisms (Albuquerque *et al*.,2020). Heavy metal pollution along the coastline can have adverse impacts on water quality, which is crucial for the growth and development of aquatic organisms (Liu *et al*., 2018).

There is a potential risk of shrimp absorbing excessive amounts of heavy metals in areas where these metals are present (Djedjibegovic *et al*., 2020). The extent of this absorption depends on factors such as the shrimp's metabolic rate, absorption capacity, and growth rate (Albuquerque *et al*., 2020). Shrimp exposed to environments contaminated with heavy metals for prolonged periods exhibited significantly lower levels of proteins in their gills, this reduction indicates a notable suppression of their stress and immune response systems compared to shrimp with short-term exposure to heavy metal (Biswas *et al*., 2021). Devastating disorders have grown in line with

*) Corresponding author

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the shrimp industry's enormous growth and specialization of intensive farming as a result of intricate linkages between some of the contaminant and a shrimp aquaculture system. It has been predicted that illness causes extensive damage in the aquatic environment (Flegel, 2019). The most common studies to date concentrated on biological responses or biochemical reactions some aquatic organisms to deal with heavy metal and illness (Baki *et al*., 2018; Flegel, 2019; Newton *et al*., 2019; Biswas *et al*., 2021), discussed dietary on supply improvement inside shrimp's body (Chae *et al*., 2019). However, in the context of shrimp aquaculture, there is a scarcity of studies exploring the bioaccumulation potential of vannamei shrimp. Additionally, there is a notable absence of comprehensive data regarding the potential long-term cancer risks associated with regular consumption of vannamei shrimp over a 70-year period, particularly in significant production regions like the North Coast of Central Java, Indonesia.

Extensive consumption of vannamei shrimp meat, contaminated with harmful substance such as heavy metal, can pose a significant danger to human health, leading to disruptions in the internal organ system, impaired blood flow, inadequate oxygen supply, and the potential onset of cancer due to blockages in the heart that hinder blood circulation throughout the body (Pragnya *et al*., 2021). The significant concern is that the contamination of heavy metals in shrimp is anticipated to be higher due to the progressively polluted environment in vannamei shrimp aquaculture. As a result, individuals who frequently consume vannamei shrimp may face an increased risk of developing cancer over their lifetime. The process by which heavy metals accumulate in shrimp bodies can be attributed to the water and sediment used in aquaculture by examining the bioaccumulation factor (Biswas *et al*., 2021). An organism that accumulates or provides information about the quality of the environment is referred to as a bioaccumulator or a bioindicator (Pragnya *et al*., 2021). Human health risks assessment (Lifetime Cancer Risk) to determine whether consumption of vannamei shrimp containing heavy metals could result in a threat to people's health. Heavy metals have the ability of poisoning blood cells by passing them through the circulation of the blood. Heavy metal takes 20-30 years to be excreted from the human body (Yang *et al*., 2020). The susceptibility factors that increase the risk of adverse health effects, consider the toxicological effects. The aim of this research is to quantify the levels of heavy metal content in vannamei shrimp and investigate whether vannamei shrimp can act as a bioaccumulator in the environment, particularly in the context of vannamei shrimp aquaculture along the northern coast of Central Java. As a reference, there is a potential risk of cancer associated with the consumption of vannamei shrimp from shrimp aquaculture in areas with significant shrimp production, particularly along the northern coast of Central Java.

Materials and Methods

The collection of samples

This study utilized *L. vannamei* shrimp samples with an average length of approximately 11.6±0.2 cm and a weight of approximately 50.6 ± 0.8 g. The shrimp samples were obtained from 9 semi-intensive vannamei shrimp farming locations in Tegal (Dampyak; Suradadi; Kedongkelor), Pemalang (Danasari; Nyamplungsari; Pesantren), Pekalongan (Depok; Wonokerto; Degayu), Central Java (Figure 1.). A total of 20 shrimps were collected from each location, with an average cultivation age of 90 days and an average weight of 1 kg per plastic bag. The shrimp were then transported to the laboratory in plastic bags filled with pond water and ice, and placed inside a styrofoam box. Water samples from each location were collected from the outlet hole located in the middle of the aquaculture ponds, also known as the aquaculture lavatory, using 600 ml bottles. These samples were collected and stored in the Styrofoam box. Sediment samples from each location were also collected from the bottom of the ponds, specifically the sediment layer containing remnants from the shrimp cultivation cycle. Each sample weighed 500 g and was collected in separate bottles, which were then gathered in the styrofoam box.

Heavy metal analysis

The vannamei shrimp from each shrimp cultivation location were washed with distilled water. The vannamei shrimp were then ground using a mortar before being reacted with an acid solution. Sample preparation for measuring the heavy metal content of Pb, Cd, and Cr in all shrimp, sediments, and water samples was conducted (Shovon *et al*., 2017). All equipment for sample preparation was washed with a 10% HNO^2 solution or acid washing and then rinsed three times with distilled water. The preparation process involved heating the shrimp and sediment samples at 60°C for 12 h. Subsequently, the samples were dissolved in 11 mL of HNO^3 and kept at 60°C for 30 mins. After cooling to room temperature, 2 mL of hydrogen peroxide were added to the samples. A digester was used to heat the solution until brown fumes were expelled and the tissues dissolved. However, the solution did not turn colorless and was subsequently diluted with distilled water. The prepared shrimp and sediment samples were placed in clean and dry glass bottles to avoid heavy metal contamination. All samples were extracted

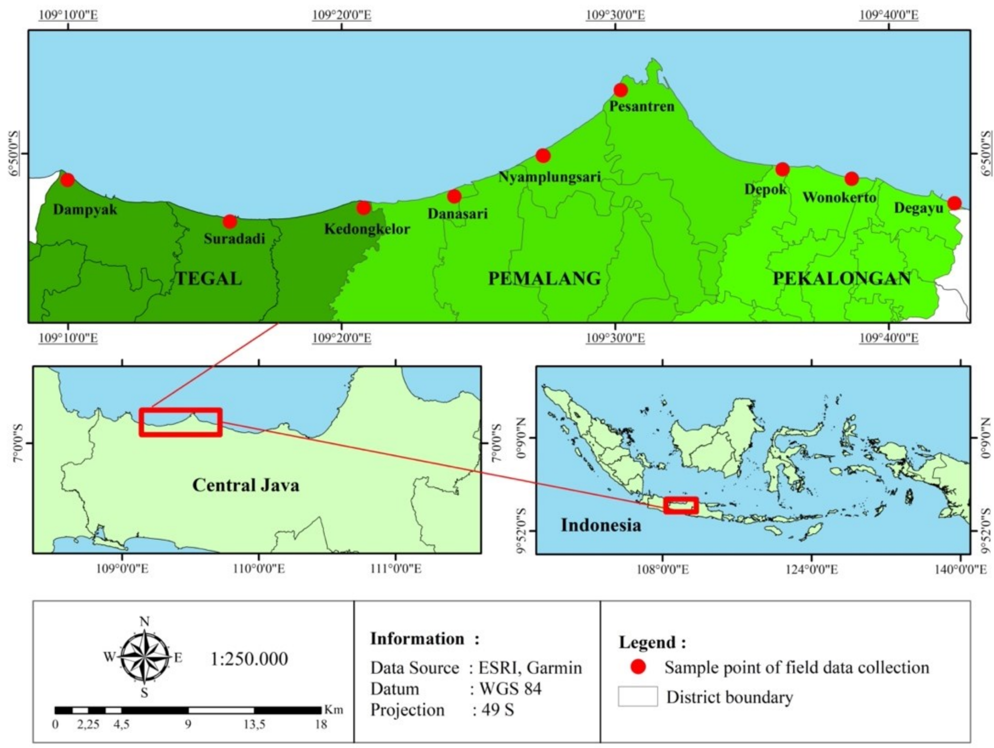

Figure 1. The study area at nine vannamei shrimp ponds included samples of shrimp, sediment, and water in Tegal (Dampyak; Suradadi; Kedongkelor), Pemalang (Danasari; Nyamplungsari; Pesantren), Pekalongan (Depok; Wonokerto; Degayu).

and the heavy metal concentrations were measured using Atomic Absorption Spectrophotometer (Perkin Elmer). The preparation of water samples from each cultivation location involved mixing 500 mL of water samples with 5 mL of HNO^3 and then heating them at 60°C. The heating process continued until the volume was reduced to 15 mL, and this step was repeated until the color of the solution turned pure white. The extracted samples were placed in clean and dry glass bottles and the heavy metal concentrations were measured using Atomic Absorption Spectro-photometer (Perkin Elmer) (Shovon *et al*., 2017).

The Bioaccumulation Factors (BAFs) was determined by dividing the concentration of each heavy metal in the sediment by the concentration of heavy metals accumulated in the biota, using the following formula. Calculation according to (United States Environmental Protection Agency, 2012) using the formula:

$$\mathrm{BAF} = \frac{\mathrm{Cm}}{\mathrm{Csd}}$$

Note: BAF= Bioaccumulation Factor; Cm= heavy metal accumulated shrimps; Csd= heavy metal accumulated sediments. When BAF> 1, then aquatic biota have a bioaccumulator potential.

Health risks of consuming shrimp for humans

In order to evaluate the health risks associated with heavy metal exposure, the Chronic Daily Intake (CDI) can be utilized. The United States Environmental Protection Agency (2011) provides a formula to determine the levels of exposure, as shown below. By calculating the CDI, it is possible to assess the potential health risks caused by the consumption of substances containing heavy metals. This information is crucial for understanding the impact of heavy metal exposure on human health and implementing appropriate risk management strategies:

$$\mathrm{CDI} = \frac{\mathrm{Cm\ x\ IR\ x\ EF\ x\ ED\ x\ CF}}{\mathrm{BW\ x\ AT}}$$

Note: Cm= shrimps that have accumulated metal; IR = consumption rate ($mg.day^{-1}$); EF= session of exposed ($day.y^{-1}$); ED= time spent influenced (70 y); CF = unit conversion; BW = body mass (kg); AT= mean period (days). This formula refers to Health Ministerial Regulation Number 28/2019.

According to the United States Environmental Protection Agency (2012), the consumption of shrimp may pose a health risk in terms of Lifetime Cancer Risk (LCR), specifically related to the presence of carcinogenic metals. This risk can be assessed using the following formula:

$$LCR = CDI \times CSF$$

Note: LCR= lifetime cancer risks; CDI= acute constant consumption; CSF = cancer slope factors

CSF is a risk generated by 1.0 mg.kg^{-1}.day^{-1} of carcinogenic heavy metals that are specifically contaminated in the body, a LCR of 10^{-6} is indicative of no cancer risk, and a LCR of more than 10^{-6} is indicative of cancer risk (United States Environmental Protection Agency, 2012).

Data analysis

Using SPSS, the analysis of the data occurred (Feng *et al*., 2023). The Kolgomorov Smirnov test was employed to figure out whether data on heavy metal levels in vannamei shrimp, water, and sediment was normal and the data were found normal. The value of P<0,05 was used to achieve homogeneous data. To identify significant changes in the content of heavy metals in shrimp samples between stations, an ANOVA was performed, and the outcomes were significant (P<0.05). Tukey's test was done as post hoc test to identify specific pairwise differences that are statistically significant.

Result and Discussion

Heavy metal contaminants in vannamei shrimp, sediment, and water

Pollution around vannamei shrimp ponds was caused by heavy metal contamination, which contaminates the surrounding waters. Heavy metals have become dangerous pollutants since they cannot be degraded by aquatic conditions (Traina *et al*., 2019). The heavy metals are subsequently transferred into the shrimps, posing a direct risk to human health. It is crucial to assess the potential environmental impact of heavy metal content on various aspects, such as water quality, soil quality, and the health of aquatic organisms within the surrounding ecosystem (Hossain *et al*., 2022). Vannamei shrimp, may contain varying levels of heavy metals influenced by the surrounding environment. Common heavy metals found in vannamei shrimp include lead, cadmium, and chromium (Newton *et al*., 2019). Lead, originating from industrial and environmental pollution, can cause long-term damage to the nervous system and organs (Baloch *et al*., 2020). Cadmium, present in water and soil, accumulates in marine animals, affecting the kidneys, lungs, and immune system (Shovon *et al*., 2017). Trivalent chromium, typically associated with seafood like vannamei shrimp, is considered safer, while hexavalent chromium, a more toxic form associated with industrial pollution, poses potential carcinogenic risks to human (Nair and Kurian, 2018). Based on the United States Environmental Protection Agency (2011), the maximum allowable Pb content is 0.5 mg.kg^{-1}. The production of vannamei shrimp in ponds along the northern coast of Central Java exceeded the threshold set by the World Health Organization (WHO), leading to restrictions on its export to certain developed countries. The Pb content in vannamei shrimp was measured at 0.86 mg.kg^{-1} on the northern coast of Central Java. To minimize the concentration of heavy metals, it is recommended to periodically clean the bottom of the pond using the siphon method. The siphon method helps to remove accumulated heavy metals through sediment and water settling at the bottom of the pond, often referred to as an "aquaculture lavatory" for gather up unwanted pollutants (Newton *et al*., 2019).

Due to their slow rate of movement, vannamei shrimps lack the ability to prevent the entry of heavy metals into the water or their adherence to sediments in ponds (Ahmed *et al*., 2019). Therefore, they can be utilized as bioaccumulators or bioindicators of heavy metals in shrimp aquaculture. Industrial waste deposition, including from fishmeal factories, gauze fabric factories, mosquito repellent factories, sarong fabric factories, tea factories, furniture factories, plastic water cup factories, black lead block factories, diesel engine industry, surimi factories, chili sauce factories, and shipbuilding factories (BPS Jawa Tengah, 2019), contribute to heavy metal contamination in the environment. Vannamei shrimp have the ability to accumulate the heavy metal Pb, which can be dissolved in pond water or precipitated in pond sediments (Figure 2.). Due to the noxious, persistent, and bioaccumulative nature of heavy metals, vannamei shrimp are highly contaminated with Pb (Djedjibegovic *et al*., 2020). Several biophysical shocks are observed as a consequence of increased feed input in shrimp aquaculture systems. Elevated concentrations of heavy metals, for instance, lead to oxygen depletion and anthropogenic activities, which may in turn reduce the rate of aerobic respiration in shrimp (Baki *et al*., 2018).

Cadmium accumulates in the shrimp on northern coast of Central Java (Figure 3.) has the mean concentration of cadmium was 0.011$\pm$0.004 mg.kg^{-1} that are eaten continuously by humans, causing heavy metals to accumulate in the human's body, increasing the development of autoimmune diseases and other health issues as a consequence (Yang *et al*., 2020). The consequence based on dose allowed for daily consumption of the heavy metal Cd according to United States Environmental Protection Agency (2011) is 0.001 mg.kg^{-1}. The water used by the shrimp aquaculture has the mean concentration

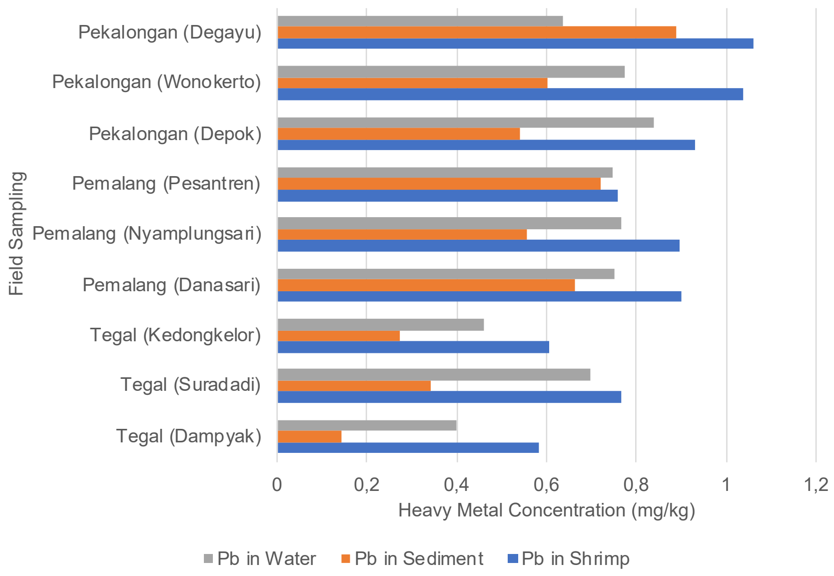

Figure 2. Lead levels in each site at northern coast of Central Java

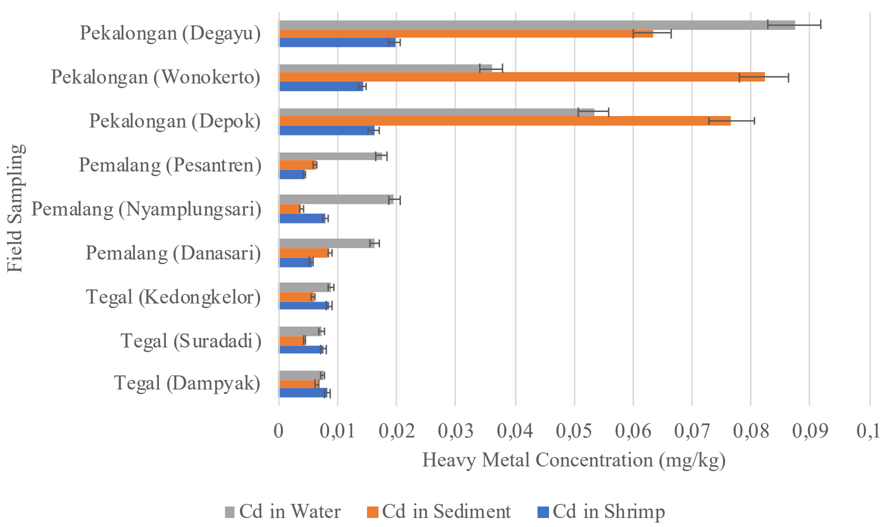

Figure 3. Cadmium levels in each site at northern coast of Central Java

of cadmium was 0.027± 0.021 $mg.kg^{-1}$. The heavy metal contamination in the water in vannamei shrimp ponds, it has been found that the health of organisms is negatively affected, especially those involved in vannamei shrimp aquaculture (Zhang *et al*., 2022). Because of heavy metal contamination, the plankton that is naturally available for vannamei shrimp to feed upon is adversely affected. The sediment has mean concentration of cadmium was 0.028±0.03 $mg.kg^{-1}$. Sediment concentrations are greater than water column concentrations, because heavy metals can disrupt the ecosystem down to trace elements, which vannamei shrimp rely on for energy (Jahan and Strezov, 2018). There is no way to measure the levels of heavy metal in the water column without measuring sediments as well as aquatic organisms that are present in the aquatic environment (Liu *et al*., 2018).

As shown in Figure 4, the chromium content is typically found in textile industrial enterprises, such as in Pekalongan, the center for batik (Indonesian traditional cloth), which is constantly generating dye waste that is created every day, therefore the Pekalongan area can be assessed to be a place with significant heavy metal content. The textile and garment industries, both of which employ dyes including chromium and lead in the manufacturing of printed clothes and batik, are major sources of heavy metal toxicity in Pekalongan (Lestari and Trihadiningrum, 2019). In the Pekalongan area, heavy metals are released during batik production, contaminating the water in rivers like the Banger River, Lodji River, Meduri River, and Bremi River, which are located near batik industries where the majority of residents are engaged in various occupations such as batik artisans, laborers, fishermen, and fish farmers. (BPS Central Java, 2019).

The heavy metals from the batik industry have an impact on the natural food sources of vannamei shrimp. Since the shrimp larvae consume natural food in the pond, this pollution can affect their food source from the beginning of production until the end of their 90-day culture period. For instance, the excessive chromium concentration in shrimp on the northern coast of Central Java was 0.95 mg.kg^{-1} (SD, 0.11). Throughout their maturation process, vannamei shrimp heavily rely on plankton, including both zooplankton and phytoplankton, as their main source of nourishment. As they mature, their diet incorporates soft meat such as worms, shellfish, snails, and mollusks. However, in cases of protein deficiency, vannamei shrimp may display cannibalistic behavior and consume other individuals of the same species (Nair and Kurian, 2018).

Vannamei shrimp are contaminated because they are crustaceans that hunt for food on the water's bottom, where sediment has accumulated. The mean concentration of chromium in sediment is 0.51$\pm$0.25 mg.kg^{-1} and in water is 0.93$\pm$0.40 mg.kg^{-1}, demonstrating that vannamei shrimp can directly absorb heavy metals from sediment at the pond's bottom. Industrial waste activities that produce major water pollution result in dosages that spread and continue to rise continuously. In response to the sharp rise of Cr waste in Pekalongan, the government has created new rules. The maximum Cr level permitted in Pekalongan is 0.05 mg.kg^{-1}, based on Health Minister Regulation Number 32/2017 which incurred contamination from industrial activity waste since they had passed the quality norms. Maintaining water supply continues to be a significant concern for aquaculture and its crucial to ensuring optimal health and welfare in shrimp production. Moreover, shrimp farmers frequently lack understanding of the significance of adequate water quality for maximizing shrimp longevity (Newton *et al*., 2019).

Bioaccumulation

Heavy metals are toxic pollutants that can enter the bodies of aquatic organisms. The vannamei shrimp has the potential to act as a bioaccumulator from the environment in the seas of the Dampyak area to Degayu based on values from 9 locations of vannamei shrimp ponds above the BAF threshold x> 1 (Table 1 & 3). Table 2 shows that six of the nine locations did not meet the BAF> 1 criteria for the bioaccumulation of the heavy metal Cd, eliminating their potential as bioaccumulators. There were only four sites with the potential to be bioaccumulative: Dampyak, Suradadi, Kedongkelor, and Nyamplungsari. It is feasible to ascertain the true environmental circumstances and the pathology of vannamei shrimp affected by heavy metals by observing the shrimp as a bioaccumulator (Ahmed *et al*., 2019).

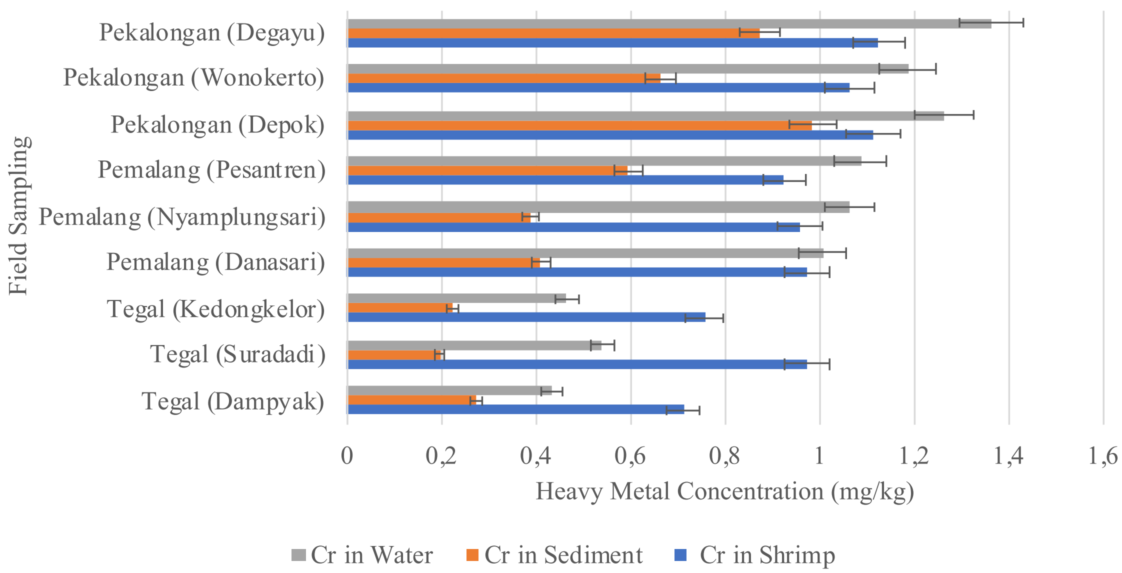

Figure 4. Chromium levels in each sites at northern coast of Central Java

Table 1. Bioaccumulation Factor (BAF) of Lead

No	BAF value	BAF </> 1	Potential as a bioaccumulator	Location
1	4,03	>1	Potential	Tegal (Dampyak)
2	2,24	>1	Potential	Tegal (Suradadi)
3	2,20	>1	Potential	Tegal (Kedongkelor)
4	1,35	>1	Potential	Pemalang (Danasari)
5	1,61	>1	Potential	Pemalang (Nyamplungsari)
6	1,05	>1	Potential	Pemalang (Pesantren)
7	1,73	>1	Potential	Pekalongan (Depok)
8	1,72	>1	Potential	Pekalongan (Wonokerto)
9	1,19	>1	Potential	Pekalongan (Degayu)

*When BAF > 1, vannamei shrimp may become a bioaccumulator of lead in aquatic environments (United States Environmental Protection Agency, 2011).

Table 2. *Bioaccumulation Factor (BAF)* of Cadmium

No	BAF value	BAF </> 1	Potential as a bioaccumulator	Location
1	1,25	>1	Potential	Tegal (Dampyak)
2	1,72	>1	Potential	Tegal (Suradadi)
3	1,44	>1	Potential	Tegal (Kedongkelor)
4	0,64	<1	Less Potential	Pemalang (Danasari)
5	0,49	<1	Less Potential	Pemalang (Nyamplungsari)
6	0,69	<1	Less Potential	Pemalang (Pesantren)
7	0,21	<1	Less Potential	Pekalongan (Depok)
8	0,17	<1	Less Potential	Pekalongan (Wonokerto)
9	0,31	<1	Less Potential	Pekalongan (Degayu)

*When BAF >1, vannamei shrimp may become a bioaccumulator of cadmium in aquatic environments (United States Environmental Protection Agency, 2011).

Table 3. *Bioaccumulation Factor (BAF)* of Chromium

No	BAF value	BAF </> 1	Potential as a bioaccumulator	Location
1	2,60	>1	Potential	Tegal (Dampyak)
2	4,91	>1	Potential	Tegal (Suradadi)
3	3,37	>1	Potential	Tegal (Kedongkelor)
4	2,37	>1	Potential	Pemalang (Danasari)
5	2,46	>1	Potential	Pemalang (Nyamplungsari)
6	1,55	>1	Potential	Pemalang (Pesantren)
7	1,13	>1	Potential	Pekalongan (Depok)
8	1,60	>1	Potential	Pekalongan (Wonokerto)
9	1,28	>1	Potential	Pekalongan (Degayu)

*When BAF> 1, vannamei shrimp may become a bioaccumulator of chromium in aquatic environments (United States Environmental Protection Agency, 2011).

Vannamei shrimp ponds, along with river paths leading to the sea, are located near industrial waste disposal sites that may be related to heavy metal accumulation in aquatic organisms (Traina *et al*., 2019). Depending on the number of heavy metals absorbed by aquatic organisms, the activity of ecosystem microorganisms, sediment texture, and aquatic organisms within their environment, the distribution of heavy metals absorbed by aquatic organisms may have a different effect *(Zhang et al*., 2022). By dissolving into the water and sinking to the bottom, heavy metal contamination concentrates in sediment and is consumed by microorganisms. Bioaccumulation occurs when heavy metals are first introduced into ecosystems and enter aquatic organisms. This process is the beginning of heavy metals spreading into ecosystems and entering organisms inside the shrimp aquaculture system pond.

Throughout the body, vannamei shrimp absorb heavy metals through the process of absorption, particularly in the stomach and intestines as well as in the respiratory tract through their gills. Absorbing heavy metals into the body will involve multiple channels for distribution, including the cell membranes, the bloodstream, and organ systems (Biswas *et al*., 2021).Vannamei shrimp is exposed to heavy metals throughout their bodies, which can increase their toxicity to free entry of heavy metals into their bodies (Albuquerque *et al*.,2020).

Risk of cancer based on vannamei shrimp consumption

Based on the findings presented in Table 4, Table 5, and Table 6, it has been established that the Lifetime Cancer Risk (LCR) values of vannamei shrimp ponds on the northern coast of Central Java are greater than 10^{-6}. Consequently, individuals who consume vannamei shrimp over 70 years face an elevated risk of developing cancer throughout their lifetime. The presence of contamination in vannamei shrimp meat can pose a significant danger, particularly when it is consumed extensively by humans. Massive consumption can lead to symptoms of disruptions in the internal organ system of humans (Pragnya *et al*., 2021). Disruptions in the system occur when disturbances arise, leading to impaired blood flow and inadequate oxygen supply. The onset of cancer initially occurs when a blockage in the heart hinders the flow of blood throughout the body (Duan *et al*., 2020).

Several factors in aquatic ecosystems are the main contributors to heavy metal contamination in vannamei shrimps, when humans consume heavy metal accumulated in shrimps, they suffer from kidney, liver, muscle, brain dysfunction, and increasing the risk of cancer (Djedjibegovic *et al*., 2020). The accumulation of heavy metals in aquatic organisms can move into the human body through the consumption of vannamei shrimp According to the results of LCR, cancer begins with disorders of the nervous system, kidneys, heart, diabetes, autoimmune diseases and strokes that spread throughout the body (Newton *et al*., 2019). According to the results of LCR, cancer begins with disorders of the nervous system, kidneys, heart, diabetes, autoimmune diseases and strokes that spread throughout the body. The accumulation of heavy metal makes humans susceptible to autoimmune diseases leading to cancer. The chromium concentration inside a human can cause diseases such as diabetes, heart block can cause cancer and stroke (Yang *et al*., 2020).

Table 4. Lifetime Cancer Risk (LCR) of Lead

No	LCR value	BAF $\leq/\geq 10^{-6}$	Cancerous Potential	Location
1	2,86	$\geq 10^{-6}$	Potential	Tegal (Dampyak)
2	3,76	$\geq 10^{-6}$	Potential	Tegal (Suradadi)
3	2,97	$\geq 10^{-6}$	Potential	Tegal (Kedongkelor)
4	4,42	$\geq 10^{-6}$	Potential	Pemalang (Danasari)
5	4,4	$\geq 10^{-6}$	Potential	Pemalang (Nyamplungsari)
6	3,73	$\geq 10^{-6}$	Potential	Pemalang (Pesantren)
7	4,57	$\geq 10^{-6}$	Potential	Pekalongan (Depok)
8	5,09	$\geq 10^{-6}$	Potential	Pekalongan (Wonokerto)
9	5,21	$\geq 10^{-6}$	Potential	Pekalongan (Degayu)

*The LCR below 10^{-6} indicates no risk of cancer cells forming in the body and the LCR above 10^{-6} indicates a risk of cells forming in the body (United States Environmental Protection Agency, 2011).

Table 5. Lifetime Cancer Risk (LCR) of Cadmium

No	LCR value	BAF $\leq/\geq 10^{-6}$	Cancerous Potential	Location
1	0,0292	$\geq 10^{-6}$	Potential	Tegal (Dampyak)
2	0,0268	$\geq 10^{-6}$	Potential	Tegal (Suradadi)
3	0,0299	$\geq 10^{-6}$	Potential	Tegal (Kedongkelor)
4	0,0197	$\geq 10^{-6}$	Potential	Pemalang (Danasari)
5	0,0278	$\geq 10^{-6}$	Potential	Pemalang (Nyamplungsari)
6	0,0151	$\geq 10^{-6}$	Potential	Pemalang (Pesantren)
7	0,0567	$\geq 10^{-6}$	Potential	Pekalongan (Depok)
8	0,05	$\geq 10^{-6}$	Potential	Pekalongan (Wonokerto)
9	0,0694	$\geq 10^{-6}$	Potential	Pekalongan (Degayu)

*The LCR below 10^{-6} indicates no risk of cancer cells forming in the body and the LCR above 10^{-6} indicates a risk of cells forming in the body (United States Environmental Protection Agency, 2011).

Table 6. Lifetime Cancer Risk (LCR) of Chromium

No	LCR value	BAF ≤/≥ 10^{-6}	Cancerous Potential	Location
1	16,9	≥10^{-6}	Potential	Tegal (Dampyak)
2	23,07	≥10^{-6}	Potential	Tegal (Suradadi)
3	17,93	≥10^{-6}	Potential	Tegal (Kedongkelor)
4	23,09	≥10^{-6}	Potential	Pemalang (Danasari)
5	22,68	≥10^{-6}	Potential	Pemalang (Nyamplungsari)
6	21,94	≥10^{-6}	Potential	Pemalang (Pesantren)
7	26,42	≥10^{-6}	Potential	Pekalongan (Depok)
8	25,23	≥10^{-6}	Potential	Pekalongan (Wonokerto)
9	26,7	≥10^{-6}	Potential	Pekalongan (Degayu)

*The LCR below 10^{-6} indicates no risk of cancer cells forming in the body and the LCR above 10^{-6} indicates a risk of cells forming in the body (United States Environmental Protection Agency, 2011).

Conclusion

Since the area near a batik fabric manufacturer facility is highly contaminated with heavy metals, the shrimp aquaculture system in Pekalongan has been severely affected. The results of the calculation of the average BAF≥ 1.0, namely vannamei shrimp in the Tegal and Pekalongan areas have the potential to become bio accumulators, in contrast to Pemalang which do not have the potential to become bio accumulators because the average value of BAF <1.0. Based on the LCR values, which are more than 10^{-6}, humans with an estimated consumption of vannamei shrimp for 70 years have the potential to get lifetime cancer effects on humans.

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