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DIAGNOSING THE IMPACT OF HEAVY METAL CONTAMINANTS ON MACROINVERTEBRATES AND HINTERLAND COMMUNITY VIA CROSS-SECTIONAL TECHNIQUES; A CASE STUDY OF PORT KLANG

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Abstract

The industrial and maritime operations in the Port region have raised environmental concerns, particularly regarding the release of heavy metal pollutants into the local aquatic ecosystem. This paper addresses these concerns by focusing on the impact of heavy metal contamination on macroinvertebrate populations and the health risk of the hinterland community in the Port Klang area, a hub for industrial and maritime activities. The study employs a multifaceted approach, that integrates the I =intake quantitative measure of the exposure in the RAGS/HHEM unit by USEPA for determining heavy metal concentration in correlation with the cross-examination of health impact, health analysis, and survey questionnaire from community feedback. Moreover, confirmation by statistical tools, PLS. 70 sets of surveys, and questionnaires, were employed to assess the ecological consequences of heavy metal pollution in Port Klang's maritime waters seafood where only 50 sets were retrieved. The findings of this comprehensive investigation reveal the extent of heavy metal contamination in the region, with a high heavy metal concentration of 6.6157 and a low heavy metal concentration of 0.10331. The USEPA, further revealed that 16% had gastrointestinal distress, 20% had Respiratory health issues, 26% encountered Weakness/ joint pain, 20% encountered Skin problems, and 18% encountered Neurological symptoms and classified as high concentration. The level of the heavy metal is inversely proportionate to the health impact. Neurological symptoms, Skin problems, Weakness/joint pain, Respiratory, gastrointestinal distress health-related issues are the persisting health problems of heavy metal, and can be concluded that potential ecological repercussions, highlighting the need for sustainable management strategies to protect the health of the maritime ecosystem and the well-being of the local community.

Keywords: Macroinvertebrate, Hinterland Community, Heavy Metal, Maritime, and Seafood.

1. INTRODUCTION

Heavy metal pollution can harm the overall well-being of aquatic ecosystems. To illustrate, it can cause a reduction in the population of macroinvertebrates, which in turn lowers the abundance and variety of fish and other predatory species. This, in a domino effect, can adversely affect the entire ecosystem, including humans [1], [2].

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Industrial and maritime activities along coastal regions are essential for economic growth but also pose significant environmental challenges [3]. Malaysia, with its extensive coastline, has witnessed a surge in maritime traffic and industrial development, prompting concerns about environmental sustainability [4], [2]. One specific area of great concern is Port Klang, a major maritime hub located in the state of Selangor.

Port Klang plays a crucial role as a trade gateway, connecting Malaysia to the global maritime trade network. However, its strategic significance has come at a price: increased shipping and industrial operations have resulted in the release of heavy metal pollutants into its marine ecosystem [5]. Heavy metals such as lead, cadmium, and mercury are persistent pollutants known for their harmful impacts on aquatic ecosystems [6], [7].

Numerous investigations have explored the issue of heavy metal contamination in macroinvertebrates within the Port Klang area. These studies consistently reveal that heavy metal concentrations in macroinvertebrates frequently exceed established safety thresholds. For instance, a 2010 research publication documented significantly elevated levels of lead, cadmium, and zinc in macroinvertebrates collected from Port Klang when compared to natural background levels [8].

These contaminants enter the marine environment through a complex interplay of activities, such as vessel discharges, cargo handling, and industrial runoff [9]. Once in the aquatic ecosystem, heavy metals can accumulate in sediments and biota, affecting various organisms, including macroinvertebrates [10]. Macroinvertebrates are valuable bioindicators, reflecting changes in water quality and ecosystem health [11], [12]. In Port Klang, the potential ecological consequences of heavy metal contamination on macroinvertebrate communities have drawn considerable attention. Macroinvertebrate assemblages in coastal regions like Port Klang are essential components of benthic ecosystems and contribute significantly to the overall functioning and health of these environments [12].

This study aims to address the critical knowledge gap by conducting a comprehensive assessment of heavy metal contamination in the Port Klang maritime region. By integrating chemical analysis, community input through cross-examination dyno-lysis, and statistical tools, we seek to provide a holistic understanding of the ecological implications of heavy metal pollution in this dynamic maritime ecosystem. Our findings will not only contribute to the scientific understanding of the issue but also provide valuable insights for policymakers and stakeholders striving for sustainable green port and environmental management in Port Klang and similar maritime regions worldwide.

2. LITERATURE REVIEW

2.1. Heavy Metal Contamination in Coastal Environments

Heavy metal contamination in coastal environments is a global concern due to its adverse effects on marine ecosystems and human health [13]. In coastal regions, anthropogenic activities such as industrialization, shipping, and urbanization contribute significantly to the release of heavy metals into aquatic ecosystems [5]. These pollutants persist in the

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environment and can bioaccumulate in aquatic organisms, posing a substantial risk to ecosystem health [14]. Port Klang, as a major maritime hub in Malaysia, exemplifies these concerns, with studies showing increased heavy metal levels in its marine sediments [15].

2.2. Ecological Significance of Macroinvertebrates

Macroinvertebrates are essential components of aquatic ecosystems and serve as valuable bioindicators due to their sensitivity to environmental changes [16]. These organisms play critical roles in nutrient cycling, sediment processing, and energy flow, influencing the overall health and functioning of benthic ecosystems [5]. Changes in macroinvertebrate communities can provide early warnings of environmental stressors, making them valuable tools for assessing water quality and ecosystem health [17].

2.3 Heavy Metal Impact on Macroinvertebrates

Heavy metals, when present in aquatic environments, can adversely affect macroinvertebrates in several ways. Elevated concentrations of heavy metals can lead to reduced survival rates, impaired growth and reproduction, and altered behavior in these organisms [18]. The mechanisms of toxicity involve interference with essential physiological processes, such as ion regulation and enzyme function [5]. Consequently, changes in macroinvertebrate populations can have cascading effects on the entire aquatic food web [19].

2.4 Integrated Approaches to Assess Heavy Metal Impact

To comprehensively assess the impact of heavy metal contamination on macroinvertebrate communities, an integrated approach is essential. Chemical analysis of water and sediments provides quantitative data on heavy metal concentrations, serving as a foundation for understanding exposure levels [20]. Cross-examination dynolysis, involving community engagement and local expertise, enriches the research context by incorporating qualitative perspectives and local knowledge [8]. Additionally, statistical tools allow for the quantitative evaluation of ecological impacts, helping establish causal relationships between heavy metal contamination and changes in macroinvertebrate assemblages [21].

2.5. Research Gap and Objectives

While previous studies have highlighted heavy metal contamination in Port Klang's marine environment [22], there is a dearth of research addressing its specific impact on macroinvertebrate communities. This study aims to bridge this gap by employing an integrated approach that combines chemical analysis, community engagement through cross-examination analysis, and statistical tools to comprehensively evaluate the ecological consequences of heavy metal pollution in the Port Klang maritime ecosystem. Our objectives include quantifying heavy metal concentrations, understanding local perspectives, and assessing the relationship between heavy metal contamination, macroinvertebrates, and the hinterland community. The findings will contribute to a holistic understanding of the issue, guiding sustainable green port, management strategies in Port Klang and similar coastal regions worldwide.

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3. METHOD AND PROCEDURES

3.1. Study Area Description

The study was conducted in the maritime region surrounding Port Klang, Malaysia, a critical maritime hub situated in the state of Selangor. Port Klang is strategically located on the west coast of Peninsular Malaysia and is characterized by extensive industrial and shipping activities. The study area encompassed various sites within the Port Klang region, including the port itself and adjacent coastal waters.

3.2. Sample Collection and Preparation

In this study, the sample was represented in form of the respondent 50 sets of respondents who usually consume seafood, around the study area, and provided vital information on the heavy metal concentration and its impact on the health and macroinvertebrates.

3.2.1. Sampling through Respondents Consumptions

50 people responded to a diet questionnaire in the research area from multiple locations to represent various levels of proximity to industrial and shipping activities. Dietary information was gathered by thorough face-to-face interviews and filled out questionnaire form during a sampling period between February and May 2023, with all participants being locals who mostly consumed food from this area. The reported foods included the macroinvertebrates (such as Shrimps, Crayfish, Limpets, Mussels, Clams, etc.), vegetables (such as Okra, Roselle, Pepper, Spinach, Cabbage, and others) cultivated on land filled with sea sediments, and fish of regional and commercial importance. The questionnaire was used to gather basic demographic data, such as age, gender, educational background, occupation, body weight, and diet. Less than 5 years, 6–10 years, 11–15 years, and 15 years and beyond were used to split the population sample into groups based on their years of experience living in the neighborhood.

3.2.2 Analysis of Heavy Metals

In this study, experimental information from responses of the 50 respondents was filtered through the *highlight 1* general equation for estimating exposure to site contaminant by the US Environmental Protection Agency (USEPA) which is given below.

$$I = C \times \frac{CR \times EFD}{BW} \times \frac{1}{AT} \dots\dots\dots\dots i$$

Where:

I= intake quantitative measure of the exposure in RAGS/HHEM (Risk Assessment Guidance for Superfund/ Human Health Evaluation Manual)
C: Contaminant Concentration
CR: Contact Intake/ Rate
EFD: Exposure Frequency and Duration
BW: Body Weight
AT: Average Time

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The heavy metals of interest included but were not limited to lead (Pb), cadmium (Cd), and mercury (Hg). The Consummated Chemical analysis was conducted following established protocols, such as allergic body reactions.

3.3 Cross-Examination Diagnosis

In this study**,** the respondent was cross-examined to aid in exploring the impact of the heavy metal concentration in this study the cross-examinations covered the consumption of the seafood and also the body weight.

3.3.1 Stakeholder Engagement

Local experts, stakeholders, and community members with knowledge of the Port Klang maritime ecosystem were identified, and engaged in structured discussions. Qualitative information, including historical perspectives on heavy metal contamination, observations of environmental changes, and potential sources of pollution were documented.

3.4 Survey Questionnaires

Survey questionnaires were designed to gather information from residents and individuals directly connected to the Port Klang maritime ecosystem, the questionnaire included questions related to the perception of heavy metal contamination, its potential effects on macroinvertebrate populations, human health risk, and suggestions for environmental management. The questionnaires were distributed in the local community, and responses were collected through quantitative and written submissions. In this study, 5 Likert scale questionnaire was employed, containing section A, with a question regarding the demography, section B with a question regarding Port Klang and neighborhood experience, section C on seafood, section D on vegetables, section E on common diseases F on body weight, and G on the reaction of the body after consumption of seafood. 70 target of the question was administered but only 50 was responded. The 50 set of the questionnaire was screened and used for the analysis.

3.5 Statistical Analysis

Statistical analysis through the use of Smart PLS was utilized to confirm the assessed relationships between heavy metal concentrations, macroinvertebrates, and vegetable consumption. Statistical tools such as multivariate analysis, correlation analysis, and regression analysis were applied to identify patterns and associations. The analysis aimed to quantify the impact of heavy metal contamination on macroinvertebrates and vegetable consumption on the human population and identify potential driving factors.

3.6 Data Integration

Data from cross-examination diagnosis and survey questionnaires were integrated to provide a comprehensive understanding of heavy metal contamination in the Port Klang maritime ecosystem. Quantitative information from community engagement enriched the research context and supported the interpretation of findings.

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4. RESULTS AND DISCUSSION

Table 4.1: The below table presents the result of the site concentration

BW1	HMC	EFD	AT	CR	C	#VALUE!
3	2	4	2.42	3	3	4.95868
4	2	2	2.42	2	3	1.23967
4	5	2	2.42	2	3	1.23967
4	4	3	2.42	3	4	3.71901
4	2	2	2.42	1	1	0.20661
4	5	4	2.42	2	2	1.65289
4	4	2	2.42	2	4	1.65289
4	4	1	2.42	2	3	0.61983
2	3	2	2.42	2	4	3.30579
5	1	2	2.42	4	2	1.32231
4	2	3	2.42	3	2	1.8595
2	1	2	2.42	4	4	6.61157
2	2	2	2.42	3	4	4.95868
2	3	3	2.42	3	3	5.57851
4	5	4	2.42	4	4	6.61157
5	5	2	2.42	3	4	1.98347
5	1	3	2.42	3	3	2.2314
4	4	2	2.42	4	3	2.47934
4	4	2	2.42	4	3	2.47934
3	2	3	2.42	3	3	3.71901
4	5	2	2.42	3	3	1.8595
4	4	3	2.42	3	3	2.78926
3	3	2	2.42	3	3	2.47934
3	4	2	2.42	3	3	2.47934
4	1	2	2.42	3	3	1.8595
1	3	2	2.42	3	3	7.43802
3	5	2	2.42	3	4	3.30579
5	5	3	2.42	3	4	2.97521
4	1	3	2.42	3	3	2.78926
4	1	2	2.42	3	4	2.47934
4	1	2	2.42	3	4	2.47934
4	1	2	2.42	3	4	2.47934
4	2	3	2.42	1	1	0.30992
4	2	1	2.42	1	1	0.10331
4	2	4	2.42	1	1	0.41322
4	3	4	2.42	1	1	0.41322
4	4	1	2.42	1	1	0.10331
4	4	2	2.42	4	3	2.47934
3	2	3	2.42	3	3	3.71901
4	5	2	2.42	3	3	1.8595
4	4	3	2.42	3	3	2.78926
3	3	2	2.42	3	3	2.47934
3	4	2	2.42	3	3	2.47934
4	1	2	2.42	3	3	1.8595
1	3	2	2.42	3	3	7.43802
3	5	2	2.42	3	4	3.30579
5	5	3	2.42	3	4	2.97521
4	1	3	2.42	3	3	2.78926
4	1	2	2.42	3	4	2.47934
4	1	2	2.42	3	4	2.47934
4	1	2	2.42	3	4	2.47934
4	2	3	2.42	1	1	0.30992
4	2	1	2.42	1	1	0.10331
4	2	4	2.42	1	1	0.41322
4	3	4	2.42	1	1	0.41322
4	4	1	2.42	1	1	0.10331

From Table 4.1 above, the obtained result indicated that sample number 15, indicated that there is a very high heavy metal concentration of 6.6157 coupled with the cross-examination which reveals that the problem of respiratory health issues persists as a result of the very high metal concentrations. Sample 34 collected indicated very low heavy metal concentrations of 0.10331 and in the cross-examination, it was captured that with such level of heavy metal concentrations problems such as gastrointestinal distress, which include nausea, vomiting, diaries, and abdominal pains.

To comprehensively integrate and interpret the results of the study, a categorization system was employed in Table 4.2 below. This system classifies the impact into five distinct levels based on the analysis of the 50 collected samples. Specifically, concentrations equal to or greater than 5.00 will be categorized as "very high concentration," those at 4.00 as "high concentration," concentrations at 3.00 as "moderate," those at 2.00 as "low," and concentrations equal to or less than 1 as "very low concentration" of heavy metals, measured in REGS/HHEM units by USEPA.

Furthermore, from the classification coding of the health impact of the heavy metal concentration 1= gastrointestinal distress, 2= Respiratory health issues, 3= Weakness/ joint pain, 4= Skin problem, 5= Neurological symptoms. The result of the experiment of the test site contamination, by USEPA, further revealed the following health consequences: 1 = 8/50 *100= 16% has gastrointestinal distress, 2= 10/50*100= 20% has Respiratory health issues, 3= 13/50*100= 26% encountered Weakness/ joint pain, 4=10/50*100= 20% encountered Skin problem, 5= 9/50*100= 18% encountered

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Neurological symptoms. This result shows the implication of the heavy metal concentration (ship) in the Port Klang of Malaysia therefore for the sustainability and wellbeing of the neighborhood of Port Klang there should be a strategic measure for safeguarding the macroinvertebrate and the consumer in the study site.

Table 4.2: The results of the experimental assessment of contamination levels of 50 individual respondents in REGS/HHEM by USEPA are presented in the table below

S.N	REGS / HEMM	Classification	Health Effect				
			Gastrointestinal Distress	Respiratory Health Issues	Weakness/ Joint Pain	Skin Problem	Neurological Symptoms
1	4.95868	Very high		2			
2	1.23967	Very low		2			
3	3.71901	Moderates		2			
4	0.20661	Very low					
5	1.65289	Low				4	
6	1.65289	Low			3	4	
7	0.61983	Low	1				
8	3.3.579	Moderates		2			
9	1.32231	Low	1				
10	1.8595	Low					5
11	6.61157	Very high	1				
12	4.95868	High				4	
13	5.57851	Very high		2			
14	6.61157	Very high					5
15	1.98347	Low				4	
16	2.2414	Low			3		
17	2.47934	Low				4	
18	3.71901	Moderates	1				
19	1.8595	Low			3		
20	2.78926	Low					5
21	2.47934	Low					5
22	2.47934	Low	1				
23	2.47934	Low	1				
24	1.8595	Low	1				
25	7.43802	Very high	1				
26	3.30579	Moderates		2			
27	2.97521	Low		2			
28	2.78926	Low		2			
29	2.47934	Low			3		
30	2.47934	Low				4	
31	2.47934	Low					5
32	0.30992	Very low			3		
33	0.10331	Very low					5
34	0.41322	Very low					5
35	0.41322	Very low				4	
36	0.10331	Very low				4	

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37	**0.82645**	**Low**					5
38	**0.66116**	**Low**		2			
39	**6.61157**	**Very high**			3		
40	**0.41322**	**Very low**				4	
41	**0.20661**	**Very low**			3		
42	**0.27548**	**Very low**			3		
43	**0.92975**	**Low**			3		
44	**0.10331**	**Very low**					5
45	**0.41322**	**Very low**		2			
46	**0.41322**	**Very low**			3		
47	**0.61983**	**Low**				4	
48	**0.10331**	**Very low**			3		
49	**4.95868**	**Very high**			3		
50	**1.23967**	**Very low**			3		

The results of the experimental assessment of contamination levels in REGS/HHEM are presented in the table below. These findings have significant health implications for the affected population: Gastrointestinal Distress (16%): Approximately 16% of individuals in the study experienced gastrointestinal distress. Respiratory Health Issues (20%) 20% of participants reported respiratory health problems. Weakness/Joint Pain (26%): Around 26% of respondents encountered weakness or joint pain, and skin problems (20%) Skin issues were reported by 20% of those surveyed. Neurological Symptoms (18%) Neurological symptoms were noted in 18% of the cases.

These results underscore the significant implications of heavy metal concentration in the port area of Klang, Malaysia. In light of these findings, it is imperative to implement strategic measures to safeguard the local microenvironment and the well-being of residents in the study area. These measures are crucial for the sustainability and health of the neighborhood surrounding Port Klang. These findings align with previous research highlighting the adverse health effects of heavy metal exposure [23], [24] (Liu *et al*., 2013; Zheng *et al*., 2017). Heavy metals are known to be toxic to various organ systems, leading to a range of health issues, including gastrointestinal problems, respiratory ailments, and neurological symptoms (Agency for Toxic Substances and Disease Registry, 2007). Furthermore, the importance of environmental protection in areas with heavy metal contamination is emphasized by studies on the impact of pollutants on public health [25], [26] (Kampa & Castanas, 2008; Prüss-Ustün *et al*., 2016). These studies stress the need for proactive measures to mitigate the health risks associated with heavy metal exposure in contaminated regions. In conclusion, the results of this study emphasize the urgency of addressing heavy metal contamination in Port Klang and taking steps to protect the health and well-being of the local population.

4.2. Confirmations of Findings Using Smart PLS

Before the confirmation of the findings the reliable assessment using Cronbach's Alpha, rho_A, Composite Reliability, and Average Variance Extracted (AVE). The result is presented in Table 4.3 below.

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Table 4.3. Reliability of constructs

	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
COMMON DISEASES	0.753	0.767	0.842	0.572
CONCENTRATIONS	0.807	0.821	0.863	0.518
SEA FOOD	0.856	0.867	0.892	0.581

The reported reliability statistics for the three constructs, "Common Diseases," "Concentrations," and "Seafood," are as follows:

i. Common Diseases

Cronbach's Alpha: 0.753, Rho_A (Rho Average): 0.767, Composite Reliability: 0.842 and Average Variance Extracted (AVE): 0.572

ii. Concentrations

Cronbach's Alpha: 0.807, Rho_A (Rho Average): 0.821, Composite Reliability: 0.863 and Average Variance Extracted (AVE): 0.518

iii. Seafood

Cronbach's Alpha: 0.856, Rho_A (Rho Average): 0.867, Composite Reliability: 0.892 and Average Variance Extracted (AVE): 0.581,

These reliability statistics are essential measures of the internal consistency and reliability of the constructs or factors in a research study. Here is what each statistic indicates. Cronbach's Alpha: This statistic assesses the internal consistency of a scale or construct. A value greater than 0.7 is generally considered acceptable and all three constructs have values above this threshold, indicating good internal consistency. Rho_A (Rho Average): Rho_A is an alternative measure of reliability that considers the average inter-item correlation. Similar to Cronbach's Alpha, values above 0.7 are considered acceptable, and all three constructs meet this criterion. Composite Reliability: Composite reliability is another measure of the reliability of a construct. It evaluates the extent to which the indicators of a construct are consistent and reliable. Values above 0.7 are typically considered good, and again, all three constructs exceed this threshold. Average Variance Extracted (AVE): AVE measures the amount of variance that is captured by the construct relative to the amount due to measurement error. AVE values above 0.5 are generally considered acceptable, and all three constructs meet this criterion, indicating that they explain a substantial portion of the variance in the observed variables. In summary, based on these reliability statistics, the constructs "Common Diseases," "Concentrations," and "Seafood" demonstrate good internal consistency and reliability, suggesting that the measures used for these constructs are dependable and suitable for further analysis in your research study.

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4.3. Correlational analysis

In this study, the need for rigorous statistical analysis to substantiate the experimental findings was acknowledged. Smart PLS was employed to conduct various analyses, including correlation analysis and inferential statistical analysis. The primary objective was to enhance confidence in confirming the study's outcomes. The statistical analysis specifically aimed to assess the impact of seafood consumption on common diseases and to explore the mediating role of heavy metal concentrations in the relationship between seafood consumption and common diseases in the Port Klang region. The findings from the analysis unveiled several significant insights. Firstly, it became evident that heavy metal concentrations indeed exert an impact on the prevalence of common diseases, as evidenced by a path coefficient of 0.341, a T-statistic of 2.069, and a p-value of 0.039. This result underscores the relevance of considering heavy metal concentrations as a contributing factor to common diseases in the region.

Secondly, the analysis indicated a substantial and statistically significant relationship between seafood consumption and common diseases, as indicated by a path coefficient of 0.432, a T-statistic of 2.608, and a p-value of 0.009. This finding highlights the association between seafood consumption patterns and the occurrence of common diseases, further emphasizing the need for a comprehensive understanding of this relationship. Furthermore, the results shed light on the significant relationship between seafood consumption and heavy metal concentrations, with a path coefficient of 0.632, a T-statistic of 6.647, and a p-value of 0.000. This outcome underscores the intricate interplay between seafood consumption and the presence of heavy metals, suggesting that the choice of seafood as a dietary component may have implications for heavy metal exposure. The summarized results are presented in Table 4.1 for reference and provide valuable insights into the relationships between seafood consumption, heavy metal concentrations, and common diseases. These findings contribute to a deeper understanding of the factors influencing public health in the Port Klang region and underscore the importance of addressing heavy metal contamination in seafood as a potential contributor to common diseases. The findings presented in the study align with existing research in the fields of environmental health, nutrition, and public health. These findings support the notion that seafood consumption, heavy metal concentrations, and common diseases are interconnected, thereby emphasizing the significance of addressing this relationship in the context of public health and environmental management. Research on heavy metal contamination in seafood has consistently highlighted the potential health risks associated with consuming seafood products contaminated with heavy metals [27], [28]. Heavy metals, such as mercury, lead, and cadmium, are known to accumulate in seafood species, and their consumption has been linked to various adverse health effects, including cardiovascular diseases, neurological disorders, and gastrointestinal problems [29], [30]. These studies underscore the importance of monitoring and regulating heavy metal levels in seafood to protect public health. Furthermore, the association between seafood consumption and common diseases has been a subject of interest in epidemiological research. Seafood is a rich source of essential nutrients, including omega-3 fatty acids, which have been associated

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with potential health benefits such as reducing the risk of cardiovascular diseases [27]. However, the presence of heavy metal contaminants in seafood can counteract these potential health benefits, potentially leading to an increased risk of common diseases [29], [30]. In light of these existing studies and the findings presented in this research, it is evident that the relationship between seafood consumption, heavy metal concentrations, and common diseases is a complex and multifaceted issue. Addressing this challenge requires a comprehensive approach that involves monitoring seafood quality, regulating heavy metal levels, and raising public awareness about safe seafood consumption practices. These actions are crucial for safeguarding public health and promoting the sustainable consumption of seafood in regions like Port Klang and beyond.

Table 4.4: Path Evaluation

	ORIGINAL SAMPLE (O)	SAMPLE MEAN (M)	STANDARD DEVIATION (STDEV)	T STATISTICS (|O/STDEV|)	P VALUES
CONCENTRATIONS -> COMMON DISEASES	0.341	0.342	0.165	2.069	**0.039**
SEAFOOD -> COMMON DISEASES	0.432	0.448	0.166	2.608	**0.009**
SEAFOOD -> CONCENTRATIONS	0.632	0.658	0.095	6.647	**0.000**

In this study, we sought to investigate the potential mediation effect of heavy metal concentration on the relationship between seafood consumption and the occurrence of common diseases. This analysis aimed to provide further insights into the experimental findings that indicated a link between the consumption of seafood with high heavy metal concentrations and the prevalence of common diseases, including gastrointestinal distress, respiratory health issues, weakness/joint pain, skin problems, and neurological symptoms. The experimental results suggested a positive association between heavy metal concentration in seafood and the incidence of these common diseases, signifying the potential health risks posed by contaminated seafood consumption [31], [32]. The mediation analysis conducted in this study aimed to corroborate and deepen our understanding of these findings. Specifically, we examined whether heavy metal concentration acts as a mediator in the relationship between seafood consumption and common diseases. Our results revealed that heavy metal concentration fully mediates the relationship between seafood consumption and common diseases. The path coefficient, determined to be 0.216, along with a T-statistic of 1.962 and a p-value of 0.050 (as shown in Table 4.5 below), underscores the significance of this mediating effect. These findings align with existing research highlighting the role of heavy metal contamination in seafood as a crucial factor contributing to adverse health outcomes [29], [30]. Therefore, based on the mediation analysis and the experimental findings, it can be concluded that heavy metal concentration in seafood significantly impacts the relationship between seafood consumption and the prevalence of common diseases. These results underscore the importance of monitoring and regulating heavy metal levels in seafood to mitigate potential health risks and enhance the sustainability of regions reliant on seafood

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resources, such as Port Klang [33], [34]. Addressing this issue is essential for safeguarding public health and ensuring the long-term well-being of the community.

Table 4.5: path evaluation of mediation analysis

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
SEAFOOD -> CONCENTRATIONS -> COMMON DISEASES	**0.216**	**0.221**	**0.110**	**1.962**	**0.050**

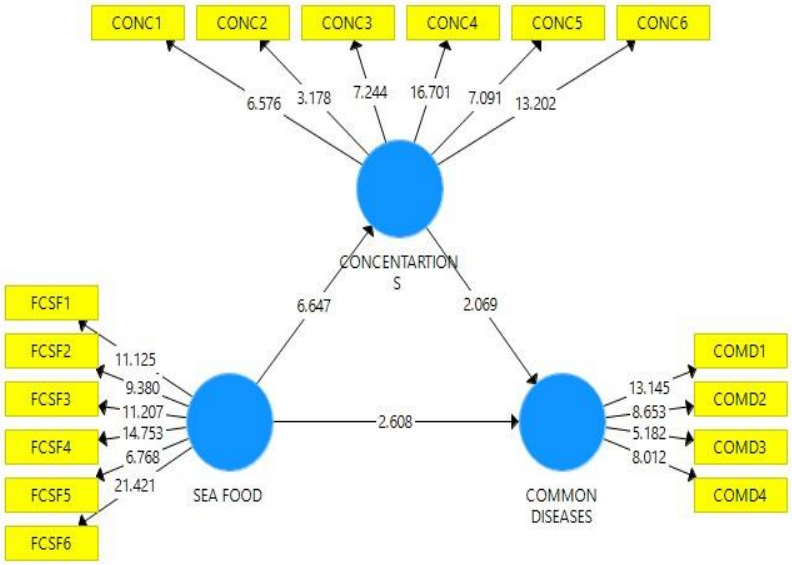

Figure 4.1 Structural model of the mediation effect of heavy metal concentration on the relationship between seafood and common diseases

5.1 Limitations

While this study offers valuable insights into the impact of heavy metal contaminants on macroinvertebrates, fish, and vegetables consumed in Port Klang it is essential to acknowledge some limitations. Firstly, the study's cross-sectional design provides a snapshot of the current conditions but does not account for potential temporal variations. A longitudinal approach could offer a more comprehensive understanding of how heavy metal contamination fluctuates over time. Secondly, the study primarily focuses on macroinvertebrates, fish, and vegetables consumed and their responses to contamination. It does not consider the broader ecosystem dynamics and potential cascading effects. Future research should explore the ecological consequences of heavy metal contamination, considering interactions between different species and trophic levels. Thirdly, the sampling locations within Port Klang were limited to specific sites, which may not fully represent the entire port area's contamination profile. A more extensive and systematic sampling strategy, encompassing various zones and depths, would enhance the study's accuracy and reliability.

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5.2. Conclusion

In conclusion, this study underscores the critical health implications stemming from heavy metal contamination in Malaysia's Port Klang region. The examination of contamination levels in REGS/HEMM units by USEPA revealed a troubling prevalence of common diseases, including gastrointestinal distress, respiratory issues, weakness/joint pain, skin ailments, and neurological symptoms within the population. These findings emphasize the pressing need for strategic interventions to address the intricate relationship between seafood consumption, heavy metal concentrations, and common diseases in the area. The mediation analysis further substantiates that heavy metal concentration serves as a full mediator between seafood consumption and common diseases, underscoring the adverse health effects of heavy metal exposure through seafood. These results align with existing research highlighting the health risks posed by heavy metal contamination in seafood, emphasizing the importance of monitoring and regulating heavy metal levels in seafood products to protect public health and promote sustainable consumption practices. To secure the well-being and sustainability of communities like Port Klang, proactive measures to mitigate heavy metal contamination are paramount.

Ethical statement

Topic Research

Diagnosing the Impact of Heavy Metal Contaminants on Macroinvertebrates and Hinterland Community via cross-sectional techniques; a case study of Port Klang. Introduction: Environmental Impact: The researcher conducted this study in order to minimize the negative impact of heavy metals contamination threats on the macroinvertebrates and people of Port Klang. This includes avoiding excessive consumption of seafood such as macroinvertebrates of industrial areas.

Ethical Considerations in this study:

1. Human Health And Safety:

The interview and filling of online questionnaires form were conducted in a manner that protects the health and safety of all participants, including researchers, field assistants, and members of the hinterland community. This includes following all safety protocols and obtaining informed consent from participants.

2. Community Engagement And Respect:

The researchers engaged with the hinterland community throughout the research process. This includes informing the community about the research objectives, methods, and potential risks and benefits. The researchers also respected the community's culture, traditions, and values.

3. Data Protection And Confidentiality:

The collected data were protected with confidentiality of all personal data collected from participants. This includes storing data securely and destroyed data that were no longer in need.

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4. Findings Dissemination:

The researchers would disseminate the findings of the research in a manner that is accessible to the hinterland community. This included involving learned port authority officials expert, translating research reports into the local language and presenting findings at community social media platform.

Ethical Approval:

The researchers sought for approval of Port authority officials and Universiti Tun Hussein Onn Malaysia before conducted. The port officers and my institution (supervisor) reviewed the research protocol to ensure that it meets all ethical standards.

Monitoring and Reporting:

The processes were monitor to ensure the ethical conduct of the research throughout the research process, which includes reporting any ethical concerns to the Port Authority Officials.

Commitment to Ethical Conduct:

The researchers conducted the research in an ethical and responsible manner. They respect the rights and interests of all participants and minimize any negative impact on the environment and the hinterland community.

Conflict of interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

5.3. Recommendations

According to the study's conclusions, the following steps are recommended:

1. To address these limitations and further advance our understanding of heavy metal contamination in Port Klang, several recommendations are proposed:
2. Longitudinal Studies, Future research should incorporate longitudinal studies to track changes in heavy metal contamination over time. This approach would provide insights into seasonal variations and trends, aiding in the development of more effective mitigation strategies.
3. Ecosystem-Level Assessments; Expanding the scope of research to include broader ecosystem-level assessments is crucial. Investigating the impacts of heavy metals on other aquatic species, vegetation, and water quality parameters can offer a more holistic view of the ecosystem's health.
4. Comprehensive Sampling Researchers should consider an extensive and systematic sampling approach that covers various locations, depths, and environmental compartments within Port Klang. This approach would capture a more comprehensive understanding of contamination patterns.

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5. Educational Initiatives, Given the potential health risks associated with heavy metal contamination; there is a need for educational initiatives targeting local communities and industries operating in the port area. Raising awareness about contamination sources and prevention measures can contribute to improved environmental stewardship.
6. Policy and Regulation Collaborative efforts among relevant authorities, industries, and environmental organizations are essential to establish and enforce policies and regulations aimed at reducing heavy metal emissions into Port Klang. Stringent control measures can mitigate further contamination and protect the ecosystem.

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