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Evaluation of Environmental Risk from Heavy Metals in Sediments in Port Areas

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Abstract: This research aims to evaluate the concentration and distribution of heavy metals in sediment in the Port area of PT Pelindo Dumai Branch, which is one of the main ports in Riau Province, Indonesia. Heavy metals such as cadmium, copper, lead, mercury and zinc are known to have significant toxic effects on maritime ecosystems and can accumulate in the food chain, potentially endangering aquatic life and human health. The research methodology involves taking sediment samples from various points around the port area, which are then analyzed using spectroscopic techniques to determine heavy metal concentrations. The results showed that the concentration of heavy metals in sediments varied, with zinc having the highest concentration (average 0.019724 mg/L), followed by copper, lead, cadmium, and mercury. This variation indicates the existence of diverse sources of pollution and uneven distribution in the port area. Although cadmium and mercury concentrations are relatively low, they still raise concerns due to their high toxicity and potential accumulation in the food chain. These results emphasize the need for more intensive environmental monitoring and targeted risk management to reduce the negative impacts of heavy metals on maritime ecosystems and human health. This research provides an important scientific basis for mitigation efforts in port areas, which are crucial to ensuring the sustainability of ecosystems and the well-being of communities that depend on marine resources.

Keywords: Air quality; Environmental management; Harbor pollution; Noise; Water quality

Introduction

Heavy metals that accumulate in maritime ecosystems are one of the most worrying environmental issues, considering their significant toxic impact on various ecosystem components (Fulke et al., 2024; Kaur et al., 2021; Saidon et al., 2024). Metals such as cadmium, copper, lead, mercury and zinc, although present in relatively low concentrations in sediments, can have lasting detrimental effects on biodiversity and the balance of maritime ecosystems (Supriyantini et al., 2015). High concentrations of heavy metals in sediments can disrupt natural biogeochemical processes and have the potential to accumulate in the food chain, causing bioaccumulation that threatens aquatic life, including fish and marine invertebrates (Mariani et al., 2021). In addition, heavy metals can affect the reproduction and growth processes of aquatic organisms, reduce the fertility and productivity of species, and cause genetic mutations and disease (Bhardwaj et al., 2021; Goutam Mukherjee et al., 2022; Taslima et al., 2022; Wrzecińska et al., 2021). These impacts are not only limited to aquatic life, but also reach human populations who depend on marine resources for food and livelihoods (Balqis et al., 2021). Therefore, research on the distribution and concentration of heavy metals in maritime sediments,

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especially in port areas, is key to understanding and managing the environmental risks they pose. This approach is important to ensure the sustainability of maritime ecosystems and reduce negative impacts on human life.

The environmental risk from heavy metal concentrations in port areas is a serious and multidimensional problem. Port areas are often exposed to higher levels of pollution due to intensive activities such as shipping, industry and transportation. Heavy metals such as cadmium, copper, lead, mercury and zinc, which can accumulate in port sediments, pose a significant environmental risk (Sukaryono, 2018). These risks are not only limited to contamination of maritime ecosystems, but also extend to potential impacts on human health (Jaiswal et al., 2018; Javed et al., 2019; Mishra et al., 2019; Okereafor et al., 2020; Rahman et al., 2019; Traina et al., 2019).

In aquatic environments, heavy metals can affect microbial, invertebrate, and fish life, disrupting important biological and ecological processes. The accumulation of heavy metals in the food chain can cause bioaccumulation, where the concentration of heavy metals increases at each trophic level, thereby threatening top predator species, including humans. This contamination can cause various health problems in aquatic organisms, including impaired reproduction, growth, and even death (Hidayat et al., 2022; Milasari et al., 2020).

For humans, consuming seafood contaminated with heavy metals from port areas can cause various health problems, ranging from digestive disorders to damage to the nerves and immune system. This health risk is especially worrying for communities that depend on marine resources as their main food or livelihood (Andrews et al., 2021; Nurbarasamuma et al., 2022; Putri et al., 2017).

In addition, heavy metals leached from sediment into water can affect water quality and endanger aquatic ecosystems and water resources used for human purposes (Huzairiah et al., 2022; Sanga et al., 2023; Utete et al., 2020). Therefore, monitoring and managing environmental risks from heavy metals in port areas is of paramount importance, not only to protect biodiversity and maritime ecosystems, but also to protect human health and well-being.

The aim of this research is to comprehensively evaluate the concentration and distribution of heavy metals in the sediments of the PT Pelindo Dumai Branch port area, as well as to identify the potential environmental risks they pose. Through detailed analysis of cadmium, copper, lead, mercury and zinc concentrations, this research aims to understand the extent to which harbor sediments are contaminated by these heavy metals.

Method

The location of this research is around the Port area of PT Pelindo Dumai Branch, which is one of the main ports in Riau Province, Indonesia. This port is strategically located on the east coast of Sumatra Island, facing the Strait of Malacca, one of the busiest shipping lanes in the world. This port area not only plays an important role in maritime trade and transportation activities, but also interacts directly with the rich maritime and coastal ecosystem. The environment around the port is characterized by a variety of habitats, including mangroves, coral reefs and sandy beaches, all of which have an important ecological role.

The dynamics of activities at Dumai Port, which include loading and unloading of goods, ship operations, and related industrial activities, make this area a potential area for studying the environmental impacts of port activities, especially those related to heavy metal contamination. The geographic and economic conditions of this port provide a unique context for the research, allowing analysis of how port activities contribute to the distribution of heavy metals in sediments and their impact on the maritime environment.

The method for collecting and analyzing sediment samples in this research was carried out with the aim of measuring the concentration of heavy metals, including cadmium, copper, lead, mercury and zinc, around the Port area of PT Pelindo Dumai Branch.

Sediment samples were taken from various locations around the port area to obtain an accurate representation of the distribution of heavy metals. Sampling is carried out using standard sediment sampling equipment, such as a grab sampler or core sampler, which allows sampling from various depths and substrate types. Samples were taken from various points that had been determined based on certain criteria, such as proximity to loading and unloading areas, ship traffic routes and industrial zones.

After collection, sediment samples are stored in clean containers and then cooled for transportation to the laboratory. In the laboratory, samples are processed for analysis, including drying, sieving, and homogenizing to ensure sample consistency.

Analysis of heavy metal concentrations in sediment samples is carried out using spectroscopic techniques, such as Atomic Absorption Spectrometry (AAS) or Inductively Coupled Plasma Mass Spectrometry (ICP-MS) (Handayani et al., 2020; Suryono, 2016). These techniques provide high accuracy and sensitivity in detecting heavy metal concentrations, even at very low levels.

Result and Discussion

The mean cadmium concentration was 0.002075 mg/L, with a standard deviation of 0.000613 mg/L, indicating relatively low variation across samples. This indicates consistent levels of cadmium contamination in the port area. Copper has an average concentration of 0.014575 mg/L with greater variations, seen from the standard deviation of 0.006634 mg/L, indicating diverse pollution sources or uneven distribution in the port area.

The concentration of cadmium in the sediment of the Port of PT Pelindo Dumai Branch, although relatively low, still raises concerns because cadmium is known as a very toxic heavy metal. Even at low concentrations, cadmium can accumulate in the food chain, endangering aquatic life and humans. The source of this cadmium can come from industrial waste disposal or the corrosion process of port equipment (Pratikino et al., 2022).

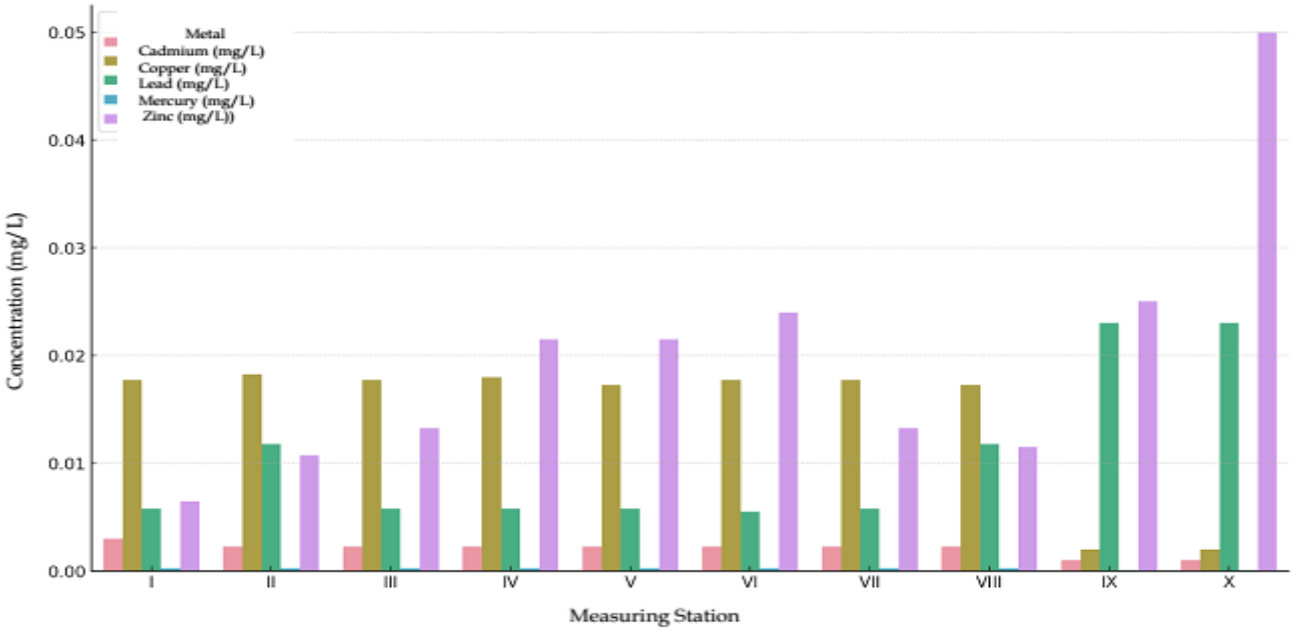

Figure 1. Concentration of heavy metals in sediments at PT Pelindo Port, Dumai Branch

Copper concentrations detected at various stations showed variations that were not very significant. Copper is an essential element for aquatic life at trace levels, but at higher concentrations, it can be toxic. The source of copper may come from the use of anti-fouling materials on ships and industrial activities around ports (Rochyatun et al., 2010).

Lead showed an average concentration of 0.010375 mg/L with significant variation, a standard deviation of 0.007097 mg/L, indicating a more pronounced difference in contamination levels between samples. This could reflect the presence of certain areas with higher levels of lead pollution. Mercury, although found in very low concentrations (average 0.000244 mg/L), remains a concern due to its high toxicity and potential accumulation in the food chain.

Lead concentrations in sediments showed more significant variations, with some stations showing relatively higher concentrations. Lead is a dangerous pollutant and has no known biological role, so its presence in aquatic environments can be a serious concern, especially because of its potential to disrupt the function of biological and ecological systems (Edward, 2020).

Zinc was recorded at a mean concentration of 0.019724 mg/L, the highest among the metals measured, and showed considerable variation (standard deviation 0.012365 mg/L). This indicates the potential for significant and diverse sources of pollution in the port area. Overall, these data illustrate the different impacts of heavy metal pollution in different parts of the port, indicating the need for targeted environmental monitoring and management to reduce the environmental risks associated with these heavy metals.

Zinc, detected at higher concentrations than other metals, is an important metal for many aquatic organisms, but at higher levels can be toxic. Zinc is often used in industry and construction materials, so its high concentration can indicate the influence of port activities and waste disposal (Febrita et al., 2022; Siaka et al., 2020).

This research provides the basis for more focused mitigation efforts. Given the potential negative impacts of heavy metals on aquatic life and human health, it is

important to develop strategies that reduce the input of these pollutants into the maritime environment.

Conclusion

Conclusions from the analysis of heavy metal data in the sediments of PT Pelindo Dumai Branch Port show significant variations in heavy metal contamination. Relatively stable cadmium concentrations indicate consistent sources of pollution, while greater variations in copper and lead reflect uneven distribution of pollutants. Mercury, even in low concentrations, remains a concern because of its toxicity. Zinc, with the highest average concentration, indicates significant accumulation potential. These findings underscore the need for effective environmental monitoring and management in ports to reduce the risk of heavy metal pollution to maritime ecosystems and human health.

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Authors Contributions
Y. makes contributions to product development, research design, research execution, data collection, and writing research articles. N.A. was a supervisor in research activities ranging from article writing, reviews, to editing. A.H. played a role in reviewing the initial manuscript and providing input.

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Conflicts of Interest
The researchers declare there is no conflict of interest.

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