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A Cross-Sectional Study of Environmental Pollution Factors Associated with Heavy Metal Levels in Katamba Fish (Lethrinus nebulosus) in Baliara Village Kabaena Island

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ABSTRACT

Introduction: Coastal environmental pollution is one of the biggest challenges for communities whose livelihoods depend heavily on marine resources. Kabaena Island, particularly Baliara Village, faces increasing pollution pressure due to nickel mining activities, unmanaged domestic waste disposal, and intensive fishing vessel operations. This study aimed to analyze the relationship between environmental pollution factors and heavy metal levels in Katamba fish (Lethrinus nebulosus).

Method: This research employed a quantitative analytic approach with a cross-sectional design. A total of 97 respondents were selected using purposive sampling. Data were collected through structured questionnaires as well as fish and seawater samples, which were analyzed in the laboratory using Atomic Absorption Spectrophotometry (AAS) and ICP-OES. Data analysis was conducted using Spearman correlation to examine the association between environmental pollution activities.

Result: The results showed that heavy metal concentrations in Katamba fish mostly exceeded the safe consumption limits set by WHO and Government Regulation No. 22/2021. Mining activities were significantly associated with Ni levels ($r = –0.200$) and seawater pollution ($\rho = 0.438$). Domestic waste exhibited a significant correlation with Pb levels in fish ($r = 0.669$), while fishing vessel activities were associated with Cd levels ($r = 0.317$). These findings highlight the substantial contribution of human activities to increasing heavy metal pollution in coastal areas.

Conclusion: There is a relationship between environmental pollutants such as mining activities, domestic waste and fishing boat activities with heavy metal levels such as Hg, Ni, Pb and Cd in seawater and catamba fish.

Introduction

Indonesia's coastal areas are ecosystems of high ecological and economic value. More than 60% of Indonesia's population lives in coastal zones, with most depending on marine resources, particularly capture fisheries, for their livelihoods. Fish not only serves as the primary protein source but is also integral to local cultural and economic identity.[1]

However, in recent decades, coastal ecosystems have been facing serious threats from human activities.[2] Expanding nickel mining operations on Kabaena Island, Bombana Regency, have significantly altered the landscape and exerted ecological pressure on marine areas. According to Bombana Statistics Bureau 2023 more than 70% of Kabaena's land area is under mining concessions. This situation poses risks of seawater pollution through erosion, runoff, and the discharge of mine waste rich in heavy metals.[3]

In addition to mining activities, pollution is also exacerbated by domestic and industrial waste discharged directly into the environment without prior treatment.[4] This type of waste often contains detergents, heavy metals, and other hazardous chemicals that flow into the ocean through drains, sewers, and rivers.[5]

Soil particles carried by rainwater often contain heavy metals from human activities and enter water bodies.[6] These metal-laden sediments are then carried to coastal waters, contaminating marine ecosystems and potentially entering the food chain.[7]

Nickel mining activities on Kabaena Island have a significant impact on environmental quality. One of the most obvious consequences is marine pollution caused by the discharge of mining waste, both in solid and liquid forms.[8] These wastes contain heavy metals such as mercury (Hg), cadmium (Cd), lead (Pb), and nickel (Ni), which are highly toxic and can accumulate in the bodies of marine organisms, including fish that serve as the main source of food for local communities.[9]

Apart from mining, environmental pollution is exacerbated by domestic household waste and fishing vessel activities.[10] Household waste often contains detergents, organic materials, and heavy metals from batteries and electronic products, which eventually flow into the sea untreated. Meanwhile, fishing vessels contribute through the use of anti-corrosion paints, lubricants, and fuel leakage.[11]

Katamba fish (Lethrinus nebulosus) is one of the main fish species consumed by Baliara villagers. The high consumption of this species, combined with the potential for heavy metal bioaccumulation, raises serious concerns about community health risks. The World Health Organization emphasizes that chronic exposure to heavy metals such as mercury (Hg), lead (Pb), cadmium (Cd), and nickel (Ni) can cause neurological, renal, and reproductive disorders, and may even becarcinogenic.[12]

Data from the Bombana Health Office indicates that in coastal areas such as Baliara Village, there has been an increase in cases of skin diseases, digestive system disorders, and symptoms associated with heavy metal poisoning. This highlights a serious threat to public health, particularly for communities that rely on fish as their primary food source.[13]

A study conducted by Mokoginta in a nickel mining area in Southeast Sulawesi showed that mining waste containing nickel (Ni), cadmium (Cd).[14] Mercury (Hg) can contaminate seawater through surface runoff and seepage into water bodies, and cause increased heavy metal levels in surrounding marine biota.[15]

Another study by Suhendar confirmed that open-pit mining activities in coastal areas directly impact sediment and seawater quality, increasing the risk of heavy metal bioaccumulation in fish.[16] Fish studied in the waters surrounding the mining area showed mercury and cadmium levels exceeding the safe thresholds for human consumption according to WHO and FAO standards.[17]

Based on these conditions, it is important to conduct a comprehensive study on the environmental pollution factors that contribute to the increasing levels of heavy metals in fish consumed by coastal communities. This research is expected to serve as a foundation for developing pollution control strategies as well as promotive and preventive efforts to safeguard public health in Kabaena Island, particularly in Baliara Village

Method

This study applied a quantitative analytic approach, with a cross-sectional design.[18]The

research was conducted in Baliara Village, West Kabaena District, Bombana Regency, Southeast Sulawesi, in 2025. The study population consisted of all residents of Baliara Village who consumed Katamba fish. A total of 97 respondentswere selected using purposive sampling, based on criteria of direct involvement in consuming locally caught fish.

Research variables, Independent variables: mining activities, domestic waste, fishing vessel activities. Intermediate variable: seawater pollution. Dependent variable: heavy metal content (Hg, Cd, Pb, Ni) in Katamba fish.

Research instruments using a structured questionnaire was used to assess the intensity of environmental pollution activities. The questionnaire contained 18 questions (6 related to mining, 6 to domestic waste, and 6 to fishing vessels). The scoring applied a simple Likert scale, where responses of "Yes" scored 3, "No" scored 2, and "Don't know" scored 1. The total score represented the intensity of pollution activity for each respondent.

Laboratory Analysis was carried out on seawater and Katamba fish samples collected from coastal points near settlements and fishing activities. Seawater was tested using ICP-OES to detect heavy metal levels, while Katamba fish samples were tested using Atomic Absorption Spectrophotometry (AAS).

Result

The majority of respondents were male (62.8%), aged 25–45 years (58.7%). In terms of occupation, most were fishermen (41.2%), followed by mining workers (28.9%), and others (29.9%). Regarding education level, the majority had secondary education (junior or senior high school).

Table 1 shows that Nickel (Ni) had the highest concentration across all points, particularly at point 2 (1.510 mg/L), followed by point 1 (1.361 mg/L), and the lowest at point 3 (0.677 mg/L). Lead (Pb) also showed relatively high concentrations at points 1 and 2 (0.601 and 0.614 mg/L, respectively), while point 3 had much lower concentrations (0.008 mg/L). Cadmium (Cd) was present in low amounts, with the highest level at point 2 (0.005 mg/L). Mercury (Hg) levels were very low and relatively stable, ranging between 0.001 and 0.002 mg/L.

Table 2 shows that all Katamba fish samples contained cadmium exceeding the safe limit of 0.1 mg/kg (WHO/BPOM). The highest Cd concentration was found in sample 1 (0.490 mg/kg), while the lowest was in sample 3 (0.230 mg/kg). Lead concentration also exceeded the permissible limit (0.3 mg/kg) in all samples, with the highest level in sample 3 (0.763 mg/kg). Nickel was found at levels much higher than the permissible limit (0.5 mg/kg), with the highest concentration in sample 1 (1,103 mg/kg). Mercury levels remain well below the safe limit of 0.5 mg/kg.

Spearman Correlation Results shows:

1. Cadmium (Cd): Mining activity showed a very strong positive correlation with Cd in fish (r = +1.00), but only a weak positive correlation with Cd in seawater (r = +0.125). Domestic waste showed a moderate positive correlation with Cd in fish (r = +0.5), but a strong negative correlation with Cd in seawater (r = –0.625). Fishing vessels showed a moderate negative correlation with Cd in fish (r = –0.5) and a strong negative correlation with Cd in seawater (r = –0.625).
2. Lead (Pb): Mining activity showed a moderate negative correlation with Pb in fish (r = –0.5), but a moderate positive correlation in seawater (r = +0.5). Domestic waste showed a moderate positive correlation with Pb in fish (r = +0.5) but a moderate negative correlation in seawater (r = –0.5). Fishing vessel activity showed a very strong positive correlation with Pb in fish (r = +1.00), but a very strong negative correlation in seawater (r = –1.00).
3. Nickel (Ni): Mining activity showed a very strong positive correlation with Ni in fish (r = +1.00) and a moderate positive correlation in seawater (r = +0.5). Domestic waste showed a positive correlation in fish (r = +0.5) but a negative one in seawater (r = –0.5). Fishing vessel activity showed negative correlations for both fish (r = –0.5) and seawater (r = –1.00).
4. Mercury (Hg): Mercury levels were low in both fish and seawater, still below safety thresholds. However, Spearman correlation showed that fishing vessel activity had a very strong positive correlation with Hg levels (r = +0.875),

mining activity had a strong negative correlation (r = –0.625), and domestic waste had a very weak positive correlation (r = +0.125).

The data are normally distributed, so the mean value is used to calculate intake and RQ. Meanwhile, the CoV value for body weight (Wb) is <30%, indicating that the data are normally distributed, so the mean value is used to calculate intake and RQ. Based on the results of the risk level calculations, it shows that the RQ value of the heavy metal Nickel (Ni) > 1. So it can be said that at present and in the next 30 years, the population of people who consume Katamba Fish (Lethrinus nebulosus) in the waters around the coast of Baliara Village, Kabaena Islands is still categorized as unsafe and at risk of the effects of the heavy metal content of Nickel (Ni) in Katamba Fish (Lethrinus nebulosus).

Table 1.
Laboratory Results of Heavy Metal Concentrations in Seawater

Sampling Point	Parameter	Unit	Result (mg/L)	Quality Standard
Point 1	Pb	mg/L	0.601	0.03
	CD	mg/L	0.003	0.01
	This	mg/L	1,361	0.05
	Hg	mg/L	0.001	0.05
Point 2	Pb	mg/L	0.614	0.03
	CD	mg/L	0.005	0.01
	This	mg/L	1,510	0.05
	Hg	mg/L	0.001	0.05
Point 3	Pb	mg/L	0.008	0.03
	CD	mg/L	0.003	0.01
	This	mg/L	0.677	0.05
	Hg	mg/L	0.002	0.05

Table 2.
Laboratory Results of Heavy Metal Concentrations in Katamba Fish

Sample	Metal	Result	Unit	Quality Standard
Sample I	CD	0.490	mg/kg	0.1
	Pb	0.521	mg/kg	0.3
	This	1.103	mg/kg	0.5
	Hg	0.001	mg/kg	0.5
Sample II	CD	0.307	mg/kg	0.1
	Pb	0.513	mg/kg	0.3
	This	1,056	mg/kg	0.5
	Hg	0.001	mg/kg	0.5
Sample III	CD	0.230	mg/kg	0.1
	Pb	0.763	mg/kg	0.3
	This	0.764	mg/kg	0.5
	Hg	0.001	mg/kg	0.5

Discussion

The findings indicate significant accumulation of heavy metals in both seawater and Katamba fish, which may pose health risks to the local coastal community.[19] This study was conducted to analyze environmental pollution factors related to heavy metal content (Pb, Cd, Ni, and Hg) in Katamba fish (Lethrinus nebulosus) in Baliara Village, and to examine the relationship between human activities (mining, domestic waste, and fishing vessels) and this pollution.

Based on laboratory analysis of three seawater samples and three Katamba fish (Lethrinus nebulosus) samples, four types of heavy metals were measured: Lead (Pb), Cadmium (Cd), Nickel (Ni), and Mercury (Hg). These results were then compared with quality standards established by Decree of the Minister of Environment No. 51 of 2004, SNI, WHO, and BPOM RI to determine the level of pollution in the study area.[20]

In seawater, the heavy metal that most frequently exceeds the quality standard is Nickel (Ni), which was detected above the threshold at all sampling points (3 out of 3 points).[21] This indicates that the coastal waters of Baliara Village have experienced significant nickel pollution, most likely originating from intensive mining activities in the surrounding area. Furthermore, Lead (Pb) was also found to exceed the quality standard at two points (points 1 and 2), while Mercury (Hg) did not exceed the threshold. Cadmium (Cd) did not show any threshold exceedance at all points, although it was still detected in low concentrations.

Meanwhile, in Katamba fish, the three main heavy metals (Pb, Cd, and Ni) were detected above the threshold set by WHO/BPOM RI in all fish samples (3 out of 3 samples). This indicates that all fish tested were significantly contaminated. The highest concentration of Cadmium (Cd) was recorded at 0.490 mg/kg, or almost five times the maximum threshold (0.1 mg/kg). The highest content of Lead (Pb) reached 0.763 mg/kg, more than twice the safe limit (0.3 mg/kg), while Nickel (Ni), which does not have strict global regulations but has a reference threshold value of 0.5 mg/kg, was also detected far above that limit (up to 1.103 mg/kg). In contrast, Mercury (Hg) remained within the safe range in all samples (0.001 mg/kg), far below the 0.5 mg/kg quality standard.

Overall, the frequency distribution of heavy metal contamination shows that Nickel (Ni) and Lead (Pb) are the dominant contaminants both in sea water and in the bodies of fish for consumption.[22] The results of this analysis further confirm that most heavy metal parameters in seawater and fish have exceeded established thresholds and show variation between locations. Nickel and lead, the primary indicators of severe pollution, specifically exhibited a wide range of values and high concentrations in both the aquatic environment and the catfish consumed by the public.

Heavy Metal Pollution in Seawater

Nickel (Ni) was the most dominant pollutant, with concentrations up to 30 times the quality standard (1,510 mg/L at point 2, compared to 0.05 mg/L). This strongly suggests that mining activities, particularly lateritic nickel mining, are the primary source of contamination. Lead (Pb) also exceeds safe limits, likely originating from mining residues, vessel activities, and Pb-containing paints. Cadmium (Cd) was detected at low levels but still poses potential bioaccumulation risks. Mercury (Hg) was within safe levels but indicates localized contamination.

Heavy Metals in Katamba Fish

Cadmium, lead, and nickel were consistently above safe limits in all samples, highlighting chronic contamination. The highest recorded values were Cd at 0.490 mg/kg, Pb at 0.763 mg/kg, and Ni at 1.103 mg/kg. Although mercury levels were safe, the combined effects of multiple heavy metals pose serious health concerns, including neurological, renal, reproductive disorders, and carcinogenic risks. These results are consistent with findings from other mining-affected coastal regions such as Morowali and Kendari.

Conclusion

The study concludes that: mining activities are significantly associated with heavy metal concentrations in Katamba fish. Mining activities are also linked to seawater contamination. Domestic waste is associated with heavy metal levels in Katamba fish. Domestic waste also contributes to seawater pollution. Fishing vessel

activities are associated with certain heavy metal levels in Katamba fish. Fishing vessel activities also contribute to seawater contamination. Suggestion for government to Strengthen mining regulations, develop domestic waste treatment facilities, and enhance monitoring of marine water quality. For Communities to increase awareness of the risks of consuming contaminated fish and participate actively in maintaining coastal cleanliness.

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