Analysis of Lead (Pb) Levels in Consumption Fish on the Pentadu Coast East of Gorontalo Province

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ABSTRACT
Fish are considered bioindicators of the presence of heavy metals in water; because of their ability to accumulate heavy metals from the environment, consuming contaminated fish can potentially increase lead levels in the human body. The purpose of this study was to analyze the lead (Pb) levels in fish for consumption on the East Pentadu Coast, Gorontalo Province, and to evaluate whether these levels were within the maximum limits according to the applicable quality standards. This study was conducted at three locations: the boat dock, the mangrove area, and the auction site. The method used in this study was a quantitative descriptive method, utilising an Atomic Absorption Spectrophotometer (AAS) and employing a purposive sampling technique. The population in this study included fish for consumption on the East Pentadu Coast, the muscles of which were collected at all three locations. The results showed that the highest lead levels in *Cetoscarus ocellatus* fish were 0.0003 mg/kg, far below the maximum limit of SNI 7387:2009, which is 0.3 mg/kg. Therefore, consumption of fish from the East Pentadu Coast is still considered safe, although the cumulative Pb properties still require vigilance.

Keyword: Consumption Fish, East Pentadu Coast, Gorontalo, Heavy Metals, Lead (Pb)

1. INTRODUCTION

Indonesia, as the world's largest archipelagic country, has the second-longest coastline at 81,000 km. This makes its narrow but resource-rich coastal areas highly vulnerable to damage if not managed sustainably (Donesia *et al.*, 2023). Increased socio-economic activity and waste disposal from industry, settlements, and agriculture have led to marine pollution, which degrades the physical, chemical, and biological quality of waters and disrupts ecosystem balance (Umasugi and Ismail, 2021). One of the main pollutants is heavy metals, which are toxic, persistent, and have the potential to accumulate in marine biota (Hasan *et al.*, 2019).

Heavy metal pollution is a global problem because these metals are long-lasting and generally have toxic effects on living organisms if their concentrations exceed certain limits. Excessive amounts of pollutants in aquatic environments can disrupt the ecological balance and alter the physical and chemical properties of water for the biota living within (Nurhidayati *et al.*, 2021).

One heavy metal frequently found in ecosystems is lead (Pb). Heavy metals such as lead are often found in the environment along with other heavy metals (Afifudin *et al.*, 2024).

These heavy metals are inherently toxic and difficult to break down in water, potentially causing pollution. Heavy metal contamination in organisms can damage organs such as the liver and gills, and can potentially lead to fish death. (Afifudin *et al.*, 2024). Lead (Pb) in the environment can be absorbed by aquatic plants and accumulate in the snails that consume them. Heavy metals that enter aquatic ecosystems are most concentrated and can accumulate in sediments, then move to aquatic organisms through the food chain (Khairuddin. and Yamin, 2025).

The higher the concentration of heavy metals in a body of water, the higher the accumulation of heavy metals in the bodies of organisms living in those waters (Kusumastuti *et al.*, 2020). One marine organism that has a high level of vulnerability to pollution is fish, given its bioaccumulative nature towards pollutants in the aquatic environment. Fish is a source of animal protein from the aquatic environment that is rich in protein, fat, vitamins, minerals, and omega-3 fatty acids, which are high in levels compared to terrestrial animal and plant sources and are easily digested by the body. Fish muscle is the main organ that attracts attention in this context because it is edible and consumed by humans (Latif *et al.*, 2024).

Although fish serve as an economical and readily accessible source of animal protein, their bioaccumulative nature towards pollutants makes them potentially one of the organisms that can accumulate heavy metals from the aquatic environment. Pollutants in water are absorbed by phytoplankton, then accumulated and magnified through the food chain from zooplankton to planktivorous fish, carnivorous fish, and longer-lived predatory fish (Kusumastuti *et al.*, 2020). Fish muscle is the main part that is edible for humans. Fish are considered indicators of heavy metal presence in water bodies. Heavy metals can enter a fish’s body through the gills, skin, and digestive system. Due to their ability to accumulate heavy metals from the environment, consuming contaminated fish also has the potential to increase lead levels in the human body (Latif *et al.*, 2024). This is supported by research conducted by (Kusumastuti *et al.*, 2020), which found that consuming contaminated marine fish (≥4 times/week) carries a 2.1 times higher risk of elevated blood lead levels compared to those who rarely consume marine fish (< 4 times/week). According to SNI 7387:2009, the maximum limit for metal contamination in fish and fish products is 0.3 mg/kg.

Understanding how heavy metals move through the food chain is fundamental to evaluating pollution levels in the study area. Therefore, this study is directed at the East Pentadu Coast with an area of 51,889 hectares or approximately 12.07% of the total area of the study site, which includes three research locations: boat docks, around mangroves, and auctions, reflecting water conditions that have a high possibility of pollution. Given these geographical conditions, the economic potential of Pentadu Timur Village lies in the fields of agriculture and fisheries. In addition to its natural resources, the village also possesses other significant potential, such as the coastal area of Pentadu Timur Village, which remains well-preserved to this day (Hatu *et al.*, 2023). This study is novel because it examines the levels of the heavy metal lead (Pb) in fish consumed by the local community along the East Pentadu Coast, an area affected by various anthropogenic activities such as boat moorings, ship painting, fish auctions, agricultural activities, and the presence of hazardous waste. To date, information regarding lead (Pb) levels in edible fish in the region remains limited; therefore, the results of this study are expected to serve as preliminary data for assessing fish safety in accordance with SNI 7387:2009, as well as to support coastal environmental management and public health protection. Taking into account the area’s size, environmental characteristics, and limited data on lead (Pb) contamination in edible fish along the East Pentadu Coast, this study focused on locations representative of various pollution sources as a novel approach to the research. This research is expected to provide initial data on lead levels in fish on the East Pentadu Coast, increase public awareness of lead pollution, and serve as a reference for the government in food safety policies and water quality monitoring.

2. RESEARCH METHOD

This study was conducted from March to June 2026 in the East Pentadu coastal area, Timaluta Subdistrict, Boalemo Regency, Gorontalo. The inclusion criteria for the sample were that the fish be fresh, fit for consumption, and obtained directly from the East Pentadu coast, while the exclusion criteria included farmed fish, preserved or rotten fish, and fish that were physically damaged or difficult to identify.

This study covered three sampling sites, with an equal number of samples collected at each site. Point III is located at the fish auction site, which was selected because it is an area with high levels of human and fishing activity, making it a potential major source of pollution. At each point, five fish were collected as research samples. The limitation of this study lies in the relatively small sample size five fish at each sampling site meaning that the results do not yet fully represent lead (Pb) levels throughout the entire East Pentadu coastal area. Therefore, further research with a larger sample size and broader geographic coverage is needed to obtain more representative results.

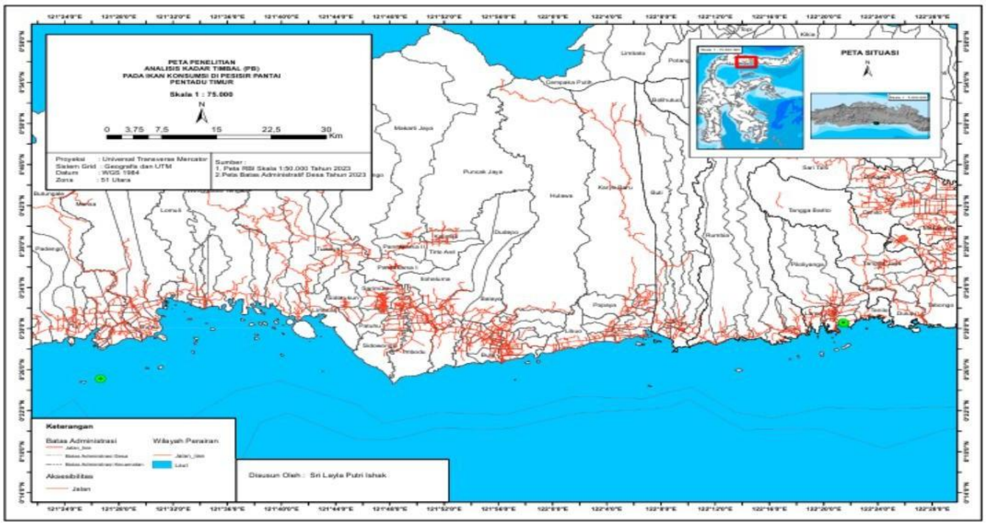

Figure 1. Map of Fish Sampling Locations

The tools used in this study were AAS (Atomic Absorption Spectroscopy), Microwave Digestion System, glass vials, GPS (Global Positioning System), nets, measuring flasks, beakers, micropipettes, volumetric pipettes, suction cups, electric heaters, scales, vessel bottles, millimeter blocks, and petri dishes and Whatman 41 paper. The materials used were fish muscle, aluminum foil, hydrochloric acid (HCl), nitric acid (HNO_3), distilled water, blanks, and standard solutions.

Data collection techniques: first, conducting initial observations to determine the sampling points, namely point I at the boat dock, point II in the mangrove forest area, and point III at the auction. Taking fish samples using fishing hooks at each location, which are then placed in a coolbox to maintain their freshness. Second, sample testing where the fish samples are weighed for their wet weight and rinsed, then the fish muscle is dried. In a 70°C oven for 24 hours. A 1 g sample was digested using 3-8 ml HNO_3 and 0.5-1 ml HCl, then filtered into a 50 ml volumetric flask using Whatman 41 paper.

Third, to make a blank solution, a 500 ml measuring flask is filled with distilled water until almost full, 750 μL of HNO_3 is added, then the volume is adjusted with distilled water until it reaches the threshold of the measuring flask. Third, the standard solution of 50 ppb Pb is made by diluting 1 ppm using the formula V1 x M1 = V2 x M2

$$V1 = \frac{100 \text{ ml x } 1 \text{ mg/l}}{1000 \text{ mg/l}} = 0{,}1\ ml$$

A total of 0.1 ml was pipetted into a 100 ml flask and diluted with blank to 1 ppm, then diluted back to 50 ppb using the same formula

$$V1\ x\ 1000\ \mu g/l = \frac{50\ \text{ml x } 50\ \mu g/l}{1000\ \mu g/l} = 2{,}5\ ml$$

A total of 2.5 ml was pipetted into a 50 ml flask and diluted using a blank solution to become a standard solution of 50 ppb Pb. The four lead level measurements used AAS with a wavelength of 217 type AA240FSS (SNI 06-69923-2004), AAS analysis began by installing a Pb cathode lamp, heating it for 10 minutes, then lighting the flame with acetylene and zeroing the reading. The standard and blank solutions were measured sequentially, and the results were calculated to determine the Pb concentration. Preparations included opening the gas flow, installing the cathode lamp, monitoring the response of the instrument via computer, setting the software with sample, blank, and standard data, and turning on the burner and setting the gas pressure to 1.8 so that the instrument could detect Pb with a detection limit of 0.01 ppm using acetylene or argon.

3. RESULTS AND ANALYSIS

The measurement results using the AAS tool showed different lead levels in each sample presented in Figure 2.

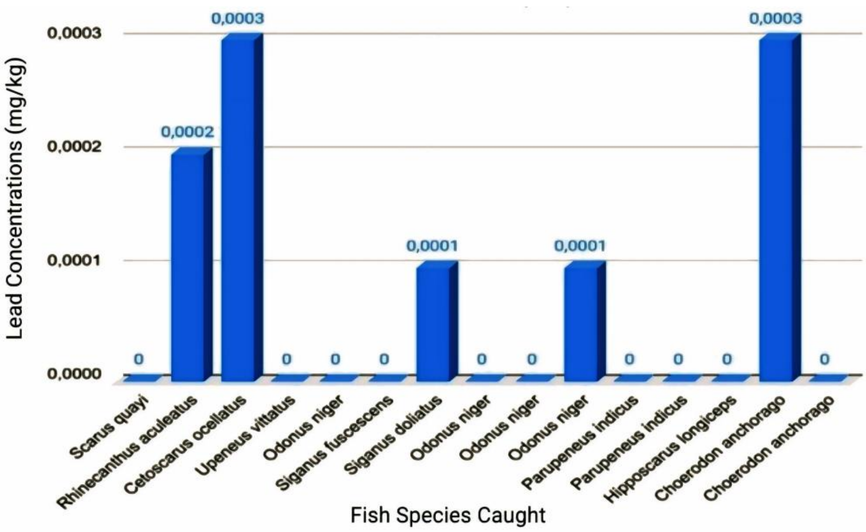

Figure 2. Results of measuring Lead Levels in Fish for Consumption

The measurement results showed that lead levels in fish varied between points. This study found a relatively small Pb level, namely 0.0003 mg/kg. This amount is very small and far below the intake threshold set by WHO, so that consumption of fish from the East Pentadu Coast is still considered safe for human health. This figure is much lower when compared to the findings (Rahmadani *et al.*, 2015) in Mamboro waters, North Palu, which recorded Pb pollution ranging from 0.35 to 0.433 mg/l. This striking difference demonstrates that the eastern Pentadu coastline has not faced the severe pressures of heavy metal pollution as other coastal areas. The differences and low lead levels between species and sampling points are thought to be influenced by environmental factors, public awareness, the trophic level of each fish, and oceanographic dynamics.

Environmental factors, where data collection was conducted at three sampling points: the boat dock, the mangrove forest area, and the auction. (Table 2) displays the results of factor measurements at the three sampling locations.

Table 2. Environmental Factors

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Pickup Point	Water pH	Tempperature	TDS (mg/l)	Wind Velocity (m/s)	Light Intensity (cd)
Point I	7.28	31.0	18.9	0.7	6874
Point II	7.12	29.8	19.3	1.0	8404
Point III	7.13	29.8	19.2	0.9	8237

At Point I, the Perahu Bridge is located at coordinates N 00°25'07.2, E 121°26'39.6. At this point, the water has a pH of 7.28, a temperature of 31.0°C, a wind speed of 0.7 m/s (measured with an anemometer), a light intensity of 6,874 cd (measured with a lux meter), and a Total Dissolved Solids (TDS) level of 18.9 mg/l. This location was formerly a mangrove tourism area but is now used for anthropogenic activities such as the mooring of fishermen's boats and painting activities.

Point II of the Mangrove Area is located at coordinates N 00°30'31.1, E 122°21'29.2. At this point, the water pH is 7.12, the temperature is 29.8°C, the wind speed measured by an anemometer is 1.0 m/s, the light intensity measured by a lux meter is 8,404 cd, and the Total Dissolved Solids (TDS) is 19.3 mg/l. This location is a mangrove forest area that remains well-preserved but is not infrequently used by small-scale fishermen to catch fish.

Point III (Auction Site) is located at coordinates N 00°30'34.9, E 122°21'26.0. At this point, the water pH is 7.13, the temperature is 29.8°C, the wind speed measured by an anemometer is 0.7 m/s, the light intensity measured by a lux meter is 8,237 cd, and the Total Dissolved Solids (TDS) is 19.2 mg/L. This location is an area where fishermen deliver their catch, which is then distributed to the community at large. At all three points, the water pH has reached a value of 7, which may be the primary reason why the lead content in the fish has.

One key factor is water pH, which plays a role in influencing the levels of lead accumulated in fish flesh. According to the study results, the water pH was alkaline, at a value of 7. This is consistent with research conducted by (Choiri *et al.*, 2025), which found that alkaline pH conditions rich in hydroxide ions (OH-) cause lead ions (Pb^{2+}) to bind with these ions and form new compounds such as lead hydroxide ($Pb(OH)_2$), lead phosphate and other water-insoluble solid compounds can form through precipitation. The formation of these solid precipitates is thought to contribute to a reduction in lead mobility, making it potentially more difficult for the metal to spread and be absorbed by living organisms. Thus, this process may help reduce the risk of lead exposure to the environment and living organisms.

In addition, the relatively high light intensity may potentially support optimal phytoplankton photosynthesis, thereby contributing to an increase in water pH, which ultimately reduces Pb mobility through the precipitation process. Based on the results obtained at the study sites, all three points exhibited relatively high light intensity: 6,874 cd at Point I, 8,404 cd at Point II, and 8,237 cd at Point III. These findings align with those of (Cheloni and Slaveykova, 2018), who noted that various environmental conditions, including light intensity, play a role in regulating the chemical form of metals and their availability, while also influencing the physiological conditions of microorganisms, which ultimately determine the rate of metal uptake.

Metals can enter and accumulate in fish through three main pathways: consumption of contaminated food (such as algae), the respiratory system or gills, and direct absorption through the skin (Priatna *et al.*, 2016). The lead levels found in fish muscle samples, which showed relatively low results, certainly cannot be taken lightly; this can be attributed to the nature of the heavy metal lead. According to (Anggraeni and Triajie, 2021), lead is a metal that is difficult to break down, making it prone to accumulating in aquatic environments; its natural presence is difficult to decompose and is easily absorbed.

Based on an analysis of lead (Pb) levels in fish meat, it was found that Pb levels in all samples were well below the quality standard, which is set at 0.3 mg/kg. The detected Pb concentrations ranged from 0 to 0.0003 mg/kg. The highest levels were recorded in samples of *Cetoscarus ocellatus* at Point 1 and *Choerodon anchorago* at Point 3, each reaching 0.0003 mg/kg. Although the concentrations were very low, the presence of Pb in some samples indicates exposure to heavy metals in the aquatic environment. This aligns with the fact that heavy metals tend to be persistent, difficult to degrade, and can enter fish bodies through water, food, gills, or contact with contaminated sediments. Research on heavy metal bioaccumulation in fish by (Fitriani *et al.*, 2025) shows that fish can serve as biological indicators of pollution due to their ability to accumulate heavy metals in body tissues, including muscle or flesh consumed by humans.

At Point 1, which is an area where boats dock, five fish species were found: *Scarus quoyi*, *Rhinecanthus aculeatus*, *Cetoscarus ocellatus*, *Upeneus vittatus*, and *Odonus niger*. Among these five samples, Pb levels were measured at 0.0002 mg/kg in Rhinecanthus aculeatus and 0.0003 mg/kg in *Cetoscarus ocellatus*, while the other three samples showed no detectable levels. Overall, Point 1 recorded a total detected Pb accumulation of 0.0005 mg/kg, which is higher than that at Point 2 and Point 3. This can be attributed to the nature of Point 1 as a mooring area that may receive contaminants from boat activities, such as fuel residues, oil, lubricants, ship paint, boat repair activities, and sediment disturbance caused by boat movement.

At Point 2, a mangrove forest area, the fish species *Siganus fuscescens*, *Siganus doliatus*, and *Odonus niger* were found. Lead (Pb) was detected only in *Siganus doliatus* at a concentration of 0.0001 mg/kg and in one sample of *Odonus niger* at 0.0001 mg/kg; no lead was detected in the other samples. The total Pb concentration at this location is 0.0002 mg/kg, making it the site with the lowest Pb accumulation compared to Point 1 and Point 3. The low Pb concentration in the mangrove area can be attributed to the ecological role of mangroves as natural filters and sediment traps. Mangrove roots can slow water flow, trap dissolved particles, and accumulate heavy metals in the roots and sediments. Research on the mangrove species Avicennia marina by (Retnosari *et al.*, 2024) indicates that mangrove ecosystems have the capacity to accumulate heavy metals such as Pb, Cu, and Zn in their roots, water, and sediments. This study was published in the Journal of Marine and Coastal Science, which is Sinta 4-accredited.

The presence of mangroves at Point 2 can serve as a protective zone against pollution originating from land or coastal activities. However, this role does not mean that the mangrove area is immune to pollution. Heavy metals entering the mangrove area can become trapped and accumulate in the sediment layer. Several studies indicate that mangrove ecosystems often function as heavy metal retention zones due to their ability to capture sediments from both terrestrial and marine sources, allowing heavy metals to accumulate in the sediments over extended periods. (Baderan, D. W. K., 2017) Mangrove forests have several important functions, including chemical and biological functions. The chemical function involves absorbing CO_2, processing waste materials, and absorbing pollutants, heavy metals, and toxic chemicals from seawater. The biological function serves as a nursery area, a spawning ground, and a source of genetic resources. Thus, the low levels of Pb in fish flesh at Point 2 may be due to minimal direct exposure to the flesh tissue; however, the potential for heavy metal accumulation in mangrove sediments still warrants vigilance.

Fish are highly mobile, so their exposure to heavy metals can be influenced by the areas they explore, the types of food they consume, their habitat, the duration of exposure, their age, body size, and lifestyle. Therefore, to strengthen the analysis, further research could include measuring Pb levels in water, sediments, and other fish organs, such as gills or livers. Based on (Haryanti and Martuti, 2020) study, it was shown that heavy metal concentrations can vary between body tissues and between species; therefore, analyzing only fish flesh is insufficient to fully understand the bioaccumulation process in aquatic environments. Consequently, it can be concluded that the presence of Pb in some fish samples is likely related to human activities around the study site.

At Point 3, the fish auction area, Pb was detected only in *Choerodon anchorago* at a concentration of 0.0003 mg/kg across 5 samples, with a total Pb concentration of 0.0003 mg/kg. Lead (Pb) concentration is expressed in mg/kg wet weight based on laboratory analysis results and in accordance with applicable quality standards. High levels of human activity at the fish market (TPI), such as loading and unloading, fuel use, and market waste, have the potential to increase pollution. Variations in Pb levels between points are influenced by environmental characteristics and human activities: Point 1 (boat mooring) had the highest total Pb, Point 2 (mangrove) had the lowest due to its filtering function, and Point 3 (TPI) showed the presence of Pb related to fishing activities. Although all samples were well below the SNI 7387:2009 quality standard of 0.3 mg/kg, Pb levels in flesh do not fully reflect contamination levels, as the metal accumulates more in sediments, gills, or livers, and is influenced by fish mobility and life patterns. Therefore, periodic monitoring and further analysis of water, sediments, and fish organs are required to assess the risk of long-term Pb accumulation.

4. CONCLUSION

The analysis results showed that the highest lead content in *Cetoscarus ocellatus* fish was 0.0003 mg/kg, far below the minimum limit of SNI 7387:2009, which is 0.1 mg/kg, so that consumption of fish from the East Pentadu coast is still considered safe even though the cumulative Pb nature still requires caution. The low Pb content is thought to be influenced by the alkaline water conditions of pH 7 which trigger Pb precipitation and high light intensity which supports an increase in pH, while the source of pollution comes from fishing activities such as boat painting and waste shipments from land through rivers which are affected by currents and wind seasons. Increased public awareness has produced positive results, but efforts to control marine pollution still need to be carried out in an integrated regional manner

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