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LEAD CONTAMINATION IN PANGASIUS DJAMBAL IN THE DAM OF KALITIDU DISTRICT, BOJONEGORO DISTRICT: AN ENVIRONMENTAL HEALTH RISK STUDY

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Abstract

Introduction: *One of the areas passed by the Bengawan Solo River is Bojonegoro. Many Bojonegoro people find fish at the point of Bendung Gerak, Ngringinrejo Village. One of the fish that is often caught is Pangasius djambal. At this location, the dominant waste contamination comes from agricultural and domestic waste. Lead can contaminate water and enter through the food chain in fish which are later eaten by humans. The purpose of this study was to analyze the environmental health risk of lead (Pb) content in Pangasius djambal in Bendung Gerak Ngringinrejo Village, Kalitidu District, Bojonegoro Regency.* ***Methods:*** *This research used field environmental health risk analysis method. The total sampling of the community was 50 respondents and was taken using accidental sampling. Community sample criteria are those who consume Pangasius djambal within 1 year. Environmental samples are Pangasius djambal taken at 3 points and analyzed using the Atomic Absorption Spectrophotometry (AAS) method.* ***Results and Discussion:*** *The results showed lead intakes at points A, B, and C were 0.0018 mg/kg/day, 0.0639 mg/kg/day, and 0.0012 mg/kg.day, respectively. The results show the RQ value of point B RQ>1 (unsafe), while points A and C are RQ≤1 (safe). It can be caused by several factors such as body weight, intake rate, consumption frequency, exposure duration, and lead concentration.* ***Conclusion:*** *Based on these results, it is necessary to do risk management at point B.*

INTRODUCTION

The Bengawan Solo River is the longest river in Java with a length of 548 kilometers (1). This river passes through the provinces of Central Java and East Java through 20 regencies and three cities. One of the districts passed by the Bengawan Solo River is Bojonegoro Regency. The people of Bojonegoro utilize the Bengawan Solo River for their daily needs, agriculture, industry, transportation, and irrigation (2). In one of the areas in the Bengawan Solo River in Bojonegoro, there is a weir that was built to provide benefits to the environment and society.

The dam, known as Bendung Gerak, is located in Bojonegoro which separates Ngringinrejo Village from Trucuk Village. This weir has functions as a flood control, irrigation, raw water provider for industry, households, agriculture, and a tourism area (3). Bendung Gerak is a favorite and popular place for anglers in Bojonegoro (4). The results of interviews conducted with the Head of Ngringinrejo Village, Kalitidu Subdistrict, Bojonegoro Regency stated that many Ngringinrejo villagers and outsiders were looking for fish in Bendung Gerak for consumption or trade.

Fish can live as bioindicators of pollution, such as heavy metals present in waters (5). According to the Section Head of the Bojonegoro Environmental Agency, the Bengawan Solo River receives liquid waste discharges from industrial waste from upstream areas. This river waste also comes from domestic waste, the use of pesticides and fertilizers, ciu, and textiles (6). Household wastes that contain lead are lead-based paints commonly used for walls, doors, windows, and waste batteries (7).

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In agricultural activities, the use of phosphate fertilizers and pesticides is one of the contributors to lead content in water bodies (8). In addition, batik waste disposed of in rivers can contain lead (9). Bengawan Solo River based on East Java Governor Regulation No.61 of 2010 concerning Determination of Water Class in River Water, the Bojonegoro area starting from Padangan Village, Padangan District, includes second class water quality which is intended for water recreation facilities / infrastructure, freshwater fish farming, for irrigating crops, livestock, and so on. The East Java Provincial Government conducted water quality tests on the Bengawan Solo River in Bojonegoro in 2019 obtained the results of Pb contamination < 0.0547 mg/l, Cd < 0.00935 mg/l, TDS = 570 mg/l, pH 7.62, NH_4 0.0362 mg/l, Mn 1.26 mg/l, and Zn 0.0113 mg/l (7). According to second-class water quality standards, the results of Pb and Cd metal contamination are still below the quality standards, so they can still be utilized as their function. However, lead can enter the food chain in fish and, if consumed by humans, it can cause health problems (10-11).

The variety of fish in Bendung Gerak that is most commonly caught and consumed by the people of Ngringinrejo Village is Jambal *Pangasius djambal*. Based on the preliminary study, the community must consume this *Pangasius djambal* in one month. The results of the preliminary study showed lead and cadmium levels of 0.18 mg/kg and cadmium < LOQ (Limit of Qualification) 0.001 mg/kg in *Pangasius djambal* from Bendung Gerak. Another study of *Pangasius djambal* Pb levels in Saguling Reservoir averaged 0.034 mg/l (12). Other research also found Pb content in *Pangasius djambal* of 0.041 mg/l (13). Although, Pb in Bendung Gerak is still below the quality standard according to BPOM No. 9 of 2022 concerning Heavy Metal Contaminants in Processed Food (0.3 mg/kg) if consumed continuously it will accumulate in the body, thus risking poisoning, kidney disease, neurological, cardiovascular, and reproduction functions (14). The purpose of this study was to analyze the environmental health risk of lead (Pb) content in *Pangasius djambal* in Bendung Gerak Ngringinrejo Village, Kalitidu District, Bojonegoro Regency.

METHODS

Research Design

This research is a quantitative study with a cross-sectional design. Cross-sectional is used because variable data collection is only taken at one time. This type of research is descriptive observational research because the data obtained will only be described and without any intervention. This research has conducted an ethical review at KEPK FKM UNEJ with certificate number 446/KEPK/FKM-UNEJ/2/2024.

Research Location

The research was conducted in Ngringinrejo Village, Kalitidu Subdistrict, Bojonegoro Regency. Fish sampling was conducted at point B (Bendung Gerak in Ngringinrejo Village) as the main location, point A (Mojo Village) of Bengawan Solo River, and point C (Ngulanan Village) as the comparison location. Selection of location B as the main location is because at that point the majority of the people of Bojonegoro and the village itself fish there for sale or consumption. *Pangasius djambal* samples were obtained from three points, namely points A, B, and C. The map below shows the sample points for *Pangasius djambal* collection (Figure 1).

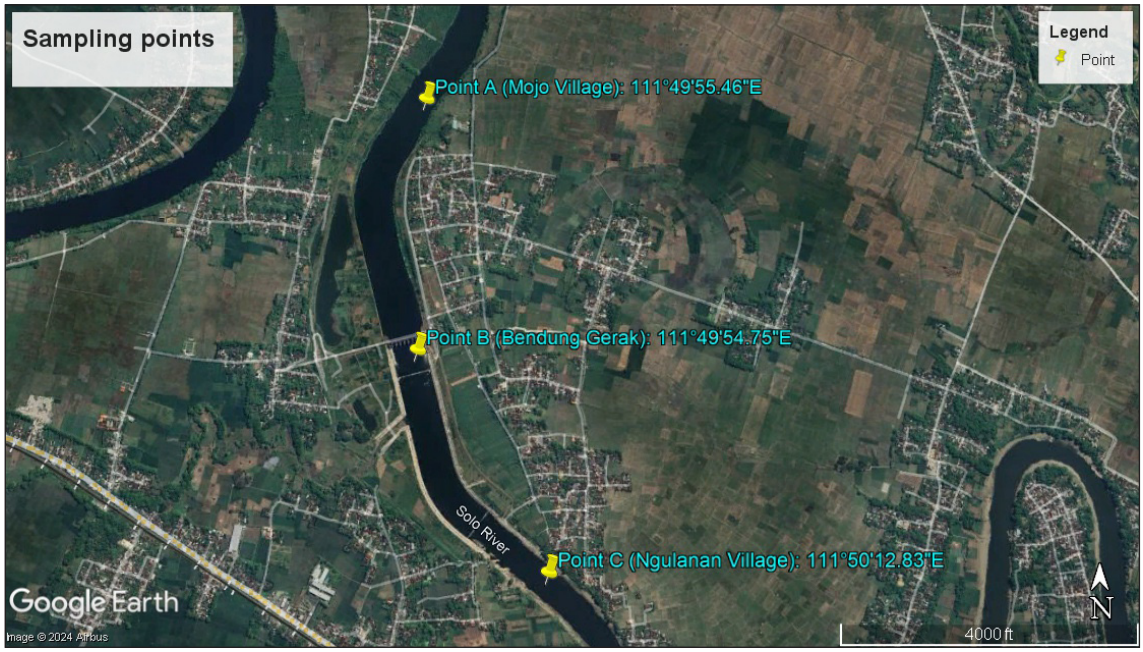

Figure 1. Sampling Point

Population and Sample

The population of *Pangasius djambal* studied came from the Bengawan Solo River flowing through points A, B, and C. In the community population, namely people in the villages of points A, B, and C in the adult category who usually consume *Pangasius djambal* from the Bengawan Solo River. Samples were taken by anglers. One fish was taken from each sample, so the total sample was three fish in community sampling using accidental sampling technique. Samples criteria were people in Ngringinrejo Village who consume *Pangasius djambal* from points A, B, and C at least within one year. Respondents are adults with male and female gender. At point A 10 samples, point B as the main point 30 samples, and point C 10 samples, so that the total sample was 50 respondents. Samples criteria are people in three villages who consume *Pangasius djambal* from points A, B, and C at least within 1 year. Respondents are adults with male and female gender.

Data Collection

Data on consumption rate, consumption frequency, exposure duration, and body weight were collected using the interview method, while lead concentration data were collected using laboratory tests. Structured interviews used questionnaires and body weight data were measured using digital scales. Consumption frequency and consumption rate data were collected using the semi-quantitative FFQ method using food pictures from the Study of Total Diet (SDT) to ask about *Pangasius djambal* consumption in the past one month. Laboratory tests were used to obtain the results of lead content in *Pangasius djambal* using the AAS (Atomic Absorption Spectrophotometry) method based on SNI 7853: 2013.

Data Analysis

The analysis used is univariate analysis and analysis with the Environmental Health Risk Assessment method. Analysis using univariate looks at the mean, median, number, percentage of respondents' answers and only wants to describe the sample data. Data on lead concentration, age, weight, frequency, and duration of exposure to *Pangasius djambal* consumption to determine intake will be analyzed in accordance with the formula that has become a calculation provision based on the calculation of Environmental health risk analysis from the Indonesian Ministry of Health.

RESULTS

Hazard Identification

An environmental health risk analysis was conducted to identify lead risk agents that could potentially cause health problems when consuming *Pangasius djambal* with lead content. Identification of lead hazards can be seen in Table 1.

Table 1. Hazard Identification

Identification	Description
Hazardous specific risk agents	Lead (Pb)
Environmental medium	*Pangasius djambal*
Specific risk agent content in the environment	Based on laboratory test results, the lead content in *Pangasius djambal* at point A was 0.005 mg/kg, point B was 0.19 mg/kg, and point C was 0.005 mg/kg.
Potential health symptoms due to the introduction of risk agents into the environment	Non-carcinogenic risk causes acute lead toxicity leading to high blood pressure, cardiovascular disease, kidney, reproductive system, brain. At carcinogenic risk, chronic damage occurs to the central and peripheral nervous system (15).

The concentration of lead in *Pangasius djambal* at all sample points is still below the quality standard. The quality standard used uses the decision of the Food and Drug Administration of the Republic of Indonesia Number 9 of 2022 concerning Requirements for Heavy Metal Contaminants in Processed Food. For lead contamination in processed fish products the maximum limit is 0.3 mg / kg. Based on the results, lead concentrations from the three points A, B, and C are included in the qualified category of lead quality standards in fish. The highest lead concentration of the three points was at point B of 0.19 mg/kg. Lead contamination from these three points can come from agricultural and domestic waste around or on the edge of the river.

Lead Dose-Response Analysis

Dose-response analysis or RfD values can be obtained from various scientific journals or related articles containing experimental research results, or from various toxicological reviews or from IRIS from the US EPA. The RfD value of lead is 0.004 mg/kg/day which was obtained from previous experimental results and the majority of other studies also used this value. Table 2 below shows the lead reference values.

Table 2. Lead (Pb) Reference Value

Agent	Dose Response	Critical Effects and References
Lead (Pb)	0.004 mg/kg/hari	Neurotoxicity, developmental delay, hypertension, cardiovascular reproductive disorders, lead poisoning, etc. (CDC, 1991)

Exposure Analysis

The distribution of respondents at points A and C amounted to 10 respondents, while point A was 30 respondents, so that the total number of respondents was 50. The average gender of the three points is mostly female. In the age characteristics of point A, most are in the age range of 33-42 years, while points B and C range from 43-52 years. The three points on the characteristics of body weight have the largest range in weight 48-58 Kg. Meanwhile, for the total body weight of all respondents, the minimum is 43 kg and the maximum is 92 kg.

Table 3. Characteristics of Respondents

Characteristics of Respondents	Min	Max	Mean	Median
Point A				
Intake Rate (R)	41.4	162.9	89.3	107.1
Exposure Duration (Dt)	12.0	44.0	23.8	25.0
Consumption Frequency (fE)	52.1	156.4	88.6	104.3
Point B				
Intake Rate (R)	41.4	196.4	99.7	84.3
Exposure Duration (Dt)	10.0	50.0	25.8	25.0
Consumption Frequency (fE)	52.1	260.7	111.2	104.3
Point C				
Intake Rate (R)	41.4	203.6	83.3	69.3
Exposure Duration (Dt)	9.0	36.0	24.3	25.5
Consumption Frequency (fE)	52.1	156.4	83.4	78.2

The data required in the intake calculation are lead concentration in fish body weight data, intake rate, exposure frequency, and exposure duration. In the calculation of intake, a normality test is required to determine the use of mean or median in the calculation. The normality test was conducted using the Shapiro Wilks test. If the data are normally distributed, the mean value is used and if not normally distributed, the mean value is used. The following table shows data on lead concentration, body weight, intake rate, exposure frequency, and exposure duration.

Calculation of intake values was using the following formula:

$$I = \frac{C \times R \times fE \times Dt}{Wb \times tavg}$$

Description:

I : intake (mg/kg/hari)
C : lead concentration (grams/day)
R : intake rate (grams/day)
fE : exposure frequency (days/year)
Dt : exposure duration (years)
Wb : body weight (kg)
Tavg : average time period

The calculation of lead intake in people at points A, B, and C who consume *Pangasius djambal* in the Bengawan Solo river is in Table 4.

Table 4. Intake Calculation Recapitulation Results and Recapitulation of RQ (*Risk Quotient*)

Population Group	Intake Value of Lead (mg/kg/day)	Recapitulation of RQ (Risk Quotient)	
		RQ Value	Description
Point A	0.0018	0.45	RQ ≤ 1
Point B	0.0639	15.98	RQ > 1
Point C	0.0012	0.30	RQ ≤ 1

The non-carcinogenic lead intake value at the three points was found to be highest at point B, then point A, and lowest at point C.

Risk Characteristics

Characterization is the final stage in determining whether or not lead risk agents at certain concentrations analyzed are safe or unsafe for consumption and can risk causing health problems in the community. The formula for calculating risk characterization or RQ (risk quotient) is as follows:

$$RQ = \frac{I}{RfD}$$

Description:

RQ : risk level
I : non-carcinogenic intake (mg/kg/day)
RfD : reference dose of lead (0.004 mg/kg/day)

Based on the results of the risk characterization calculation, the *Pangasius djambal* taken at point B is worth 15.98, meaning RQ> 1. These results can be interpreted that the risk level of lead exposure in *Pangasius djambal* consumed by the people of Ngringinrejo Village with a concentration of 0.19 mg/kg is not safe for consumption for people with a body weight of 61.70 kg, with a consumption of 85.71 grams / day, exposure 365 days / year for the next 30 years with the assumption that lead exposure comes only from *Pangasius djambal*. Meanwhile, the risk level of consumption of lead-containing *Pangasius djambal* in the community at points A and C is still in the safe category for consumption because RQ ≤1.

Risk Management

The results of the calculation of the risk level in the community who consume *Pangasius djambal* with lead content from the Ngringinrejo Village Gerak Dam are included in the unsafe category or RQ> 1. Therefore, risk management strategies and ways of managing risks are needed so as not to cause health problems. The risk management strategy needs to establish acceptable safe limits in the management of ingestion exposure, namely safe concentrations and safe ingestion rates.

Risk management strategy for determining the safe concentration of non-carcinogenic lead (Cnk) uses the formula:

$$Cnk = \frac{RfD \ x \ Wb \ x \ tavg}{R \ x \ fE \ x \ Dt}$$

$$Cnk = 0.0119 \text{ mg/kg}$$

Based on these results, the safe concentration for the people of Ngringinrejo Village in consuming *Pangasius djambal* from Bendung Gerak is below 0.0119 mg/kg.

The non-carcinogenic safe consumption rate (Rnk) was determined with the formula:

$$Rnk = \frac{RfD \ x \ Wb \ x \ tavg}{C \ x \ fE \ x \ Dt}$$

$$Rnk = 5.28 \text{ grams/day}$$

Based on these results, the safe consumption rate for the people of Ngringinrejo Village in consuming *Pangasius djambal* from Bendung Gerak is below 5.28 grams/day.

After conducting a risk management strategy by calculating the safe limit of lead concentration and consumption rate in consuming *Pangasius djambal* from Bendung Gerak, the Ngringinrejo Village community can carry out risk management methods. There are several approaches to risk management to reach the safe limit, such as technological, socioeconomic, and institutional approaches.

DISCUSSION

Hazard Identification

The concentration of lead in *Pangasius djambal* at point B was 0.19 mg/kg, higher than at point A and point B which had a concentration of 0.005 mg/kg. The difference in lead concentration in fish can be influenced by several factors, such as duration of exposure, method of metal ingestion, the weight of the fish and environmental conditions (15). The higher lead concentration in fish from point B could be influenced by the weight of the fish used as a sample of 4.8 kg, while the weight of *Pangasius djambal* from points A and C was around 1 kg. Fish body weight is related to the accumulation of lead in the fish body (16). The location of the highest lead concentration in *Pangasius djambal* is located in the weir area. That sampling locations close to the weir had higher lead concentrations than other locations. This occurs due to a decrease in water flow and a reduction in the volume of water in the water body after passing through the dam (17). In addition, the water at the weir has a calm current, causing heavy metals in the sediment to be high. Heavy metals that dissolve in waters are more easily deposited on sediments when the current is weak (18). Sediments at the bottom of these waters can be eaten by fish, so that metals can enter through the food chain (19).

The environmental conditions at the three sampling points have the same characteristics, namely close to residential areas and agricultural land. The large number of people living on the banks of the Bengawan Solo River can increase domestic waste contamination. The pollutant load can increase along with the increasing population in the riverbank, thus potentially increasing the contamination of domestic waste and organic and inorganic materials (14). Domestic waste that contains lead is lead-based paint, which is commonly used to paint walls, doors and windows, and batteries (7). In agricultural activities, the use of fertilizers and pesticides serve as a contributor to lead in water (20). The potential for lead contamination in Bendung Gerak also comes from the gases of motor vehicles passing across the bridge. Motor vehicles can increase lead in the environment if they use gasoline that contains Tetra Ethyl Lead (TEL) and Tetra Methyl Lead (TML) (17). These vehicle gases then crystallize with the help of rainwater and are carried into the water so that water bodies are contaminated with lead (21). Heavy metals in waters that enter the fish body continuously and are not balanced with the detoxification ability and metabolic rate of fish can cause metal accumulation in fish tissue or called the bioaccumulation process (22).

The concentration of lead in *Pangasius djambal* from the three sampling points is still below the quality standard according to BPOM No. 9 Year 2022 regarding Requirements for Heavy Metal Contaminants in Processed Food. Nevertheless, the majority of people consume *Pangasius djambal* 1-2 times a month. If this is done continuously, it can have health effects, because there is a bioaccumulation process in the body (10-11). Health problems that can arise from the consumption of fish containing lead are high blood pressure, cardiovascular disease, kidney, reproductive system, and brain damage, while chronic damage occurs in the central and peripheral nervous system (14). Children are particularly vulnerable to lead due to ineffective renal excretion and greater gastrointestinal absorption (23). Pregnant women and breastfeeding mothers, if exposed to lead, can pass it on to their babies during pregnancy and while breastfeeding (24).

Lead Dose-Response Analysis

This study exposed the risk agent through ingestion, so it used the RfD value of lead obtained from the Integrated Risk Information System (IRIS) of 0.004 mg/kg/day. Another research also used an RfD of 0.0035

mg/kg or 0.004 mg/kg/day (22). These values were obtained from experiments with lead risk agents. If the community intake exceeds the RfD value, it can have adverse health effects (22). However, according to the EPA's IRIS, when the dose exceeds the RfD, it cannot be definitively concluded that it will cause adverse health effects (25).

Lead exposure in adults can cause cardiovascular effects, hypertension, decreased kidney function, and reproductive problems for both men and women. In addition, for pregnant women, lead accumulates in the body and is stored in the bones with calcium. During pregnancy, lead is released from the mother's bones and can be transferred to the fetus or breastfeeding baby. This can result in premature birth, effects on the baby's brain, kidneys, and nervous system, risk of maternal miscarriage, and potential behavioral or learning problems (26). This RfD value is used to determine a safe reference value and is used as a calculation for the next step of Environmental health risk analysis, namely risk characterization.

Exposure Analysis

The majority of community respondents in point B were female rather than male. Lead exposure can affect all genders, but there are vulnerable groups such as pregnant women who are more susceptible to the effects of this exposure. In pregnant women, lead exposure can cause adverse pregnancy effects, such as miscarriage, stillbirth, prematurity, and low birth weight (27). In addition, exposure in women is also associated with decreased fertility, impaired reproductive health, hormonal imbalances that can disrupt menstruation, including impaired ovarian function, effects on libido, and pregnancy outcomes. In men, lead can reduce libido, sperm quality and impair prostate function (28).

Age and duration of exposure can be a factor in the accumulation of lead in the body. The age distribution of respondents was mostly between 43-52 years old and the duration of exposure in point B communities averaged 25.83 years. In adults with a long duration of exposure, lead can accumulate in the body for a long period of time and the release of lead in the body is generally very slow (7). People in point B consume catfish longer than people in point A and C. In addition to the exposure duration value, it can also be seen from the exposure frequency. If the frequency of exposure of respondents is high, the higher the respondents will be exposed to lead. Therefore, people who have been exposed to lead for many years have a greater chance of worsening their health due to lead exposure (29).

Lead intake or calculation of lead exposure through ingestion pathway in non-carcinogenic effects was calculated using lead concentration data, community consumption rate, consumption frequency, exposure duration, body weight, and average period. The result of lead intake calculation in Ngringinrejo Village was 0.0639 mg/kg/day with a body weight of 84.29 kg in an exposure duration of 25.83 years. This result is higher than the intake calculation of Mojo Village of 0.0018 mg/kg/day and Ngulanan Village of 0.0012 mg/kg/day. The amount of intake can be influenced by lead concentration, exposure frequency, intake rate, exposure duration, and body weight (30). In Ngringinrejo Village, the five factors that influence lead intake are greater than in the other two villages. The three population intakes will be compared with the RfD value of lead of 0.004 mg/kg/day. If the value exceeds the established dose, it is more likely to pose a significant health risk to the human body (31).

Risk Characterization

Characterization of the risk of lead with non-carcinogenic effects in the community of point B (Ngringinrejo Village) resulted in RQ > 1 or unsafe risk level and other points are still at safe risk (RQ ≤1). Another study stated that people who consume anchovies have an RQ> 1 or unsafe for consumption within 30 years (19). Projected in a lifetime of 50 years, it is more risky for unsafe consumption by the community than the projection of 30 years, because the longer the exposure to lead, the higher the accumulation of lead in the body and the greater a health risk (29).

A high level of risk (RQ) in the community can be caused by factors such as frequency of fish consumption, intake rate, duration of exposure, and lead concentration. The higher of these factors will affect the intake of lead in the body. If the lead concentration is high with a long duration of exposure, more lead in the body accumulates continuously (32). This can increase public health risks. Lead can increase red blood cell damage leading to a decrease in red blood cells. Lead exposure can also interfere with the growth and maturation of red blood cells leading to anemia. In addition, lead can inactivate glutathione, the main antioxidant in the body, leading to increased oxidative stress and cell damage (33). Therefore, if the RQ > 1, this condition needs to be anticipated to make preventive efforts so as not to endanger public health (19).

Risk Management

Risk management consists of risk management strategies and risk management methods. Risk management strategies are carried out by determining

the safe limit value of the risk agent concentration and intake rate. As a result of the calculation, the safe lead concentration for the people of Ngringinrejo Village without changing other variables is below 0.0119 mg/kg. Lead accumulation in fish tissue can cause oxidative stress due to excessive production of Reactive Oxygen Species (ROS), causing neurotoxicity, immune response, and synapse damage (34). Lead toxicity can also affect various systems in fish, such as the digestive, respiratory, and nervous systems, which can be used as indicators of toxicity in aquatic environments (35).

In addition to paying attention to safe lead concentrations, it is also necessary to be aware of the number of servings of fish consumption from this dam. Identifying and avoiding high-risk foods that are likely to contain lead can help minimize exposure in the body (36). The safe intake rate for the people of Ngringinrejo Village is below 5.28 grams/day. If it is assumed that one portion of *Pangasius djambal* consumed by the community based on the food picture from the Indonesian Ministry of Health is 275 grams, then the community can safely consume one portion of *Pangasius djambal* every two months. The community needs to reduce the consumption of fish caught from Bendung Gerak, especially *Pangasius djambal*, because it has the risk of causing health problems. Reducing the rate of fish consumption needs to be done when the fish has been contaminated with lead.

In addition to the risk management strategies that have been carried out to determine safe limits, it is also necessary to manage risks appropriately. An example of risk management to reduce lead concentration in fish is to process fish through grilling, boiling, and microwaving. Suitable cooking methods to reduce lead levels in fish are grilling (180°C, 20 minutes), crabs can reduce lead levels by 35.6% and cooking shrimp by boiling (180°C, 10 minutes) reduces lead levels by 21.2% (37).

Reduction of lead concentration in fish in addition to the cooking process can also be through soaking in natural materials containing citric acid. In the socioeconomic approach, it can replace the staple food, namely *Pangasius djambal*, with other safe food ingredients. Institutional approaches are carried out with interventions by the local environmental agency or related agencies to check the quality of water and fish in the Bengawan Solo River in Bojonegoro and points where there is a lot of fishing. Based on checking and improving water quality monitoring, it can be used as a basis for determining the no-fishing zone. In addition, environmental recovery programs around rivers polluted by heavy metals can be carried out with rehabilitation, domestic and industrial waste management. Other factors that cause human exposure to lead apart from consumption are exposure to lead through air, public environment such as from vehicle fumes, and work environment polluted with lead. Smoking and not using personal protective equipment when working in the field, on activities, or during travel also affect blood lead (38). Therefore, these factors must also be considered by the community and government.

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CONCLUSION

The lead content in *Pangasius djambal* at point B of the Ngringinrejo Village Gerak Dam was 0.19 mg/kg. The reference dose (RfD) value of lead used is 0.004 mg/kg/day. Non-carcinogenic exposure to lead in *Pangasius djambal* at point B is 0.0639 mg/kg/day, while at points A and C it is 0.0018 mg/kg/day and 0.0012 mg/kg/day. The results of the risk characterization of non-carcinogenic lead exposure in *Pangasius djambal* from the Ngringinrejo Village Gerak Dam are in an unsafe condition for public consumption in the next 30 years. Risk management is carried out by determining the safe concentration of lead in *Pangasius djambal* consumed by the community, which is <0.0119 mg/kg and the safe consumption rate of the community is below 5.28 grams / day or 1 serving within a period of 2 months. Reduction of lead content in fish can be done by boiling, baking, and microwaving or by soaking the fish using citric acid content such as lime or tomato filtrate.

The city government of Bojonegoro is advised to make countermeasures and prevention efforts by implementing environmental recovery programs around lead-contaminated rivers through vegetation rehabilitation, industrial waste management, and other efforts to reduce the source of pollution. In addition, it is necessary to educate the public about the dangers of lead in fish from the Bengawan Solo River and take steps to minimize the risk of lead exposure. The community can protect the environment by not throwing garbage in the Bengawan Solo River, and start using organic fertilizers and/or organic pesticides. In addition, anglers can choose locations that have been identified by the government as safe zones and free from heavy metal content or reduce the frequency of fishing in areas that have heavy metal levels.

REFERENCES

1. Rukhmanah T. 4 Sungai Terpanjang di Pulau Jawa, Nomor 1 Jadi Jalur Transportasi Kerajaan Majapahit. Surabaya: Inews Jatim; 2022. https://Jatim.Inews.Id/Berita/4-Sungai-Terpanjang-Di-Pulau-Jawa-Nomor-1-Jadi-Jalur-Transportasi-Kerajaan-Majapahit
2. Endarwati MC, Hari W, Widodo S. Arahan Penataan Ruang Sempadan Sungai di Wilayah Perkotaan Kabupaten Bojonegoro. *Jurnal Pembangunan Wilayah dan Kota*. 2021;17(1):108–118. https://doi.org/10.14710/pwk.v17i1.36535
3. District Government of Bojonegoro. Bendung Gerak. Bojonegoro: District Government of Bojonegoro; 2014. https://Bojonegorokab.Go.Id/Berita/596/Bendung-Gerak
4. Sigit. 5 Spot Mancing Terbaik di Bojonegoro yang Paling Sering Dikunjungi. Bojonegoro : Bangsaonline; 2022. http://Bangsaonline.Com/Berita/112761/5-Spot-Mancing-Terbaik-Di-Bojonegoro-Yang-Paling-Sering-Dikunjungi
5. Pratiwi DY, Nugroho AP, Yustiati A. Bioakumulasi Ion Tembaga pada Ikan Nila (*Oreochromis Niloticus L.*) di Instalasi Pengolahan Air Limbah (IPAL), Bantul. *Jurnal Akuatika Indonesia*. 2019;4(2):57-64. https://doi.org/10.24198/jaki.v4i2.25260
6. Mazda G. Bengawan Solo Menghitam DLH Bojonegoro Akibat Limbah Ciu. Bojonegoro: Tugu Jatim; https://Tugujatim.Id/Bengawan-Solo-Menghitam-Dlh-Bojonegoro-Akibat-Limbah-Ciu/
7. Agency for Toxic Substances and Disease Registry. Lead Toxicity. United States: Centers For Disease Control; 2023. https://Www.Atsdr.Cdc.Gov/Csem/Leadtoxicity.Html
8. Amalo D, Bana JJ, M Dima AO, Moi Nono K, Pacheco S. Analisis Kandungan Logam Timbal (Pb) pada Bayam Hijau (*Amaranthuss Tricolor L.*) di Sentra Produksi Pertanian Oebobo Kota Kupang. *J Biotropikal Sains.* 2023;20(2):55–61. https://ejurnal.undana.ac.id/index.php/biotropikal/issue/download/591/7-ANALISIS%20KANDUNGAN
9. Fatiha II, Irawanto R. Pengaruh Limbah Cair Home-Industri Batik terhadap Kemampuan *Echinodorus radicans*. *In: Seminar Nasional Biologi 6 Gunung Djati Conference Series*. 2021;1(1):47–54. https://conference.uinsgd.ac.id/index.php/
10. Farhan JE, Rohani MF, Sumaiya N, Tuj JMF, Akter Y, Shahjahan M, et al. Bioaccumulation and Bioremediation of Heavy Metals in Fishes—A Review. *Toxics*. 2023;11(6):1-28. https://doi.org/10.3390/toxics11060510
11. Engwa GA, Ferdinand PU, Nwalo FN, Unachukwu MN. Mechanism and Health Effects of Heavy Metal Toxicity in Humans. In: Poisoning in the Modern World - New Tricks for an Old Dog?. Croatia: Intechopen; 2019. https://doi.org/10.5772/intechopen.82511
12. Nuraeni A, Samosir A, Sulistiono S. Logam Berat Timbal (Pb) Pada Hati Ikan Patin (*Pangasius djambal*) di Waduk Saguling, Jawa Barat. *Jurnal Teknologi Perikanan dan Kelautan*. 2022; 12(2):113–123. https://doi.org/10.24319/jtpk.12.113-123
13. Nasution AY, Indriani RI, Farmasi F, Kesehatan I, Abdurrab U. Determination of Lead (Pb) in Patin Fish Oil (*Pangasius Hypophthalmus*) Using Atomic Absorption Spectrophotometry (AAS) Penetapan Kadar Timbal pada Minyak Ikan Patin (*Pangasius Hypophthalmus*) dengan Metode Spektrofotometri Serapan Atom. *Jurnal Proteksi Kesehatan*. 2021;10(1):1–5. https://doi.org/10.36929/jpk.v10i1.314
14. Collin MS, Venkatraman SK, Vijayakumar N, Kanimozhi V, Arbaaz SM, Stacey RGS, et al. Bioaccumulation of Lead (Pb) and Its Effects on Human: A Review. *Journal of Hazardous Materials Advances*. 2022;7(100094):1-8. https://doi.org/10.1016/j.hazadv.2022.100094
15. Mehana ESE, Khafaga AF, Elblehi SS, Abd El-Hack ME, Naiel MAE, Bin-Jumah M, et al. Biomonitoring of Heavy Metal Pollution using Acanthocephalans Parasite in Ecosystem: An Updated Overview. *Animals*. 2020;10(5):1-15. https://doi.org/10.3390/ani10050811
16. Ali H, Khan E, Ilahi I. Environmental Chemistry and Ecotoxicology of Hazardous Heavy Metals: Environmental Persistence, Toxicity, and Bioaccumulation. *Journal of Chemistry*. 2019;1(6730305):1–14. https://doi.org/10.1155/2019/6730305
17. Jean JQDB, Prihatmo G, Pakpahan S. Kadar Logam Berat Timbal (Pb) pada Ikan Nila (*Oreochromis Niloticus*) di Sungai Gajah Wong, Yogyakarta. *Prosiding Seminar Nasional Biologi*. 2020;6(1):372–379. https://doi.org/10.24252/psb.v6i1.15896
18. Maulina DRA, Pringgenies D, Haryanti D. Kandungan Logam Berat Pb dan Cd Dalam Sedimen di Pantai Trimulyo dan Pantai Tirang, Semarang. *Journal of Marine Research*. 2024;13(1):20–28. https://doi.org/10.14710/jmr.v13i1.35038
19. Meirindany T, Dalimunthe KT. Analysis of Environmental Health Risk of Lead (Pb) Pollution in Marine Products Circulating at Sambu Market Medan. *Journal of Pharmaceutical and Sciences*. 2023;6(4):1919–1926. https://doi.org/10.36490/journal-jps.com.v6i4.279
20. Liu Z, Bai Y, Gao J, Li J. Driving Factors on Accumulation of Cadmium, Lead, Copper, Zinc In Agricultural Soil and Products of the North China Plain. *Scientific Reports*. 2023;13(1):1–13. https://doi.org/10.1038/s41598-023-34688-6
21. Selmi, Wiharto, Patang. Analisis Air, Substrat Tanah dan Cemaran Logam Berat Timbal (Pb) dan Cadmium (Cd) pada Ikan Nila (*Oreochromis Niloticus*) pada Waduk Tunggu Pampang Kelurahan Bitoa, Kota Makassar. *Jurnal Pendidikan Teknologi Pertanian*. 2019;5(2):36–46. https://doi.org/10.26858/jptp.v5i2.9626
22. Palgunadi NPGS, Purnama IGH. Bioakumulasi dan Analisis Risiko Kesehatan Masyarakat dari Pencemaran Logam Berat Pb dan Cd pada Ikan yang ditangkap di Tukad Badung, Denpasar. *Archive of Community Health*. 2022;9(1):33–49. https://doi.org/10.24843/ACH.2022.v09.i01.p03
23. Akbar SA, Rahayu HK. Tinjauan Literatur: Bioakumulasi Logam Berat pada Ikan di Perairan

Indonesia. *Lantanida Journal*. 2023;11(1):51–66. https://doi.org/10.22373/lj.v11i1.17834

24. Center of Disease Control and Prevention. Childhood Lead Poisoning Prevention. United States: Center of Disease Control and Prevention; 2021. https://www.cdc.gov/nceh/lead/prevention/populations.htm
25. Environmental Protection Agency. Integrated Risk Information System (IRIS) Reference Dose (Rfd): Description and Use in Health Risk Assessments Background Document 1A March 15, 1993. United States: Environmental Protection Agency; 2023. https://www.epa.gov/iris/reference-dose-rfd-description-and-use-health-risk-assessments#1.3.2
26. Environmental Protection Agency. Learn About Lead. United States: Environmental Protection Agency; 2024. https://www.epa.gov/lead/learn-about-lead#effects
27. World Health Organization. Lead Poisoning. Geneeva: World Health Organization; 2023. https://www.who.int/news-room/fact-sheets/detail/lead-poisoning-and-health
28. León OLL, Pacheco JMS. Effects of Lead on Reproductive Health, Lead Chemistry. Croatia: Intechopen; 2020. https://doi.org/10.5772/intechopen.91992
29. Anggraini F, Anwar A, Risva. Analisis Risiko Kesehatan Lingkungan Non-Karsinogenik Tembaga pada Ikan Nila Keramba yang Dikonsumsi dan Dibudidayakan Masyarakat di Desa Jembayan. *HIGIENE: Jurnal Kesehatan Lingkungan*. 2019;5(1):14–21. http://journal.uin-alauddin.ac.id/index.php/higiene/article/view/6778
30. Fatmayani I, Gafur A, Arman. Analisis Risiko Kesehatan Lingkungan Pajanan Timbal dan Kromium pada Masyarakat yang Mengonsumsi Kerang *Marcia hiantina* di Perairan Selat Makassar. *Window of Public Health Journal*. 2022;3(2):309–320. https://doi.org/10.33096/woph.v3i2.384
31. Nag R, Cummins E. Human Health Risk Assessment of Lead (Pb) Through the Environmental-Food Pathway. *Science of Total Environment*. 2022;810(151168):1-14. https://doi.org/10.1016/j.scitotenv.2021.151168
32. Hidayat H, La Taha LT, Dewi B SB. Analisis Risiko Pajanan Timbal (Pb) dalam Kerang pada Masyarakat di Wilayah Pesisir Pantai Galesong Desa Palalakkang Kec. Galesong Kab. Takalar. *Sulolipu*. 2022;22(2):219-230. https://doi.org/10.32382/sulolipu.v22i2.2902
33. Center of Disease Control and Prevention. Lead Toxicity: What Are Possible Health Effects From Lead Exposure?. United States: Center of Disease Control and Prevention; 2023. https://www.atsdr.cdc.gov/csem/leadtoxicity/physiological_effects.html
34. Lee JW, Choi H, Hwang UK, Kang JC, Kang YJ, Kim K Il, et al. Toxic Effects of Lead Exposure on Bioaccumulation, Oxidative Stress, Neurotoxicity, and Immune Responses in Fish: A Review. *Environmental Toxicology and Pharmacology*. 2019;68(1):101–108. https://doi.org/10.1016/j.etap.2019.03.010
35. Ishaque A, Ishaque S, Arif A, Abbas H. Toxic Effects of Lead on Fish and Human. *Biological and Clinical Sciences Research Journal*. 2020;1(47):1–8. https://doi.org/10.54112/bcsrj.v2020i1.47
36. Wang M, Liang B, Zhang W, Chen K, Zhang Y, Zhou H, et al. Dietary Lead Exposure and Associated Health Risks in Guangzhou, China. *International Journal Of Environmental Research And Public Health*. 2019;16(8):1-16. https://doi.org/10.3390/ijerph16081417
37. Abd-Elghany SM, Zaher HA, Elgazzar MM, Sallam KI. Effect of Boiling and Grilling on Some Heavy Metal Residues in Crabs and Shrimps from the Mediterranean Coast at Damietta Region with Their Probabilistic Health Risk Assessment. *Journal of Food Composition and Analysis*. 2020;93(103606):1-9. https://doi.org/10.1016/j.jfca.2020.103606
38. Wulandari ET, Wulandari DD, Qodriyah NL, Rohmah W. Faktor-Faktor yang Mempengaruhi Kadar Timbal (Pb) dalam Darah Secara Fisiologis (Literature Review). *In: Prosiding National Conference for Ummah*. 2020;1(1):5–24. https://conferences.unusa.ac.id/index.php/NCU2020/article/view/602