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Environmental Health Risks Assesment of Human Exposure to Pb Pollution Around Soyoan River, Indonesia

Analisis Risiko Kesehatan Lingkungan Paparan Cemaran Pb Pada Masyarakat di Sekitar Sungai Soyoan, Indonesia

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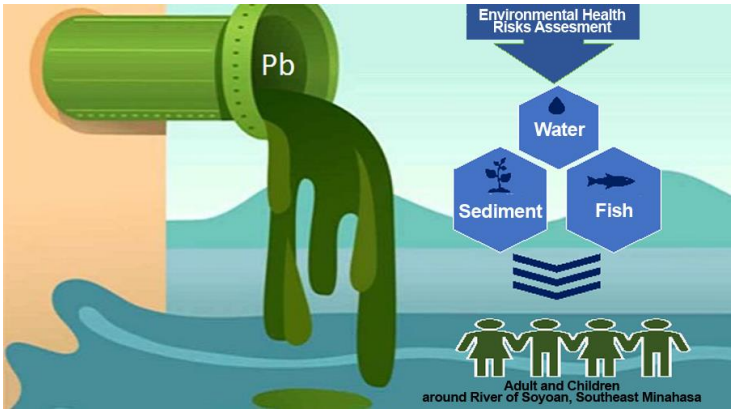
Abstract
The presence of the heavy metal lead (Pb), which accumulates in water and sediment, will enter into the life of organisms which can have a toxic effect on the organisms in it. This study aimed to analyze the health risks of consuming Mujair fish (*Oreochromis Mossambicus*) which contains the heavy metal Pb in the river flow of Soyoan Village, Ratatotok District, Southeast Minahasa Regency. The research method was descriptive with an environmental health risk analysis (ARKL) approach. Determination of lead levels in fish, water, and sediments used the Atomic Absorption Spectrophotometer method with a graphite furnace. The results showed that the average Pb in Mujair fish was 0.23 mg/kg, the average Pb in water was 1.48 mg/liter, and the average in sediment was 52.98 mg/kg. Pb concentrations in aquatic fish and sediments had exceeded the threshold. The Risk Quotion (RQ) value wasstill below 1 (RQ < 1), meaning that Mujair fish (*Oreochromis Mossambicus*) in the Soyoan river was still safe for consumption. The ECR value ≤ 10-4 indicated that making risk management was not something that needs to be prioritized. However, the presence of high concentrations was an indicator so that the rate of intake and frequency of exposure can be reduced. In Islamic teachings, it has been explained that damage to the environment due to human actions has an adverse effect on the biota and threatens the surrounding community's health.

Abstrak
Keberadaan logam berat timbal (Pb) yang menumpuk pada air dan sedimen akan masuk kedalam kehidupan organisme dapat menimbulkan efek toksik terhadap organisme di dalamnya. Tujuan penelitian ini yaitu untuk menganalisis risiko kesehatan akibat mengkonsumsi ikan Mujair (*Oreochromis Mossambicus*) yang mengandung logam berat Pb di Aliran Sungai Desa Soyoan Kecamatan Ratatotok Kabupaten Minahasa Tenggara. Metode Penelitian yaitu deskriptif dengan pendekatan analisis risiko Kesehatan lingkungan (ARKL). Penetapan kadar timbal pada ikan, air dan sedimen dilakukan dengan menggunakan metode Spektrofotometer Serapan Atom dengan graphite furnance. Hasil penelitian yaitu rerata Pb pada ikan Mujair 0,23 mg/kg, rerata Pb pada air 1,48 mg/liter dan rerata pada sedimen 52,98 mg/kg. konsentrasi Pb pada ikan air dan sedimen sudah melebihi ambang batas. Nilai Risk Quotion (RQ) masih dibawah 1 (RQ < 1) berarti ikan Mujair (*Oreochromis Mossambicus*) di aliran sungai Soyoan masih aman untuk dikonsumsi. Nilai ECR ≤ 10-4 menunjukkan bahwa pembuatan manajemen risiko bukan hal yang perlu diperioritaskan. Namun keberadaan konsentrasi tinggi menjadi indikator agar laju asupan dan frekuensi pajanan dapat dikurangi. Dalam ajaran Islam telah dipaparkan bahwa kerusakan di lingkungan akibat perbuatan pada manusia ini tidak hanya menimbulkan efek buruk pada biota namun juga menganam kesehatan masyarakat di sekitar.

Graphical Abstract



Keyword
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INTRODUCTION

The entry of a pollutant into the environment exceeding the environmental capacity threshold can occur in rivers (Cañedo-Argüelles et al., 2013). Anthropogenic activities will produce waste that contains heavy metals and enters the waters. Heavy metals are toxic and will accumulate in sediments and aquatic biota through bioconcentration, bioaccumulation, and biomagnification. Lead (Pb) indicates heavy metal pollution in waters from human activities (Ali & Khan, 2019).

Soyoan River is a river in the district of Ratatotok, Southeast Minahasa. Along this river, people have activities such as gold mining, both legal and illegal, fishing, bathing, animal husbandry, and agriculture. The flow of household and agricultural waste from residents plays a role in pollution (Song et al., 2014). People who consume fish from the River have the potential also to accumulate heavy metals and potentially cause health risks (Maurya et al., 2019).

Based on data from the Basaan Community Health Center as a working area in Soyoan village in 2021, skin diseases, headaches, allergies, and diarrhea will be included in 10 major diseases. These diseases occur in the environment using water, soil, or air media to enter and accumulate in the human body. Pb can enter the human body through breathing, food, and contact with the skin. Also, most of the lead enters the red blood cells and circulates throughout the body, and finally concentrates in the liver and kidneys and then spreads to the bones, teeth, and brain (Sembel, 2015).

This study defines Mujair fish (*Oreochromis Mossambicus*) as a bioindicator due to the people's habit of fishing and consuming Mujair fish. One method can be used for risk analysis of lead (Pb) in fish consumed by residents is the Environmental Health Risk Analysis (ARKL) method. ARKL can be done to monitor non-carcinogenic effects called Risk Quotients (RQ). If the RQ value is at least 1, then the risk needs to be controlled, but if the RQ is less than 1, the risk does not need to be controlled but is maintained so that the RQ does not exceed 1.

The presence of lead in the waters will contaminate aquatic ecosystems, thus accumulating in aquatic biota and sediments. Aquatic biota that contains lead at specific concentrations can harm biotas and are toxic if they enter the human body (Yuan et al., 2022; Zaynab et al., 2022). Several studies have examined the lead content in rivers. This study complements previous findings regarding lead content in rivers. Considering that the Soyoan River is a river that influences people's lives and studies on risk assessment estimates have never been carried out, this study needs to be carried out. This study aims to estimate the health risks of lead metal pollution to people who consume Mujair fish (*Oreochromis Mossambicus*) in the Soyoan river, Ratatotok subdistrict, Southeast Minahasa, and formulate possible risk management.

METHODS

This study used a descriptive research design using the Environmental Health Risk Analysis (ARKL) method. This research was conducted in the river of Soyoan Village, Ratatotok District, Southeast Minahasa Regency, in September 2022. The sampling method is purposive sampling. The purposive sampling method is used in research because this technique considers determining a particular sample because not all of the samples have the required criteria for the research objectives. Sampling was carried out at three points on the Soyoan river, Ratatotok subdistrict, Southeast Minahasa, consisting of the rivers upstream, middle, and downstream of the river. Sampling was repeated three times, namely morning, afternoon, and evening.

Water samples were taken using a Nansen bottle at 30-50 cm depth. The amount of water taken is 2 liters for each sample bottle. Sediment sampling using a sediment grab tool. The sampling of fish is done by fishing or using fishing trawls. Fish meat is sliced through whole fish along the spine, from the back of the head towards the tail (fillet). Samples of fish meat, water, and sediment were put into a cool box and taken to the laboratory to be analyzed for the heavy metal Lead (Pb) content using the AAS (Atomic Absorption Spectrophotometer) method.

This study was carried out in various stages, including hazard identification, dose-response analysis, exposure analysis, and characteristic risk analysis. Hazard identification is the first step in Environmental Health Risk Analysis (ARKL) which is carried out to find out the causes of health risks from risky agents. So that the identification of the problem is also added to the potential effects of health problems, the hazard that will be analyzed in this study is Lead (Pb).

The dose-response analysis is the relationship between the total amount of an agent received or absorbed by a living thing and the changes that occur in living things.

Table 1
Hazard identification of Lead (Pb) Levels in Fish, Water and Sediments

Source	Potential environmental media	Risk Agent	Concentration			TVL*
			Max	Min	Average	
Heavy Metal Pollution in the Soyoan River	Mujair Fish (*Oreochromis Mossambicus*)	Pb (mg/kg)	1.67	0.01	0.23	0.201
	Water	Pb (mg/l)	3.13	0.23	1.48	0.032
	Sediment	Pb (mg/kg)	115.09	21.46	52.98	30.23

Note: TLV = Threshold Limit Values; * = value based from CCME (2001)

While dose-response is the relationship between the total amount of an agent received or absorbed by living things and the changes that occur in these living things. Reference Dose (RfD) is the reference dose or concentration of daily exposure to non-carcinogenic risk agents that is estimated not to cause disturbing effects even though the exposure occurs throughout life (lifetime). Exposure analysis is the evaluation of agent exposure to living things. Exposure analysis is the fourth step in Environmental Health Risk Analysis (ARKL) (Directorate General of PP, 2012). Exposure analysis is also in the form of estimating the intake of fish that enters the human body that consumes these fish. Exposure analysis is closely related to fish concentration, ie if the concentration is high, then the intake is also potentially large. However, the value of fish intake can also be influenced by other factors, such as the amount and frequency of fish consumption. An example is the habit of people consuming and fishing for fish. Based on ARKL guidelines by the Directorate General of PP and PL. (2012) determined the intake formula 1:

$$Ink = \frac{C \times R \times fE \times Dt}{Wb \times t\,avg} \quad (1)$$

Risk characterization is useful for determining how much the risk level is at concentrations determined in the analysis that have the potential to cause health effects (with characteristics such as the amount of consumption, body weight, frequency, time and duration of exposure) or not (Directorate General of PP, 2012). The risk characteristics are Excess Cancer Risk (ECR) values for carcinogenic agents and Risk Quotient (RQ) for non-carcinogenic agents. It is said that RQ < 1 is safe; if RQ ≥ 1, it is not. Meanwhile, the ECR is safe if the ECR ≤ E-4, where one person in 10,000 people is at risk of cancer.

RESULTS

Based on table 1, there was a relationship between potential environmental sources and media and risk agents. The risk agent then had a measurable concentration of a substance that could potentially be harmful if it entered the human body, consumed potential environmental media, and could cause potential health symptoms. The risk agent of Pb in Mujair fish had an average of 0.23 mg/kg. While for water and sediment, the averages were 1.48 mg/l and 52.98 mg/kg, respectively.

Table 2 shows the SF value of 0.0085. Slope factor (SF), namely the dose or concentration of daily exposure to carcinogenic risk agents that were estimated not to cause disturbing effects or not cause cancer even though the exposure occurred throughout life (lifetime). Table 3 explains the components in the study including notation, meaning of notation, default unit, value.

Table 2
Dose Response Analysis

Agent	Dose Response		Critical Effects and References
	RfD*	SF*	
Lead (Pb)	0.0035	0.0085	Mental disorders and decreased intelligence (intelligent IQ), lead poisoning "plumbism": loss of appetite (anorexia), anemia (because lead will bind to red blood cells), weight loss, difficulty defecating (constipation), lethargy or irritability (BPOM RI, 2010).

Note: RfD = Reference Dose, SF = Slope factor, * = value base from United States Environmental Protection Agency (2022)

Table 3
Notation, Meaning of Notation, Unit, and Default Value

Notation	Meaning of Notation	Unit	Default Value
Ink (Intake)	The total concentration of risk agents (mg) that enters the human body with a certain body weight (kg) every day	mg/kg x day	None
C (consentration)	Concentration of risk agents in clean/drinking water or in food.	mg/kg (Food)	None
R (Rate)	Consumption rate or the amount of water volume or the amount of food weight that enters every hour	gram/day (Food)	Fish caught: 54 grams/day
fE (frecuency of exposure)	Lamanya atau jumlah hari terjadinya pajanan setiap tahunnya	day/year	Residential exposure: 350 days/year
Dt (duration time)	The duration or number of days of exposure each year	year	Residential (settlement) / lifetime exposure : 30 years, children 6 years
Wb (weight of body)	Human body weight / population / population group	kg	Asian Adult/Indonesian : 55 Kg; Children: 15 kg
tavg(nk) (time average)	Average time period for non-carcinogenic effects	day	30 years x 365 days/year = 10,950 days

From this formula, the maximum, minimum, and average intake values for adults and children are presented in table 4. The average intake for adults was 0.000217, while the average intake for children was 4.41 x 10-5

Table 5 shows the overall level of risk from Pb exposure to Mujair fish based on people's consumption patterns, safe (RQ<1) for people for all age groups. In more detail, the risk level above can be interpreted as follows: The risk level of Pb exposure in Mujair fish consumed by the adult population group with an average concentration of 0.00023 mg/g was safe for adults with a body weight of 55 kg with consumption of 54 gr/day, exposure 350 days/year for 30 years, and safe for children who consumed Mujair fish as much as 54 gr/day, exposure 350 days/year for six years. If the RQ value exceeds 1 (one) and the ECR value exceeds 10-4, it is necessary to carry out risk management. Table 5 shows that the overall ECR value is less than equal to 10-4, meaning that risk management was not necessary.

DISCUSSION

Heavy metals have a natural affinity to remain locked in the sediment compartment due to their active precipitation tendency. Over time, heavy metals will be released and dissolve in water. Then it will be absorbed by biota and aquatic plants (Dutta et al., 2022). Assessment of heavy metals in fish is critical because it is a potential ecological indicator, especially for pollution studies. Fish can demonstrate the impact of water pollution by metals on ecosystems. The etiology of fish and human diseases is related to water pollution and metal accumulation in organisms (Moiseenko et al., 2018).

Lead (Pb) Concentration in Water

Aquatic animals absorb lead (Pb) from the environment or feed, namely phytoplankton, zooplankton, and micro plants that have accumulated lead and will be bound to protein in their body tissues. The initial uptake of Pb by aquatic organisms can be through three main processes, namely through the respiratory organs (gills), the body surface, and from food or water through the digestive system. The amount of metal absorption and the metal content in water is usually proportional. That is, the increase in the metal content in the tissues corresponds to the increase in the water content. In non-essential metals (including Pb), the content in the network continues to increase according to the increase in metal concentrations in the environmental water. (Alim, D.H., 2014; Julhidah, J., 2018; Sukma, R.M.at.all., 2020)

Heavy metals such as Pb are soluble in water and have low solubility with some anions (Darmono 2001). The average Pb content in the water at the study site was 1.48 mg/l with a minimum value of 0.23 mg/l and a maximum of 3.13 mg/l. This value has exceeded the threshold set by PP RI no 22 of 2021, which is 0.03 mg/l.

greater than that of Pb in water because heavy metals

Table 4
Intake values for adults and children

Population Group		C (mg/g)	R (g/day)	Fe (day/year)	Dt (year)	Wb (kg)	t Avg	Intake (mg/kg.day)
	max	0.00167	54	350	30	55	10950	0.001572
Adult	min	0.00001	54	350	30	55	10950	9.41E-06
	rerata	0.00023	54	350	30	55	10950	0.000217
	max	0.00167	15	350	6	15	10950	0.00032
Children	min	0.00001	15	350	6	15	10950	1.92E-06
	rerata	0.00023	15	350	6	15	10950	4.41E-05

Lead (Pb) Concentration in Fish

The concentration of Pb in fish is the amount of lead metal content in Mujair fish (*Oreochromis mossambicus*) obtained through examination with the SSA method, which can enter the human body through digestion and cause effects on health that are chronic and accumulative. The average Pb content in fish at the study site was 1.67 mg/kg, with a minimum value of 0.01 mg/kg and a maximum value of 0.23 mg/kg. The average and maximum Pb values in fish have exceeded the threshold set by BPOM RI no 23 of 2017, which is 0.20 mg/kg.

The content of heavy metals in fish reflects past exposure conditions through water or food. It may indicate that the current animal situation before toxicity affects the ecological balance of populations in aquatic environments (Okereafor et al., 2020). The consumption of fish meat contaminated with heavy metals such as Cd will be stored in the liver and kidneys and can cause health problems in humans (Moiseenko et al., 2018).

Lead (Pb) Concentration in Sediments

The average Pb content in the sediment at the study site was 52.98 mg/kg, with a minimum value of 21.46 mg/kg and a maximum of 115.09 mg/kg. The average and maximum Pb values exceeded the threshold set by the CCME in 2001, namely 30.2 mg/kg. The concentration of Pb in sediments is bind organic matter more easily and efficiently settle to the bottom of the water and unite with sediment (Kahlon et al., 2018).

Sediments are particles from chunks of rock, the remains of marine organisms. The presence of heavy metals greatly affects the pollution level in sediments, where heavy metals have properties that easily bind and settle to the bottom of the waters and unite with sediments so that the levels of heavy metals in sediments are higher than in water (Harahap, 2022).

Environmental Health Risk Analysis

Based on the results of the study, it was found that the RQ value <1. It means the fish consumed by people living in the Soyoan river basin are still safe from exposure to Pb metal. Assuming lead exposure only comes from fish. If the levels of lead in shellfish increase every year and there is an increase in the frequency of exposure and the rate of intake, the risk level of the people in the Soyoan River basin will also increase.

This study is in line with Alwi and Yasnani (2016), the risk level (RQ) in the population of the people on the banks of the Wanggu River in Lalolara Village at this time (real-time) is <1, meaning it is still safe or not at risk in consuming these shellfish. The research results of Alik et al (2022) and Maddusa et al (2022) obtained Mercury (Hg) and Cadmium (Cd) in

Table 5
Risk level RQ and ECR values by population group

Population Group		RQ	ECR
	Max	0.449	1.33 x 10-5
Adult	Min	0.002	8.002 x 10-8
	Rerata	0.061	4.84 x 10-6
	Max	0.091	2.72 x 10-6
Children	Min	0.0005	1.63 x 10-8
	Rerata	0.012	3.74 x 10-7

Note: RQ = Risk Quotion, ECR = Excess Cancer Risk

nilem fish (Ostoechillus Vittatus) of 0.0103 mg/kg and 0.0067 mg/kg with RQ < 1 So it was declared not at risk against non-carcinogenic diseases in the next 30 years.

In contrast to research of Putra et al. (2016) found that mullets containing Pb in the Tapak river had a high level of risk (RQ> 1). It is caused by the rate of intake of mullet, which is a lot every day, the frequency of eating mullet every year, and the long duration of exposure can increase Pb intake in the body so that the risk for Pb exposure is also high. Research of Simbolon (2018), the concentration of Pb metal in sediments and green mussels is far above the quality standard, so green mussels from these waters are unfit for consumption by the public. It can be seen from the health risk value (RQ), which has exceeded one at each sampling location. The highest arsenic (As) concentration in Nilem fish (*Ostoechillus Vittatus*) in the Bakan River was 2.28 mg/kg. The lowest was 0.20 mg/kg, and the average concentration was 0.9967 mg/kg. The average risk level (RQ) value is 1.2679, the lowest RQ is 0.1437, and the highest RQ is 4.1942 (Liono et al. 2022).

Risk Management

Risk management is an effort based on information about health risks obtained through a risk analysis to prevent, mitigate, or recover adverse health effects from exposure to toxic substances. In the Environmental Health Risk Analysis (ARKL), the principle of risk management is carried out if the risk level (RQ) > 1. From the calculation results, the risk level for the population around the Soyoan river is less than 1 (RQ<1). The mean ECR for adults and children does not exceed 10 -4 (ECR ≤ E-4). It means that the level of risk is acceptable or safe. It means that the people around the Soyoan river are still safe and not at risk of consuming Mujair fish from the Soyoan river, so there is no need for risk management.

The earth and everything in it is God's creation to support human life, as in the verse of the Koran Surah Ali Imran/191, which translates as:

> *"...Our Lord, You did not create this aimlessly..."*

The verse shows that every human being should protect the environment from damage and pollution that can interfere. Therefore protecting the environment from damage is people responsibility (Baharuddin & Musa, 2018). However, excessive exploitation of natural resources makes the environment polluted.

This is contrary to the translation of the Koran Surah Al-A'raf Verse 56

> *" And cause not corruption upon the earth after its reformation"*

So it was evident that human activities, especially industries that cause pollution of the legal environment are haraam in Islam with strong grounds for prohibiting them in the Qur'an and Hadith (Kamran et al., 2022).

CONCLUSIONS

This study found that the average Pb content in Mujair fish (*Oreochromis Mossambicus*), water, and sediment has exceeded the threshold. The average risk level (RQ) for the age group of adults and children is still less than 1 (RQ<1). So that people who consume tilapia fish in the Soyoan river are still safe. The average ECR for adults and children shows an acceptable or safe level of risk, so there is no need for risk management. The results of this study can provide an overview of public health in real-time, which stakeholders can use to make policies to deal with pollution in the surrounding environment. However, the fish, water, and sediment samples tested in this study were limited, so we suspect the results may not be comprehensive, given the vast river area. This study provides recommendations to the government and related agencies to improve environmental quality monitoring in the Soyoanm River and reduce pollutant materials entering the river because Pb concentrations have exceeded the threshold. People who consume Mujair fish (*Oreochromis Mossambicus*) in research locations need to reduce the intake and frequency of exposure rate to reduce the risk of lead agents.

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AUTHORS' CONTRIBUTIONS
Sri S. Maddusa designed the study, formulated the concept, collected data, and analyzed the data. Woodford B.S. Joseph eviewed the manuscript, enrolled participants, acquired the data Shalom M.T. Pomantow revised the manuscript. Afnal Asrifuddin collected data and revised the manuscript. Rahayu H. Akili collected data and performed the field work. Nur E. A. Bahrain revised the manuscript and performed the field work. All

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COMPETING INTERESTS

The author(s) declare no potential conflict of interest with respect to the research, authorship, and/or publication of this article.

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