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EVALUATING HEAVY METAL POLLUTION IN THE BATANG MASUMAI RIVER WATER, MERANGIN DISTRICT, JAMBI PROVINCE USING THE HEAVY METAL POLLUTION INDEX/HPI

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ABSTRACT

Evaluating Heavy Metal Pollution In The Batang Masumai River Water, Merangin District, Jambi Province Using The Heavy Metal Pollution Index/HPI. *River water pollution has become a major concern, particularly in regions where human activities occur without proper regulation. This study investigates heavy metal contamination in the Batang Masumai River, Merangin Regency, Jambi Province, where local residents conduct mining near the riverbanks. Water samples were taken from upstream, midstream and downstream, then analyzed using Atomic Absorption Spectrometry (AAS) to detect concentrations of seven metals: mercury (Hg), cadmium (Cd), nickel (Ni), iron (Fe), copper (Cu), manganese (Mn), and lead (Pb). Heavy metals are among the most dangerous pollutants due to their toxicity, persistence, and impact on human health Pollution levels were evaluated through the Heavy Metal Pollution Index (HPI) and compared with SNI 6242:2015 and WHO 2022 standards. The results showed that cadmium, nickel, iron, and mercury exceeded allowable limits. The HPI results reflect a serious level of water pollution. Based on the 2015 SNI standard, the HPI scores are 214.45 for downstream, a striking 57893.41 for midstream, and 120.61 for upstream. Using the the WHO 2022 criteria, the values are 486.03 (downstream), 4.186.55 (midstream) and 267.83 (upstream). Except for the upstream based on SNI 6242:2015, all areas show high contamination levels (HPI ≥ 200), highlighting a concerning environmental issue. Mercury and cadmium, known for their high toxicity and bioaccumulation potential, were the most concerning. These findings underscore the urgent need for remediation efforts, continuous environmental monitoring, and increased public awareness to protect aquatic ecosystems and ensure the safety of water resources for surrounding communities.*

INTRODUCTION

River water is one of the surface water sources utilized by many communities to meet their daily needs. River water pollution has become a major issue in several countries, especially in developing nations such as Indonesia [1,3]. The increasing population, along with limited sanitation facilities and inadequate wastewater treatment systems, has led to significant surface water pollution. This underdevelopment in sanitation infrastructure has also triggered various problems, including the deterioration of surface and groundwater quality, air pollution, and public health concerns [4,5]
Water pollution such as rivers can be caused by various types of waste activities (waste),

ranging from organic waste, household waste, to hazardous and toxic waste from industry. Heavy metals such as chromium, lead, arsenic, cadmium, and mercury are often associated with dangerous health impacts [6,7]. These metals end up in the environment as a result of human activities, natural processes, and industrial activities [8,9]. The majority of heavy metals released into the environment come from industrial processes [10,11]. Large amounts of pollution are released into the air, water and land as a result of the use of metals in mining, smelting and manufacturing [12,13].
In the Merangin Regency of Jambi Province, there are several artisanal and small-scale mining activities carried out independently by local communities along the riverbanks. Some of these activities include gold mining and sand extraction, which are often conducted without proper environmental management. Industrial activities are also present near the Batang Masumai River, which further contribute to the pollution load in the area (14). Currently, the water quality in rivers across Merangin has begun to decline, as can be observed through changes in the physical characteristics of the water. Given this situation, it is important to assess the water quality of the Batang Masumai River, particularly in terms of heavy metal contamination.
River water quality is assessed by laboratory testing of 7 heavy metal parameters (Hg, Cu, Fe, Pb, Cd, Mn and Ni.) using the analysis method with Atomic Absorption Spectrometry (AAS), using SNI 6242: 2015 (mg/L) and WHO Guidelines for Drinking-Water Quality/MCL (mg/L) 2022 [14]. Focus on the suitability of river water as a source of drinking water and evaluated using the Heavy Metal Pollution Index (HPI) is a method to assess the level of heavy metal pollution in water [15]

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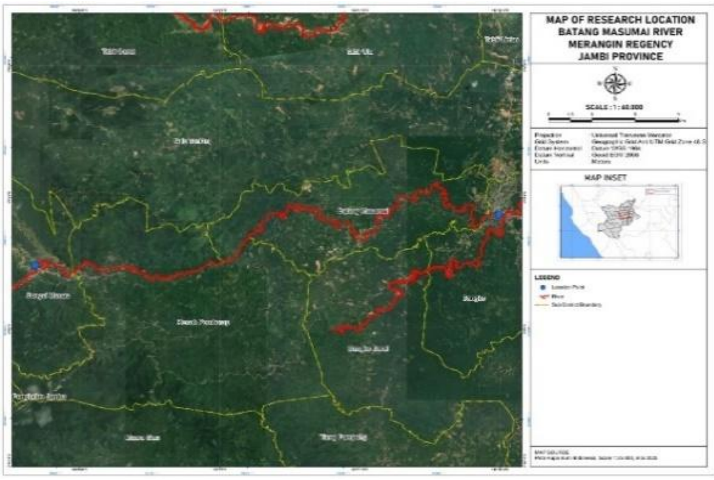

Figure 1. Sampling Locations in Batang Masumai River

The Batang Masumai River is located upstream in Kelumpang Hamlet, Sungai Manau District, the middle is in Salam Buku Village, Batang Masumai District, and downstream is in Pasar Atas Village, Bangko District. Batang Masumai River is one of the small rivers in Merangin Regency, which flows into the Merangin River [16–18]. The length of the Batang Masumai River is 100.74 km and the width is 40 m.The depth of the upstream river is 0.6 m, middle 1.6 m and downstream 1.5 m.Based on the results of the water quality examination of the Batang Masumai River carried out by BWS Sumatra IV, the average discharge of the Batang Masumai River in 2020 was 8.23 m3/second. [19] The research was conducted in March 2024.

Table 1. River Water Quality Classification

Class	Utility
I	Water that can be used as raw water for drinking water, and/or other uses that require the same water quality as its use..
II	Water that can be used for water recreation infrastructure/facilities, freshwater fish farming, animal husbandry, water for irrigating plants and/or other uses that require the same water quality as its use..
III	Water that can be used for freshwater fish farming, animal husbandry, water for irrigating plants and/or other uses that require the same water quality as its use.
IV	Water that can be used to irrigate plants and/or other uses that require the same water quality as its use.

Source :(Indonesian Government Regulation; 2021)

Water quality standards according to Government Regulation No. 22 of 2021 concerning the Implementation of Environmental Protection and Management, the size of the limits or levels of living things, substances, energy, or components that are or must be present and/or pollutant elements that are tolerated in river water, because our focus is on the suitability of river water as a source of drinking water, we use class 1 (Water that can be used for raw water for drinking water, and/or other uses that require the same water quality as its use).

MATERIALS AND RESEARCH METHODS

This research is an observational study, quantitative descriptive research design with a cross-sectional approach. The main focus of quantitative research is to measure the level of river water pollution, objectively Water Quality Measurement Laboratory (Observational). This study analyzed primary data from laboratory examinations in the form of water quality of the Batang Masumai River. Based on the measurement of 7 heavy metal parameters Hg, Cu, Fe, Pb, Cd, Mn and Ni. The sampling process involved several steps to ensure the collection of representative wastewater samples. Initially, samples were taken from domestic wastewater sources at three different points along the river. Each sampling location was carefully selected, and three replicate samples were collected at each site to ensure accuracy and consistency. Sampling was conducted during daylight hours to minimize the effects of environmental factors such as sunlight. The sampling procedure followed the guidelines and standards set by the government, specifically referring to SNI 8995:2021, to maintain quality and reliability of the collected data.

Samples were collected in separate polyethylene bottles for the measurement of selected heavy metals (Hg, Cu, Fe, Pb, Cd, Mn and Ni.). About 2 mL of 65% HNO3 was added to prevent metal precipitation [21]. Laboratory Analysis: Testing for heavy metal content using techniques such as Atomic Absorption Spectrophotometry (AAS).

Table 2. Determination of Sampling Points for the Batang Masumai River, Merangin Regency, Jambi Province

Location	**Coordinate Points**	**Information**
Kelumpang Village, Sungai Manau District	101°58'58.008" E - 2°6'26.948" S	Upstream
Greetings Book Village, Batang Masumai District	102°15'24.496" E - 2°4'35.468" S	Midstream
Pasar Atas Subdistrict, Bangko District	102°16'26.592" E - 2°4'23.832" S	Downstream

The assessment of river water quality is conducted through the laboratory analysis of seven key heavy metal parameters, namely mercury (Hg), copper (Cu), iron (Fe), lead (Pb), cadmium (Cd), manganese (Mn), and nickel (Ni). This evaluation employs the SNI 6242:2015 standard and the World Health Organization (WHO) Guidelines for Drinking-Water Quality (2022), with a primary emphasis on determining the water's suitability as a potential source of drinking water.

A widely used method to quantify heavy metal contamination in aquatic systems is the Heavy Metal Pollution Index (HPI). This index evaluates contamination by comparing the concentration of heavy metals present in a water sample with threshold values established by national and international regulatory bodies. The HPI methodology comprises several systematic steps, including sample collection, chemical analysis, establishment of standard limits, and computation of index values [22]

The maximum permissible limit (Si) for each heavy metal is determined based on its toxicity and potential health effects, as defined by standards such as those from SNI and WHO. This value represents the threshold beyond which the presence of the metal poses a health risk. The actual concentration of each heavy metal in the water sample is denoted as Ci. The relative pollution level of each metal is quantified by calculating a sub-index (Qi) using the formula:

$$Qi = \times 100\left(\frac{Ci}{Si}\right)$$

Where Qi represents the sub-index of the *i-th* metal, Ci is the observed concentration, and Si is the corresponding permissible limit [23]

To account for the relative toxicity of each heavy metal, a unit weight (Wi) is assigned. This weight is inversely proportional to the permissible concentration limit, meaning that metals with lower permissible thresholds (indicating higher toxicity) are given greater significance in the index calculation. The unit weight is computed using the equation [24]

$$Wi = \left(\frac{1}{S_i}\right)$$

The HPI is calculated by combining the sub-index values, each weighted based on its unit weight.[22]. Here is the general formula for calculating HPI:

$$HPI = \frac{\sum (Wi \times Qi)}{\sum Wi}$$

Information:

Qi is a sub-index of the i-th metal

Wi is the unit weight of the i-th metal.

Where HPI is the Heavy Metal Pollution Index, Wi is the unit weight, and Qi is the sub-index

for each metal. The summations are carried out over all heavy metals considered in the study. The resulting HPI value offers a comprehensive interpretation of heavy metal contamination levels in the water body:
HPI < 100: Indicates low contamination, and the water is generally considered safe for human consumption.
100 ≤ HPI < 200: Reflects moderate contamination, necessitating routine monitoring and potentially preventive measures.
HPI ≥ 200: Signifies high contamination levels, warranting immediate attention and remediation to ensure water safety.
The application of the HPI provides a robust, quantitative framework for evaluating water quality, particularly with respect to heavy metal pollution. This approach facilitates the identification of contamination hotspots and supports the development of targeted water management and remediation strategies (Rahman et al., 2024). Regulatory thresholds used in this analysis are established based on extensive scientific research on toxicology and public health impacts.

Table 3. Heavy Metal Standards for Drinking Water

Heavy Metal	SNI 6242:2015 (mg/L)	WHO 2022 (mg/L)
Mn (Manganaese)	0.05	0.08
Cd (Cadmium)	0.003	0.003
Cu (Copper)	0.5	2.00
Pb (Lead)	0.01	0.01
Ni (Nickel)	0.02	0.07
Fe (Iron)	0.2	0.30
Hg (Merkury)	0.001	0.006

Source:(WHO, 2022:Khalid et al., 2020:SNI 6242:, 2015)

RESEARCH RESULTS AND DISCUSSION

Laboratory Analaysis Results

The results of the water quality analysis of the Batang Masumai River conducted in the Padang State University laboratory on March 19, 2025 using the Atomic Absorption Spectrometry (AAS).
The heavy metal analysis covered seven parameters: Manganese (Mn), Cadmium (Cd), Copper (Cu), Lead (Pb), Nickel (Ni), Iron (Fe), and Mercury (Hg).

Table 4. Heavy Metal Concentration Levels in River Water

Heavy Metal	River Location		
	Downstream	Midstream	Upstream
Mn	-0.0044	-0.0049	-0.0123
Cd	0.0269	0.0188	0.0146
Cu	0.0536	0.0523	0.0559
Pb	-0.0479	0.0038	-0.0349
Ni	0.0382	0.0393	0.0287
Fe	6.1488	5.4628	5.4800
Hg	-0.0285	0.8714	-0.0285

HPI calculation using standard quality standards SNI 6242 :2015

Heavy Metal Pollution Index (HPI) is a method to assess the level of heavy metal pollution in water. Here we use the HPI formula based on the concentration of heavy metals in the water being tested, compared to the threshold set by water quality standards.SNI 6242 :2015.

Table 5. Heavy Metal Concentration Levels

Heavy Metal	River Location			SNI (mg/L)
	Downstream	Midstream	Upstream	
Mn	-0.0044	-0.0049	-0.0123	0.05
Cd	0.0269	0.0188	0.0146	0.003
Cu	0.0536	0.0523	0.0559	0.5
Pb	-0.0479	0.0038	-0.0349	0.01
Ni	0.0382	0.0393	0.0287	0.02
Fe)	6.1488	5.4628	5.4800	0.2
Hg	-0.0285	0.8714	-0.0285	0.001

Source : (SNI 6242:, 2015)

The sub-index (Qi)

Table 6. Qi (Sub-Indeks Logam)

Logam Berat	Downstream Qi (%)	Midstream Qi (%)	Upstream Qi (%)
Mn	0	0	0
Cd	896.67	626.67	486.67
Cu	10.72	10.46	11.18
Pb	0	38	0
Ni	191	196.5	143.5
Fe	3074.4	2731.4	2740
Hg	0	87140	0

Heavy Metal Unit Weight (Wi)

Each heavy metal is assigned a unit weight (Wi) based on its relative importance and toxicity. The unit weight is inversely proportional to the permissible limit, reflecting that metals with higher toxicity should have a greater weight.[28].

Table 7. W**i** Heavy Metal Weight)

Heavy Metal	Si (mg/L)	Wi = 1 / Si SNI
Mn	0.05	20
Cd	0.003	333.33
Cu	0.5	2
Pb	0.01	100
Ni	0.02	50
Fe)	0.2	5
Hg	0.001	1000
	Total ∑Wi	1510.33

Table 8. Wi × Qi (Bobot Logam Berat x Sub-Indeks Logam)

Heavy Metal	Downstream Wi × Qi	Midstream Wi × Qi	Upstream Wi × Qi
Mn	0	0	0
Cd	298888.9	208889	162222.22
Cu	21.44	20.92	22.36
Pb	0	3800	0
Ni	9550	9825	7175
Fe)	15372	13657	13700
Hg	0	87140000	0
∑	323832.55	87486391.81	182119.58

Heavy Metal Pollution Index (HPI)

The HPI is calculated by combining the sub-index values, each weighted based on its unit weight.[29].
Here is the general formula for calculating HPI:

$$HPI = \frac{\sum (W_i \times Q_i)}{\sum W_i}$$

Table 9. Heavy Metal Pollution Index/HPI

Location Point	∑ (Wi × Qi)	∑ Wi	HPI
Downstream	323832.55	1510.33	214.45
Midstream	87486391.81	1510.33	57893.41
UpStream	183119.58	1510.33	120.61

Information :

Downstream = 214.45
HPI ≥ 200→ High contamination This means that heavy metals in downstream areas are quite dangerous, especially because Cadmium and Iron are quite high.
Middle = 57893.41
*HPI ≥ 200*very, very extreme → Very high contaminationThis is mainly due to the super high mercury (87,140× Wi). This mercury metal needs special attention, it is dangerous to health.
Up Stream = 120.61
100≤ HPI < 200→ Moderate contamination Still alert, but lower than downstream and midstream.

There is high to extreme heavy metal pollution in the middle and downstream areas of the River. Very high values (≥ 200) indicate high contamination in the middle and downstream locations. HPI values far above 200 indicate that the concentration of heavy metals, especially metals such as cadmium and mercury, has reached a very high level and far exceeds the permissible limit. This location requires serious attention and immediate remediation measures to reduce the impact of contamination on groundwater quality and to ensure that water can be safely consumed. Negative values in the initial data are values below the detection limit, for negative or minus values must be changed to zero so that the HPI calculation is valid.

HPI calculation using standard quality standardsWHO Guideline for Drinking Water Quality/MCL 2022 River Water

Table 10. Heavy Metal Concentration Levels in River Water
And WHO Guidelnies for Drinking Water Quality/MCL 2022

HM	Lokasi Sungai			WHO 2022 (mg/L)
	Downstream	Midstream	Upstream	
Mn	-0.0044	-0.0049	-0.0123	0.08
Cd	0.0269	0.0188	0.0146	0.003
Cu	0.0536	0.0523	0.0559	2.00
Pb	-0.0479	0.0038	-0.0349	0.01
Ni	0.0382	0.0393	0.0287	0.07
Fe)	6.1488	5.4628	5.4800	0.30
Hg	-0.0285	0.8714	-0.0285	0.006

Laboratory results on river water Cadmium, Iron and Mercury have exceeded WHO quality standardsGuideline for Drinking Water Quality/MCL 2022

The sub-index (Qi)

Tabel 11. Qi (Metal Sub-Index)

HM	Qi Downstream	Qi Midstream	Qi Upstream
Mn	0	0	0
Cd	896.67	626.67	486.67
Cu	2.68	2.62	2.80
Pb	0	38.00	0
Ni	54.57	56.14	41.00
Fe	2049.60	1820.93	1826.67
Hg	0	14523.33	0

Heavy Metal Unit Weight (Wi)

Tabel 12. Qi (Metal Sub-Index)

Heavy Metal	Maximum Limit (Si)	Wi = 1/Si WHO
Mn	0.08	12.50
Cd	0.003	333.33
Cu	2.00	0.50
Pb	0.01	100
Ni	0.07	14.29
Fe	0.30	3.33
Hg	0.006	166.67
	Total ∑Wi	630.62

Table 13. Calculating Wi×Qi for each metal and location

Logam Berat	Downstream Wi×Qi	Midstream Wi×Qi	UpStream Wi×Qi
Mn	0	0	0
Cd	2989	2089	162222.22
Cu	1.34	1.31	1.40
Pb	0	3800	0
Ni	779.87	802.13	586.89
Fe	6823.16	6064.23	6088.89
Hg	0	2420550	0
∑	306,492.70	2,640,117.57	168,898.22

Heavy Metal Pollution Index (HPI)

The HPI is calculated by combining the sub-index values, each weighted based on its unit weight.[29]. Here is the general formula for calculating HPI:

$$HPI = \frac{\sum (Wi \times Qi)}{\sum Wi}$$

Table 14. Heavy Metal Pollution Index/HPI

Lokasi	∑(Wi× Qi)	∑Wi	HPI
Downstream	306,492.70	630.62	486.03
Midstream	2,640,117.57	630.62	4186.55
Upstream	168,898.22	630.62	267.83

HPI Description:

Downstream (486.20) → High contamination (HPI ≥ 200)
Midstream (4198.55) → High contamination (HPI ≥ 200) but higher than other locations
Upstream (267.83) → High contamination (HPI ≥ 200)

The Batang Masumai River demonstrated elevated pollution levels across all observed sites—upstream, midstream, and downstream. Among these, the midstream site exhibited the highest measurement at 4,198.73, reflecting a condition of extreme contamination. This observation aligns with the findings of Andriani (2023), who reported that mercury concentration indices at all three sampling points were categorized as highly polluted. Such conditions indicate that the river water in this area is unsuitable for direct human consumption without adequate treatment. Prolonged exposure to mercury-contaminated water poses serious public health risks, including neurological impairments, kidney damage, and developmental disorders, particularly in children and pregnant women. Consequently, immediate and sustained remediation efforts are essential to restore water quality and protect community health.

CONCLUSIONS AND RECOMMENDATIONS

This research offers an in-depth assessment of heavy metal contamination in the Batang Masumai River, located in Merangin Regency, Jambi Province, during March 2025. Findings revealed that cadmium (Cd), nickel (Ni), and iron (Fe) concentrations exceeded the permissible limits set by SNI 6242:2015, with cadmium and iron also surpassing the thresholds outlined in the WHO Guidelines for Drinking Water Quality/MCL 2022. While lead (Pb) and manganese (Mn) levels generally remained within acceptable ranges, several other heavy metals were frequently detected above safe limits, creating notable health risks for the surrounding communities. Based on the Heavy Metal Pollution Index (HPI) calculated using SNI 6242:2015 standards, downstream and midstream sites recorded values of 214.45 and 57,893.41, respectively—both classified as very high contamination (HPI ≥ 200) due largely to elevated mercury concentrations—while the upstream site recorded 120.61, indicating moderate contamination (100 ≤ HPI < 200). Using WHO standards, HPI values for downstream, midstream, and upstream sites were 486.03, 4,186.55, and 267.83, respectively, all categorized as highly contaminated (HPI ≥ 200), with the midstream site displaying particularly extreme levels. These results highlight the urgent need for remediation to reduce heavy metal levels—especially cadmium and mercury—and ensure that the water is safe for human consumption. The study emphasizes the necessity of continuous monitoring and focused interventions, particularly in the midstream region where contamination is most severe.

Effectively tackling heavy metal contamination requires a comprehensive approach that integrates suitable remediation technologies with policy-driven measures tailored to the contamination profile of each location. Priority should be given to areas experiencing the highest pollution loads, while ongoing surveillance in less impacted zones remains essential to maintain overall water quality. In addition to technical interventions, fostering strong community involvement and collaboration with key stakeholders is critical for ensuring the effectiveness and sustainability of remediation programs. Encouraging public participation in water quality monitoring and educational outreach can strengthen control measures and cultivate a shared sense of responsibility. Overall, the outcomes of this study provide a sound foundation for evidence-based policymaking and support proactive initiatives to protect both water resources and public health.

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