

Analysis of Shallow Groundwater Pollution Levels Using Physical and Chemical Parameters around the Gold Mine in Longlongan Village Sekotong Tengah

Noviani^{1*}, Lalu Ahmad Didik Meiliyadi^{1,2}, Irwan¹, Isniwana Damayanti^{2,3}

¹Departement of Physics Education, Faculty of Education and Teacher Training, Universitas Islam Negeri Mataram, Jln. Gajah Mada 100, Jempong Baru, Mataram, Indonesia

²Advance Science and Integration Research Group, Universitas Islam Negeri Mataram, Jln. Gajah Mada 100, Jempong Baru, Mataram, Indonesia

³Departement of Natural Science Education, Faculty of Education and Teacher Training, Universitas Mataram, Mataram, Indonesia

*e-mail: 210108022.student@uinmataram.ac.id

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Abstract. This study was conducted in small-scale gold mining areas in the Sekotong Tengah region, which have the potential to cause environmental pollution, particularly to the quality of shallow groundwater that is widely used by the community for daily needs. This study aims to analyze the level of shallow groundwater pollution around the Sekotong Tengah gold mine based on physical and chemical parameters. The physical parameters analyzed include temperature and total dissolved solids (TDS), while the chemical parameters include copper (Cu) content, shallow groundwater pH, and mercury (Hg). This study uses a quantitative descriptive method with groundwater sampling at several shallow groundwater points located around the mining area. The analysis results show that several groundwater quality parameters have changed from their natural conditions, especially in terms of pH and heavy metal Hg content, which are indicated to exceed the established quality standards. This shows the impact of gold mining activities on shallow groundwater quality. Based on the results of this study, it can be concluded that shallow groundwater around the Sekotong Tengah gold mine has the potential to be polluted and requires environmental management efforts and continuous water quality monitoring to protect public health and sustainability.

Keywords: Shallow Groundwater, Physical Parameters, Chemical Parameters, Gold Mining, Pollution.

INTRODUCTION

Mining is one of the industries that plays an important role in the country's economic development (Sumardi et al., 2022). Mining activities must be carried out with consideration for environmental principles. Mining generally has an impact on the environment (soil, water, air, living organisms) and socio-economic conditions (Toyoda et al., 2022). Mining is a phenomenon that often arises in society is pollution. One type of pollution that is very dangerous is water pollution (Meiliyadi et al., 2025). High levels of water pollution can cause a lot of damage to both humans and the surrounding environment. Water pollution can cause environmental problems and is closely related to air pollution and land use (Sudarningsih, 2021; Syuzita et al., 2022).

Gold mining also has positive and negative impacts on the environment and society. The area around the mine is very prone to gold processing using fusion and cyanidation methods pioneered by migrant communities (Mirayanti et al., 2025). This process has become increasingly common when gold ore has characteristics suitable for processing through fusion and cyanidation. However, simple gold processing technology neglects worker safety and the processing environment. The impact of gold mining activities can also include water pollution due to the use of chemicals (hazardous and toxic substances such as mercury, cyanide, etc.) and the exposure of chemicals from mining materials that then pollute water sources (Toyoda et al., 2022). Various techniques have been used to address heavy metal pollution, which can generally be classified into three categories: physical, chemical, and biological approaches. Gold

mining activities, especially those carried out by communities traditionally or without official permits, generally use simple technology and hazardous chemicals such as mercury (Hg) and cyanide (CN). The use of these materials has a high potential to pollute the environment if the processing waste is not managed properly (Meiliyadi et al., 2024a).

Shallow groundwater around mining areas is highly vulnerable to pollution (Meiliyadi & Syuzita, 2022). Its proximity to the ground surface makes this water easily contaminated by mining waste, both in the form of heavy metals and other chemical compounds. In addition, the geological conditions and soil types in Central Sekotong allow mining waste to quickly seep into the groundwater layer. This condition is a serious concern because shallow groundwater is the main source of water for the community for cooking, bathing, and daily consumption. Physically, this can be seen from the opening of a large area of land into barren land in the form of a sandy field containing tailings. Chemically, it causes pollution of water, soil, and vegetation due to the use of hazardous substances (Nurhidayati et al., 2021). Biologically, it can be seen from the loss of vegetation and associated organisms (Nair et al., 2022).

In the Sekotong Tengah region, small-scale gold mining has been going on for quite some time and has become a source of livelihood for some communities. However, these activities often neglect environmental safety and health aspects. Liquid and solid waste from gold processing is generally disposed of directly into the surrounding environment, both into the soil and water bodies, without undergoing any prior treatment (Ezzeddine et al., 2021). This condition raises concerns about the contamination of shallow groundwater used by the community for their daily needs.

Various studies have shown that gold mining activities have a significant impact on the quality of surrounding water (Meiliyadi et al., 2023). However, to date, there has been no study that specifically focuses on the quality of well water around the Pelangan Gold Mine in Sekotong. This is a particular concern, given that the community in the area is highly dependent on well water to meet their daily needs, such as bathing, cooking, washing, and various other household activities. Well water is the main source of clean water for them, so its quality directly affects the health and lives of the community. Therefore, this research is urgent and important, especially to identify whether the well water in the area has been contaminated by hazardous chemicals such as mercury, arsenic, and various other heavy metals that may be produced by gold mining activities.

pH and TDS measurement activities also help the community and industry in maintaining water quality (Meiliyadi et al., 2024b). By knowing the pH and TDS values, we can determine whether the water is suitable for consumption, use in agriculture, or industrial purposes. This is an important basis for efforts to maintain health, the environment, and the sustainability of water resources.

RESEARCH METHODS

In this study, the population studied was all wells around the Longlongan village, Sekotong mine, Sekotong District, West Lombok Regency. There are 4 well water points around the Pelangan Sekotong gold mine. Referring to Permenkes No. 32 of 2017 concerning methods for sampling well water, the sampling point for well water must take into account the flow pattern of the well water. Samples can be taken from free (unpressurized) well water and pressurized well water. In this study, well water samples were taken from free (unpressurized) well water, which could come from dug wells or drilled wells.

Physical parameter analysis was performed using a TDS meter, including Temperature and total dissolved solids (TDS) (Nurhidayati et al., 2021). Chemical parameter analysis included Hg and Cu content measured using Atomic Absorption Spectroscopy (AAS) and well water acidity (pH) measured using a pH meter (Syuzita et al., 2022). The data produced then compared with the standard water quality values based on Indonesian Minister of Health Regulation No. 32 of 2017. The measurements were taken twice. The following are the formulas for determining the

average value of each sample and the standard deviation formula as shown in equation 1 and equation 2 (Asri et al., 2021; Didik et al., 2020; Ningsih; et al., 2019).

$$\bar{x} = \frac{\sum_{i=1}^n x_i}{n} = \frac{x_1 + x_2 + x_3 + \dots + x_n}{n} \quad (1)$$

$$s_d = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n - 1}} \quad (2)$$

RESULTS AND DISCUSSION

Measurement of Physical Parameters

Temperature is a relative measure of the thermal condition of an object. Its relativity means that an object can undergo changes in thermal condition as a result of heat transfer from a hotter object to a cooler object, thereby creating thermal equilibrium.

This study found that the temperature of each sample was still within the threshold range of approximately 26-30 °C. This indicates that the temperature parameter is still safe for the well water studied. Temperature plays an important role in various natural processes and human activities. In the environmental field, temperature affects climate, weather, and ecosystem conditions. Temperature changes can affect plant growth, animal activity, and the overall environmental balance. Water temperature, for example, greatly affects the life of aquatic organisms (Meiliyadi et al., 2024b).

Temperature measurements of four shallow groundwater samples showed that water temperature is a relatively stable parameter with insignificant variations, meeting drinking water quality standards and health quality standards for clean water. Water temperature is an important parameter in maintaining the balance of aquatic ecosystems, especially for the metabolic processes of aquatic biota (Syuzita et al., 2022). An increase in temperature will cause dissolved oxygen in the water to increase, thereby increasing oxygen consumption by aquatic organisms but, on the other hand, having an impact on the decrease in oxygen solubility in water.

Naturally, groundwater temperature tends to be more stable than surface water temperature because it is protected by a layer of soil. However, gold mining activities that clear land and remove vegetation can increase the temperature of the surrounding environment. The loss of land cover causes an increase in direct sunlight exposure to the soil surface, which in turn can affect shallow groundwater temperature. This condition can accelerate the physical and chemical processes that occur in groundwater (Wahyuni et al., 2023).

An increase in water temperature can increase the solubility of heavy metals such as copper (Cu) and mercury (Hg), making these metals more easily dissolved and dispersed in groundwater. In addition, higher temperatures can also affect the activity of microorganisms that play a role in the degradation of pollutants. Therefore, regular monitoring of shallow groundwater temperature is still necessary to support water quality and environmental management around the Sekotong Tengah gold mining area.

The results of Total Dissolved Solids (TDS) measurements in shallow groundwater around the Sekotong Tengah gold mine show significant variations between samples, as shown in Table 1. Well A water samples have very high TDS values, while other samples are in the middle range. This is due to their proximity to the gold mine processing source. High TDS values indicate a large amount of dissolved substances in the water, both inorganic minerals and compounds resulting from human activities. This condition is strongly suspected to be influenced by gold mining activities that cause the dissolution of rock minerals into groundwater. When compared to drinking water quality standards, the TDS values at the research location tend to exceed the specified threshold, so that the groundwater is potentially unfit for direct consumption.

Table 1. TDS Measurement Results

No	Point Sampling	Experiment I	Experiment II	Average	Standard Deviation	Description
1	A	2095	2195	2145.0	7.07	Exceeding the threshold
2	B	588	578	573.5	6.57	Below the threshold
3	C	579	599	566.5	4.95	Below the threshold
4	D	765	773	769.0	2.47	Below the threshold
Threshold				1000 mg/L		

TDS levels can affect water quality, especially in terms of taste, clarity, and usability. Water with low TDS generally has a fresher taste, while water with high TDS can taste bitter or salty. In everyday use, water with excessively high TDS can also cause scaling on household appliances and water pipes. Although TDS is not always harmful, excessively high TDS levels can be an indicator of the presence of harmful substances in the water. Therefore, TDS measurement is important to ensure that water is suitable for consumption, household use, and industrial use. Water treatment such as filtration and reverse osmosis are often used to reduce TDS levels to meet water quality standards (Syuzita et al., 2022).

Soluble substances that affect TDS can come from natural sources or human activities. Naturally, water that passes through soil and rocks will dissolve certain minerals. Meanwhile, household, agricultural, and industrial waste can also increase the TDS value in water. TDS does not indicate the type of substances contained, only the total amount. The TDS value is important because it is related to water quality. Water with low TDS generally tastes fresher and is safer for consumption, while excessively high TDS can affect the taste of water and indicate the presence of certain contaminants. In everyday life, TDS also affects the use of water for cooking, washing, and household appliances.

TDS measurement is usually performed using a device called a TDS meter. This device works by measuring the electrical conductivity of water, as the more dissolved substances there are, the higher the conductivity. By knowing the TDS value, we can assess whether the water is suitable for use according to our needs, such as for drinking, aquariums, or industrial purposes.

Theoretically, TDS content will increase if contaminated by household, agricultural, and industrial waste (Irwan et al., 2016). Rocks and air containing calcium, bicarbonate, phosphorus, and other minerals can also cause TDS (Sari & Huljana, 2019). Referring to Dwi Rani's research, the TDS level in the study area did not exceed the threshold limit due to the existence of gold mining far from the river flow and sedimentation in the Batanghari River.

Measurement of Chemical Parameters

pH is one of the organic chemical parameters used to determine the level of acidity or alkalinity in groundwater. According to health quality standards for hygiene and sanitation purposes, the pH of water ranges from 6.5 to 8.5 (Didik et al., 2014; Yahdi et al., 2025). Groundwater is considered acidic if its pH value exceeds 8.5, in which case the water is alkaline.

The pH measurements taken around the Sekotong gold mine in this study also varied, as shown in Table 2. Sample A had a pH value of 6.2, sample B 6.8, sample C 7.5, and sample D 8.2. There are several factors that influence pH fluctuations around the Sekotong Tengah gold mine. One of them is the distance from the sampling location.

Table 2. pH Measurement Results

Point Sampling	pH	Description
A	6.2	Below quality standards
B	6.8	Still meets quality standards
C	7.5	Meets quality standards
D	8.2	Within quality standards

pH values that are not within the neutral range can increase the solubility of heavy metals such as copper and mercury. This condition causes heavy metals to dissolve more easily and spread in groundwater. Small-scale gold mining activities that use chemicals have the potential to cause changes in the pH of shallow groundwater. Gold processing waste containing certain chemical compounds can lower or raise the pH value of water. Water with a pH that is too acidic or too alkaline is not suitable for use as clean water because it can cause corrosion in pipes, reduce user comfort, and increase the solubility of heavy metals in water. Therefore, regular pH monitoring is essential as an early indicator of changes in water quality and as a basis for efforts to control environmental pollution around the Sekotong Tengah gold mining area.

pH measurement results around the Sekotong Tengah gold mine show variations between samples. Sample A had a pH value of 6.2, sample B 6.8, sample C 7.5, and sample D 8.2. These differences in pH values were influenced by several factors, one of which was the distance of the sampling location from the mining activity site. Soil conditions and interactions with mining waste chemicals can also affect pH fluctuations. pH values that are not in the neutral range can increase the solubility of heavy metals such as copper (Cu) and mercury (Hg). This condition causes these metals to dissolve more easily and spread in groundwater, thereby increasing the risk of contamination. Therefore, pH is not only an indicator of water acidity but also plays a role in assessing the risk of chemical pollution in the environment around the mine.

The results of the analysis of copper (Cu) content in four shallow groundwater samples show that the Cu content in sample A (0.005 mg/L) is far below the established quality standards, as shown in Table 3. In contrast, sample B shows a Cu content of 0.79 mg/L, which exceeds the quality standards. Similarly, samples C and D showed values of 0 mg/L, indicating that there was no accumulation of Cu metal at that point.

Table 3. Cu content Measurement Results

Point Sampling	Cu Content (mg/L)	Description
A	0.005	Below quality standards
B	0.79	Exceeds quality standards
C	0	Not detected
D	0	Not detected

Copper is an essential metal, meaning that it is needed by living organisms at certain levels, but can be toxic in excess. The results of the copper analysis show that most samples are still below the quality standard, but one sample has a copper content that exceeds the permissible threshold. This condition indicates the presence of localized Cu contamination. The high Cu content is thought to originate from the weathering of mineral rocks and gold mining waste entering the groundwater system (Wati et al., 2023). Meanwhile, the undetectable presence of Cu in several samples indicates that the distribution of heavy metal contamination is uneven and greatly influenced by the distance from the source of contamination and local hydrogeological conditions.

In addition, the presence of Cu in groundwater can also affect the organoleptic quality of water, such as taste and color. Therefore, although some of the measurements are still within safe limits, the increase in Cu levels in shallow groundwater around the Sekotong Tengah gold mine needs to be watched and requires continuous monitoring to prevent more serious pollution. Excessive copper exposure can cause health problems, such as gastrointestinal irritation, nausea, vomiting, liver and kidney damage. In aquatic organisms, high copper concentrations can inhibit the growth, reproduction, and survival of various types of fish and plankton. Therefore, monitoring copper content in water, especially groundwater used for human consumption, is very important to prevent health risks and ecosystem damage.

In the context of gold mining, copper is often found together with gold ore and can be carried into groundwater through the process of mining waste dissolution. Although copper concentrations in shallow groundwater are usually still below quality standards, its presence must still be monitored, as long-term accumulation of this metal can have an impact on human health and aquatic organisms. Waste management and routine water quality monitoring are key to controlling the risk of copper pollution.

The high Cu content is thought to originate from the weathering of mineral rocks and gold mining waste entering the groundwater system. While some samples did not detect Cu, this indicates that the distribution of heavy metals is uneven. The presence of Cu in groundwater can also affect the organoleptic quality of water, such as taste and color, so even though some samples are still safe, continuous monitoring is still necessary (Didik, 2016).

Excessive copper exposure can have negative effects on human health, such as gastrointestinal irritation, nausea, vomiting, and liver and kidney damage (Tarigan et al., 2025; Wadhawan et al., 2020). In aquatic organisms, high copper concentrations can inhibit the growth, reproduction, and survival of fish and plankton. Therefore, monitoring Cu levels is very important to protect human health and ecosystem sustainability (Feisal et al., 2024).

In the context of gold mining, copper is often carried into groundwater through the dissolution of mining waste. Although copper concentrations in shallow groundwater are usually still below quality standards, its presence must still be monitored. Proper waste management and routine water quality monitoring are key to controlling the risk of Cu pollution and ensuring environmental sustainability around mining areas (Tan et al., 2022).

The results of Hg analysis as shown in Table 4 indicate that the mercury (Hg) content in shallow groundwater samples varies. Sample A (0.0006), Sample B (0.0012), Sample C (0.0009) and Sample D (0.0021). Samples A and C have Hg concentrations below the quality standard, so they are still considered safe in terms of mercury content. Conversely, samples B and D show Hg concentrations that exceed the quality standard, indicating the potential for pollution.

Table 4. Hg content Measurement Results

Point Sampling	Hg Content (mg/L)	Description
A	0,0006	Below quality standards
B	0,0012	Exceeds quality standards
C	0,0009	Below quality standards
D	0,0021	Exceeds quality standards

Increased Hg levels at several sampling points are thought to be related to gold mining activities, particularly the use of mercury in the amalgamation process (Mirayanti et al., 2025). This condition has the potential to pose health risks if groundwater is used for daily needs, thus requiring environmental management and regular water quality monitoring.

The main source of mercury (Hg) contamination in groundwater and waterways is gold mining activities that use mercury in the process of separating gold from ore. The use of mercury in traditional gold mining is often not well regulated, so that mercury used for the amalgamation process can pollute the environment. After use, mercury that is not bound or properly managed can be released into the environment and enter the groundwater system, poisoning nearby water sources. Mercury (Hg) is a heavy metal that occurs naturally in the environment. This metal is widely found in rocks, ore, soil, water, and air in the form of inorganic and organic compounds. Mercury has various chemical forms, including gas (Hg), inorganic mercury (Hg⁺ and Hg²⁺), and organometallic compounds such as femilmercury, dimethylmercury, and methylmercury (MeHg).

The results of mercury content analysis show that at several sampling points, mercury levels were detected in shallow groundwater. In fact, at several locations adjacent to mining

areas, mercury levels approached or exceeded the established quality standards. This indicates that gold mining activities contribute to the chemical contamination of groundwater.

Therefore, the high mercury (Hg) content in shallow groundwater around the Sekotong Tengah gold mine indicates the need for pollution control efforts, regular water quality monitoring, and the implementation of more environmentally friendly mining practices. The presence of mercury in groundwater is very dangerous because it is toxic and can accumulate in the human body. Mercury-contaminated groundwater has the potential to cause health problems if used in the long term. Therefore, the results of these chemical parameter measurements indicate that the quality of shallow groundwater around gold mines needs serious attention.

Excessive exposure to mercury can have serious health effects, particularly on the nervous system, kidneys, and brain development (Liosis et al., 2021; Nishad et al., 2025). Children and pregnant women are the most vulnerable to the effects of mercury because it can interfere with growth and cognitive function. Therefore, controlling mercury pollution and monitoring food and the environment are very important to protect the health of the Sekotong Tengah community.

CONCLUSION

The results of the study show that the physical parameters of temperature and Total Dissolved Solids (TDS) in shallow groundwater at the study site are generally still within the permissible range according to clean water quality standards. The water temperature is relatively stable and does not show significant deviations from the ambient temperature, so it does not trigger extreme physical or chemical changes. The measured TDS values indicate that the level of dissolved minerals is still safe, although at some points there is a tendency for an increase due to the influence of geological and mining activities around the site. The pH value of the groundwater is in the slightly acidic to neutral range, which indicates the influence of the surrounding environmental conditions, including the interaction of water with rocks and waste from gold mining activities. Although most pH values still meet quality standards, these pH changes have the potential to affect the solubility of heavy metals in groundwater if not properly managed. The results of copper (Cu) metal analysis show that the concentration of Cu in shallow groundwater is generally still below the quality standard threshold. This indicates that Cu pollution is not yet significant. Mercury (Hg) Content Confirms that mercury (Hg) content is the most critical parameter in this study. The discovery of Hg in several groundwater samples indicates strong contamination due to gold mining activities. The results of this study also show a relationship between the distance of wells from the mine site and groundwater quality. Wells located closer to the mining area tend to have lower water quality than wells further away. This confirms that gold mining activities have a direct impact on the level of shallow groundwater pollution. Regular monitoring is necessary to determine changes in water quality and prevent health risks to the communities that use it. Overall, shallow groundwater around the Sekotong Tengah gold mine has partially deteriorated in quality, although not all parameters exceed quality standards.

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