Analysis of Water Quality in Abandoned Illegal Gold Mining Pit in Ketapang Regency, West Kalimantan, Indonesia

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Abstract

Abandoned illegal gold mining pits in Ketapang Regency, West Kalimantan, Indonesia, have the potential to pose significant environmental risks due to residual contaminants from gold extraction processes. This study aimed to evaluate the water quality of such mining voids in accordance with the Indonesian Government Regulation No. 22 of 2021 (Annex VI) on surface water quality standards. The research team collected water samples from ten randomly selected points and analyzed them for cyanide (CN^-), mercury (Hg), temperature, pH, and total dissolved solids (TDS). The results showed that cyanide concentrations ranged from 0.0930 to 0.178 mg/L, exceeding the regulatory threshold of 0.02 mg/L by 4–9 times. In contrast, mercury was detected at 0.0000940 mg/L, well below the permissible limit of 0.002 mg/L. Water temperature (28.7–33.3°C) and TDS (20–22 mg/L) complied with regulatory standards, while pH values ranged from 3.83 to 4.43, reflecting the natural acidity of peatland environments in the study area. The elevated cyanide levels indicate that the water in these abandoned mining voids is not suitable for environmental or community utilization without prior treatment. These findings highlight the need for monitoring and environmentally sound remediation strategies to mitigate cyanide contamination risks in post-mining landscapes.

Keywords: *Environmental quality standards; Gold mining; Void; Water quality; Water pollution*

1. Introduction

Ketapang Regency, located in West Kalimantan, is one of the regions in Indonesia with significant mining potential, particularly in gold mining. Gold mining activities in Ketapang are not only managed by companies but also carried out by local communities, including illegal gold mining (PETI). Although the existence of gold mining has the potential to improve the local economy, it also poses considerable environmental impacts [1]. Mining activities in this area have resulted in the formation of mine voids, which can act as runoff ponds and potentially become sources of environmental pollution [2]. Water that accumulates in mine voids often contains suspended particles, heavy metals, and exhibits altered pH levels, which may negatively affect surrounding aquatic ecosystems [3].

According to Government Regulation No. 22 of 2021, industrial wastewater, including that originating from mining activities, must comply with established quality standards before being discharged into the environment. Furthermore, Annex VI of Government Regulation No. 22 of 2021 specifically regulates the national water quality standards. In certain circumstances where post-mining activities leave behind mine voids, these voids must provide economic, social, and environmental benefits [4]. More efficient utilization of such voids is expected to stimulate economic growth for both the community and local government [5].

Previous studies have shown that metal concentrations in mine void water can exceed the permissible threshold if not properly managed. Heavy metals are particularly hazardous due to bioaccumulation processes, in which the concentration of chemical elements increases in the bodies of living organisms, potentially leading to health impacts on humans depending on the organ or tissue where the metals accumulate [6]. Therefore, efforts to maintain the water quality of mine voids are crucial to ensure that such water remains suitable for potential utilization.

This study aims to analyze the water quality of mine voids resulting from illegal gold mining in Ketapang Regency. The findings are expected to provide information on the water quality status of gold mine voids and serve as recommendations for the sustainable management and optimal utilization of these aquatic resources. Based on this background, the study specifically evaluates whether the water

characteristics of illegal gold mine voids in Ketapang comply with the national water quality standards as stipulated in Government Regulation No. 22 of 2021, thereby offering recommendations for environmental management strategies to mitigate the adverse impacts of mine void water pollution.

Research on water quality in post-mining areas has been widely conducted, both in legal and illegal mining sites. Previous studies have indicated that tailing ponds from bauxite mining often contain physical and chemical parameters that fail to meet the established quality standards, particularly pH and BOD [5]. A study conducted in former coal mining voids reported that the water quality was still in compliance with Class I water designation, including parameters such as total phosphate, nitrate, and total *E. coli* bacteria [7].

Another study evaluating water quality and health risks related to illegal gold mining activities in the estuaries of the Pra and Ankobra Rivers, Ghana, revealed that turbidity, phosphate, lead, copper, and iron were the major contributors to water pollution, with potential health risks for local communities [8]. Research carried out in former gold mining areas in Tumbang Baringei Village and Tanoyan Selatan Village focused on mercury concentrations, which were found to remain below the threshold limits [9], [10].

Several other studies have also assessed water quality in former sand mining ponds and areas affected by illegal gold mining (PETI), demonstrating non-compliance with water quality standards for various designated uses [11] - [13]. However, a study on former gold mining ponds reported that water samples exceeding the permissible limits of water quality standards were only found in mining areas that had been abandoned for approximately one year [14].

While previous studies have documented mercury and cyanide contamination in post-mining waters in countries such as Ghana and Sudan, there is currently no site-specific assessment of abandoned illegal gold mining pits in Ketapang Regency, West Kalimantan. Most previous investigations have focused on legally operated mining sites, tailing ponds, or river systems impacted by mining activities, which differ in management practices, environmental controls, and post-operational reclamation measures. Illegal gold mining voids represent a distinct environmental concern, as they are typically unmanaged, lack engineered containment systems, and are often located in sensitive peatland ecosystems. Furthermore, there is a lack of integrated assessment evaluating both cyanide (CN^-) and mercury (Hg) contamination simultaneously within peat-dominated hydrological settings. To date, no study has comprehensively assessed the compliance of abandoned illegal gold mining void water in Ketapang against the national surface water quality standards stipulated in Government Regulation No. 22 of 2021 (Annex VI). Therefore, this study aims to fill this knowledge gap by providing site-specific empirical data and regulatory-based evaluation to support evidence-based environmental management in illegal post-mining landscapes.

2. Method

2.1. Study Area and Sampling Design

This study employed a quantitative field-based approach to evaluate water quality in abandoned illegal gold mining pits located in Sungai Pelang Village, Ketapang Regency, West Kalimantan, Indonesia. The study area is characterized by lowland topography with peat-dominated soils and swamp ecosystems.

Water sampling was conducted at ten randomly selected points within abandoned mining voids. The selection of ten sampling points was considered sufficient for a reconnaissance-level environmental assessment, given the relatively homogeneous morphology of the pits and safety constraints associated with unstable pit edges and landslide-prone areas. Random sampling was applied to minimize spatial bias while ensuring safe access during collection.

All samples were collected as surface grab samples at approximately 20–30 cm below the water surface to represent the most environmentally relevant water layer for potential exposure and ecological interaction. Sampling was conducted during daytime (between 10:00 and 13:00 local time) under relatively consistent weather conditions to reduce diurnal temperature variation effects.

The sampling location map is presented in the figure below.



Figure 1. Location Map of Sampling

2.2. Field Measurements and Sample Preservation

In situ measurements included temperature, pH, and Total Dissolved Solids (TDS), using calibrated portable instruments. Instrument calibration was performed prior to field measurements following manufacturer specifications.

Water samples for laboratory analysis were collected using clean polyethylene bottles and preserved according to Indonesian National Standard (SNI 6989). Cyanide samples were stabilized using NaOH to maintain pH >12, while mercury samples were acidified with HNO_3 to pH <2 to prevent metal adsorption and transformation. All preserved samples were stored in insulated containers and transported to the accredited Environmental Laboratory of the Housing and Environmental Agency (Perkim-LH) of Ketapang Regency within the recommended holding time.

Quality assurance and quality control (QA/QC) procedures included equipment calibration, duplicate sample verification, and laboratory blank analysis to ensure analytical reliability.

2.3. Laboratory Analysis

Cyanide (CN^-) concentrations were determined using the spectrophotometric method (IK-19/A/LLDK), while mercury (Hg) concentrations were analyzed using Atomic Absorption Spectrophotometry (AAS) in accordance with US EPA Method 7473 (2007). All analyses were conducted by certified laboratory personnel using calibrated instruments.

The method detection limit (MDL) was applied in reporting mercury concentrations. Values below the detection threshold were reported accordingly to reflect analytical limitations.

2.4. Data Analysis

The measured parameters, including cyanide (CN^-), mercury (Hg), temperature, pH, and TDS, were statistically summarized using descriptive statistics (minimum, maximum, mean, and standard deviation). The results were compared against the surface water quality standards stipulated in Government Regulation No. 22 of 2021 (Annex VI) to evaluate regulatory compliance. Comparative

analysis was conducted to determine the degree of exceedance relative to threshold values, particularly for cyanide concentrations, to assess potential environmental risk implications.

Table 3. Threshold Values of Surface Water Quality Standards (Lakes)

Parameter	Class I	Class II	Class III	Class IV
Cyanide (mg/l)	0,02	0,02	0,02	-
Mercury (mg/l)	0,001	0,002	0,002	0,005
Temperature (°C)	Dev 3	Dev 3	Dev 3	Dev 3
pH	6-9	6-9	6-9	6-9
TDS (mg/l)	1.000	1.000	1.000	1.000

The following are the threshold values of surface water quality standards as regulated in Government Regulation No. 22 of 2021, Annex VI on Environmental Protection and Management:

3. Results and Discussion

3.1. Cyanide (CN^-)

According to Government Regulation No. 22 of 2021, the permissible concentration of cyanide in surface water is limited to 0.02 mg/L. The cyanide (CN^-) concentration analysis was conducted at the Environmental Laboratory of the Department of Housing, Settlement, and Environment (Perkim-LH) of Ketapang Regency. The following figure presents a comparison of cyanide (CN^-) concentrations in abandoned illegal gold mining ponds with the standard values regulated in Government Regulation No. 22 of 2021.

Cyanide concentrations ranged from 0,093 to 0,178 mg/L, with a mean of 0,1235 ± 0,0289 mg/L (n = 10). These values exceed the Indonesian water quality standard (0,02 mg/L; Government Regulation No. 22/2021) by approximately six times on average, indicating consistent contamination across all sampling points rather than isolated hotspots.

Elevated cyanide levels are commonly associated with gold processing activities, particularly in poorly managed or illegal mining operations. Similar patterns of mining-related water contamination have been reported in other regions [15], [16]. In illegal mining contexts, the absence of environmental controls increases the likelihood of residual chemical persistence [17].

The acidic conditions observed in this study (mean pH 4,17) may enhance cyanide toxicity, as low pH favors the formation of hydrogen cyanide (HCN), a more toxic species. Acidic mine environments can also increase contaminant mobility and ecological risk [18].

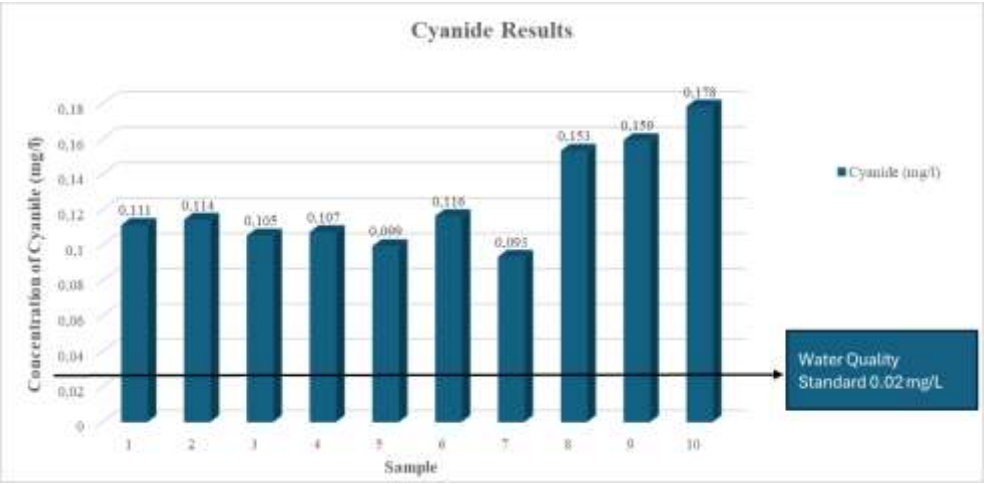

Figure 2. Cyanide (CN^-) Analysis Results

Given the relatively stagnant nature of abandoned mining pits, dilution potential is limited, allowing contaminants to persist. Potential exposure pathways include aquatic ecosystem exposure, groundwater interaction, and direct human contact. Cyanide inhibits cellular respiration and can cause acute toxicity at elevated concentrations. Considering that measured levels substantially exceed regulatory limits, the water cannot be considered environmentally safe. Effective management or remediation is therefore necessary to prevent long-term ecological impacts [19].

3.2. Mercury (Hg)

The mercury (Hg) concentration parameter in this study was analyzed at the Environmental Laboratory of the Department of Housing, Settlement, and Environment (Perkim-LH) of Ketapang Regency. The following figure presents a comparison of mercury (Hg) concentrations in water from abandoned illegal gold mining ponds with the quality standards established by Government Regulation No. 22 of 2021.

Based on laboratory analyses of water samples collected from 10 points in the abandoned artisanal and small-scale gold mining (ASGM) ponds in Sungai Pelang Village, the detected mercury (Hg) concentration at all sampling points was uniformly reported as 0,0000940 mg/L. This uniformity is attributable to the analytical method detection limit (MDL) applied during laboratory testing. The reported value represents the lowest quantifiable concentration measurable by the instrument, indicating that mercury was present at trace levels but remained below the reliable quantification range. Therefore, the identical values do not imply homogeneous environmental concentrations but rather reflect methodological reporting limitations.

Referring to Government Regulation No. 22 of 2021 (Annex VI – Surface Water Quality Standards), the maximum permissible limit for mercury (Hg) is 0,002 mg/L. The detected concentration corresponds to only 4.7% of the regulatory threshold, indicating compliance with national water quality standards. Nevertheless, the presence of mercury, even at trace levels, warrants attention due to its persistence, toxicity, and potential transformation into methylmercury (MeHg), which is bioaccumulative and poses ecological and human health risks.

The relatively low mercury concentration in surface water at the study site may be influenced by several factors. First, the cessation of ASGM activities has eliminated active pollutant inputs. A study conducted in Tambang Sawah, Bengkulu, reported low mercury concentrations in river water (0.0011 ppm) but substantially higher concentrations in sediments (114,37 ppm), indicating that mercury tends to accumulate in sediments following the termination of mining activities [20].

Second, mercury exhibits strong affinity for particulate matter and organic material, promoting rapid sedimentation in aquatic systems. Research has shown that mercury concentrations are typically highest in sediments, intermediate in aquatic biota, and lowest in surface waters [21]. This behavior supports the likelihood that residual mercury at the study site may be predominantly sediment-bound rather than dissolved in the water column. Given that sampling in this study focused on surface grab samples, sediment-associated mercury was not directly evaluated.

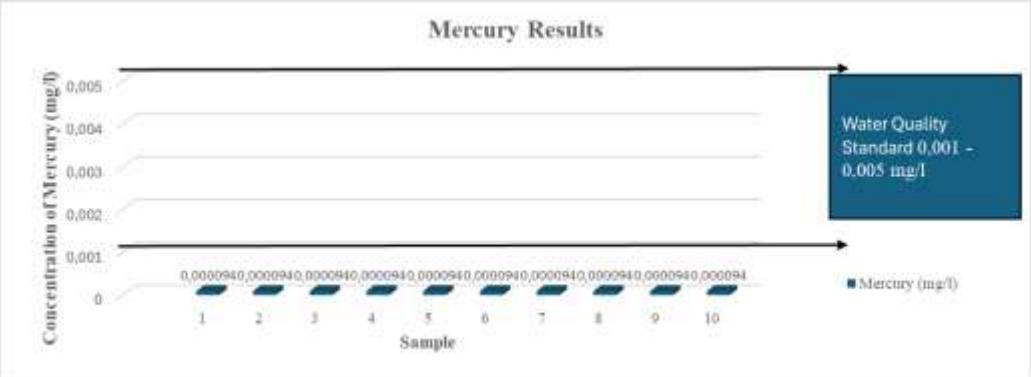

Figure 3. Mercury (Hg) Analysis Results

Third, the transition from mercury amalgamation to cyanide-based processing in certain ASGM areas may have contributed to reduced mercury inputs. Evidence from small-scale mining regions indicates that shifts toward cyanide leaching can significantly decrease mercury contamination in aquatic environments [22]. However, while mercury levels may decline, other environmental risks such as cyanide contamination may emerge.

Overall, although measured mercury concentrations in surface water comply with regulatory standards, the potential presence of sediment-bound mercury cannot be excluded. Further investigation involving sediment analysis would be necessary to comprehensively evaluate long-term environmental risk in abandoned illegal mining ponds.

3.3. Temperature

Government Regulation No. 22 of 2021 stipulates that the temperature difference between surface water and ambient air must not exceed three degrees Celcius. In this study area, surface water temperatures range from twenty-five to thirty-two degrees Celcius, while ambient air temperatures range from thirty-one to thirthy-three degrees Celcius (BMKG, 2025).

According to Government Regulation No. 22 of 2021, the permissible threshold requires that the difference between surface water temperature and ambient air temperature does not exceed 3°C. Field measurements showed water temperatures ranging from 28.7–33.3°C, while ambient air temperature averaged 31°C. The calculated temperature differences (0.6–2.3°C) remained within the regulatory threshold. This finding is consistent with [23], which stated that elevated temperatures occur because water quality measurements were conducted under extremely hot field conditions at midday in an open area without vegetation cover, where the water surface was directly exposed to sunlight.

Table 4. Differences Between Water Temperature and Ambient Temperature in the Study Area

Sample Code	Water Temperature (ºC)	Environmental Temperature (ºC)	Δ T (ºC)
Hg-01 dan CN-01	29,4	31	1,6
Hg-02 dan CN-02	29,3	31	1,7
Hg-03 dan CN-03	29,5	31	1,5
Hg-04 dan CN-04	29,6	31	1,4
Hg-05 dan CN-05	28,9	31	2,1
Hg-06 dan CN-06	28,7	31	2,3
Hg-07 dan CN-07	28,9	31	2,1
Hg-08 dan CN-08	33,3	31	2,3
Hg-09 dan CN-09	29,4	31	1,6
Hg-10 dan CN-10	30,4	31	0,6

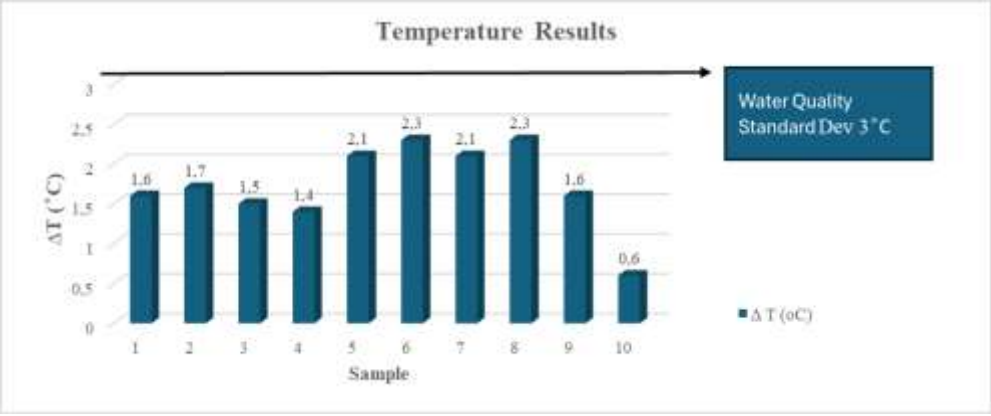

Figure 4. Temperature Analysis Results

Although temperature values comply with the standard, thermal conditions play an important role in chemical dynamics within mining voids. Elevated temperatures, particularly under direct solar exposure in unvegetated open pits, may accelerate chemical reactions and increase the volatility of certain compounds. In acidic conditions (mean pH 4.17), higher temperatures can enhance the transformation of cyanide species, potentially increasing the proportion of hydrogen cyanide (HCN),

which is more toxic and volatile. Thus, while temperature itself does not exceed regulatory limits, it may indirectly influence contaminant behavior and environmental risk within the pond system.

3.4. pH

According to Government Regulation No. 22 of 2021, the permissible pH range for surface water is between 6 and 9. The pH parameter was measured directly in the field. The following figure presents a comparison of pH values in abandoned illegal gold mining ponds with the standards established by Government Regulation No. 22 of 2021.

The study site lies in a lowland area characterized by swamps with the potential presence of peat soil. Based on regional peatland characteristics and field observations, this study interprets peat soil as contributing to the low pH of the water, resulting in acidic conditions. Government Regulation No. 22 of 2021 (Annex VI) does not impose standard pH limits on peat water, as the regulation recognizes acidity as a natural characteristic of peatland ecosystems. This finding aligns with Waryati et al. [24], who reported that peat water in Kalimantan naturally exhibits a pH range of 3–5. Consequently, this study does not use the measured pH value of 4 as an indicator of compliance with surface water quality standards. High concentrations of dissolved organic matter, particularly humic acids, drive the acidic condition of peat water. Therefore, this study classifies the measured pH value of 4 as a natural characteristic of peat-influenced water and does not consider it a determinant of environmental water quality compliance.



Figure 5. pH Analysis Results



Figure 6. Interactive Map of Ketapang Peatlands

3.5. TDS

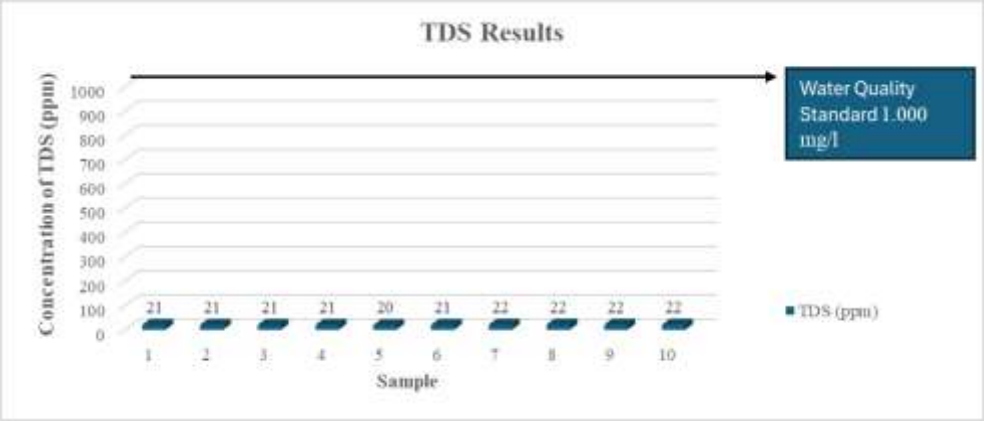

Figure 6. TDS Analysis Results

The measurement of Total Dissolved Solids (TDS) was conducted directly in the field. The following figure presents a comparison of TDS levels in water from abandoned illegal gold mining ponds with the standards stipulated in Government Regulation No. 22 of 2021.

Field measurements indicated that Total Dissolved Solids (TDS) levels ranged between 20–22 mg/L, which represents approximately 2% of the maximum allowable limit (1,000 mg/L) under Government Regulation No. 22 of 2021. These values classify the pond water as very low in dissolved mineral content.

Low TDS suggests limited overall ionic strength in the water column, indicating that the system does not contain high concentrations of dissolved salts or mineral residues. However, low TDS does not imply the absence of chemical contamination. Cyanide concentrations were significantly elevated despite the low TDS values, demonstrating that specific toxic contaminants may occur even when total dissolved solids remain minimal. This finding highlights that TDS alone cannot serve as a proxy indicator for chemical safety in abandoned mining pits.

Furthermore, in acidic peat-influenced waters, low mineral buffering capacity combined with low TDS may reduce the system's ability to neutralize contaminants. Consequently, although the TDS parameter complies with regulatory standards, the overall environmental risk remains governed primarily by the elevated cyanide concentration and its chemical behavior under acidic conditions.

4. Conclusion

The assessment of water quality in abandoned illegal gold mining ponds in Sungai Pelang Village, Ketapang Regency, shows that cyanide concentrations ranged from 0.0930 to 0.178 mg/L, mercury (Hg) was detected at 0.0000940 mg/L, water temperature ranged from 28.7 to 33.3 °C, pH values ranged from 3.83 to 4.43, and TDS values ranged from 20 to 22 ppm.

Comparison with Government Regulation No. 22 of 2021 indicates that cyanide concentrations significantly exceed the permissible threshold, while mercury, temperature, and TDS comply with regulatory limits. The acidic pH values reflect peatland characteristics rather than mining impacts alone.

Despite compliance in most parameters, elevated cyanide concentrations represent the primary environmental concern. Under acidic conditions, cyanide may transform into more toxic and volatile species, increasing ecological risk to aquatic organisms. Therefore, the water in these abandoned illegal mining ponds is not suitable for utilization due to cyanide contamination.

These findings highlight the need for environmental management measures, including cyanide monitoring, containment strategies, and potential remediation approaches such as chemical neutralization, natural attenuation assessment, or phytoremediation. Regulatory oversight and post-mining environmental control are essential to prevent long-term ecological degradation in unmanaged illegal mining voids.

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