



ENVIRONMENTAL CONDITION ANALYSIS OF POST-COAL MINING LAND AS A BASIS FOR SUSTAINABLE ENVIRONMENTAL MANAGEMENT

Salmani¹

Politeknik Negeri Banjarmasin, Kalimantan selatan, Indonesia.

Email: salmani@poliban.ac.id

Abstract: Coal mining contributes significantly to economic development and energy supply for communities and industries. However, these activities often cause substantial environmental changes, particularly in land conditions after mining operations cease. Post-mining areas frequently experience environmental degradation, including reduced soil fertility, water contamination, landscape alteration, and disruption of ecological balance. Assessing environmental conditions in post-mining land is therefore essential to support sustainable environmental management and effective land reclamation planning. This study examines environmental conditions in former coal mining areas by analyzing soil quality, water quality, and vegetation conditions to understand the level of environmental degradation and ecosystem recovery. The research applied a descriptive quantitative approach through field observations and laboratory analysis. Soil and water samples were collected from several observation points within a post-mining site in South Kalimantan. Soil analysis included parameters such as pH, organic carbon content, and essential nutrients including nitrogen, phosphorus, and potassium. Water quality parameters included pH, total suspended solids (TSS), iron (Fe), and manganese (Mn). Vegetation conditions were also observed to evaluate ecological recovery in the study area. The results indicate that soil conditions in the post-mining land are characterized by acidic pH (4.8), low organic matter content (1.25%), and limited nutrient availability, indicating poor soil fertility. Water quality analysis shows acidic conditions with a pH of 4.2 and TSS values reaching 356 mg/L, exceeding the environmental standard of 200 mg/L. Iron and manganese concentrations also exceed permitted environmental limits. Vegetation observations show limited plant growth dominated by pioneer species, indicating that ecosystem recovery has not yet progressed optimally. These findings highlight the need for integrated environmental management strategies to support sustainable post-mining land restoration.

Keywords: *post-mining land, environmental quality, soil quality, water quality, sustainable management*

INTRODUCTION:

Coal mining is an important industrial activity that helps support the economy and provides energy for the country. In many countries, like Indonesia, coal is still a key part of the energy industry and plays a big role in supporting industries and helping the economy grow. Even though there are some good things about mining, it is well known that these activities cause a lot of harm to the environment, especially to the land once the mining is done. Clearing land, taking away the top layer of soil, and digging for minerals can cause big changes in the environment, like affecting the physical, chemical, and living parts around it.

If mining is not done properly, it can lead to major harm to the environment. The Ministry of Environment and Forestry says that mining activities done without proper environmental care can



harm ecosystems, make the land worse, and reduce soil quality. These problems can cause lasting damage to the environment [1]. Previous studies have highlighted that post-mining areas generally exhibit poor soil fertility due to the removal of topsoil and the depletion of organic matter and essential nutrients required for plant growth [2] [3]. Land that was once used for mining often has damaged soil structure, less organic material, changed land shape, and missing natural plants. These conditions usually need a lot of work to bring back the natural processes in the ecosystem.

Environmental changes in areas where mining has stopped can be seen by looking at how the soil's physical and chemical features have changed. Land that has been affected by mining often has less fertile soil, fewer nutrients, and is more likely to experience erosion. These factors can make it harder for ecosystems to recover on their own [4]. In many cases, mining operations also accelerate soil acidification processes and reduce soil microbial activity, which further limits the natural recovery capacity of the ecosystem [5] [6]. After mining is done, the land is usually hard to use again or fix up unless there are good environmental plans and organized efforts to restore it.

Besides making the soil worse, mining can also cause acid mine drainage. This type of water has harmful heavy metals mixed in it, which can pollute nearby water sources. Acid mine drainage happens when sulfide minerals are exposed during mining and then mix with oxygen and water, causing the water to become acidic and contain higher levels of metals like iron and manganese. This condition can lower the quality of both surface and groundwater and might harm aquatic ecosystems and the environment's health [7]

The International Institute for Environment and Development says that when managing the environment in mining, it's important to use a sustainable method. This method should take into account the original environmental conditions, the effects of mining activities, and plans for restoring the ecosystem once mining is done [8]. Sustainable environmental management works to fix ecosystems, make the land more productive, and reduce bad effects on nearby communities. Checking the environmental conditions in areas after mining is a key part of figuring out the best ways to manage the environment. Environmental analysis often checks the condition of soil, water, and plants to understand how much the environment has been damaged and how well it is getting better [9]. This information is important for helping create good reclamation and recovery plans, which are part of managing land in a sustainable way [10].

This study is meant to look at the environmental conditions in areas that were once used for coal mining. It will check the soil quality, the quality of the water, and the features of the plants growing there. This study's findings should offer valuable scientific insights that can help with managing the environment in a sustainable way and assist in creating good plans for restoring areas that have been affected by mining.

METHODOLOGY :

Research Design

This study used a descriptive quantitative method to examine the environmental conditions of land that was once used for coal mining. The study looked at how clean the environment is by checking physical, chemical, and biological factors. These factors help show how much the environment has been harmed and guide what steps should be taken to manage it properly.



Fieldwork and lab tests were done to get accurate environmental information. Soil and water samples were taken straight from the area where mining happened to check the environment's condition after the mining was finished. The findings from the lab tests were looked at to figure out how much the environment had been damaged and to suggest ways to manage the environment in a sustainable way after mining is done. The research design also looks at past environmental studies done in mining areas to make sure the analysis results are trustworthy and can be compared with other studies.

2.2 Research Procedure

The way the research was done in this study is shown in Figure 1. The diagram shows the steps of the research process in order, beginning with identifying the problem, followed by collecting and analyzing data, and then assessing the environmental impact in an area that used to mine coal. The study started by figuring out the main problems and looking at existing research to learn more about environmental challenges that happen after mining land is no longer used. The next step was figuring out the study area, which is in a place that used to be a coal mine. Once the research area was decided, they started collecting environmental samples.

Soil and water samples were gathered from various spots that show different environmental situations in the area after mining took place. Soil samples were collected from the top layer, and water samples were taken from the mining water pools and the surface water areas. The samples that were collected were taken to the lab to check for different environmental factors. These factors included the acidity of the soil and water, how much organic carbon was present, the amount of nutrients available, the level of suspended particles in the water, and the amounts of heavy metals like iron and manganese. The lab results were studied and understood to check the environmental conditions of the land after mining and to find out if there was any damage to the environment, as well as to come up with ways to manage and protect it.

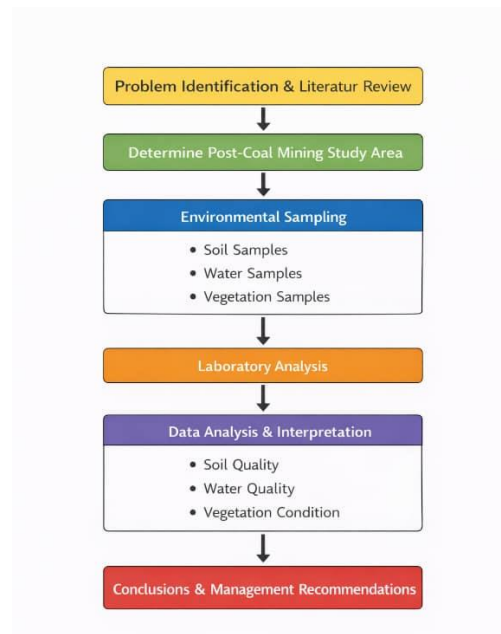


Figure 1 Research flowchart of environmental assesment in post-coal mining land



2.3. Sampling Procedure

Sampling was done in a place that used to be a coal mine. Soil and water samples were taken from different spots that show various environmental conditions in the study area. Soil samples were collected from the top 20 centimeters of the soil using a special tool to represent the topsoil layer that was affected by mining activities. Water samples were gathered from mine water ponds and surface water pools using clean sampling bottles that can hold 1 liter of liquid.

Sampling locations were chosen according to several factors, including :

1. Areas previously excavated during mining operations
2. Locations with visible surface water accumulation
3. Areas that show different types of land surfaces after mining has taken place.

This way of taking samples helps to fully assess the environmental conditions in the area after mining is done.

2.4. Soil Quality Analysis

Soil quality was checked to find out the environmental condition of land that was used for mining, using different physical and chemical factors. The parameters analyzed include :

1. Soil pH
2. Organic carbon content (C-organic)
3. Nitrogen (N)
4. Phosphorus (P)
5. Potassium (K)

Laboratory testing was done using standard methods for analyzing soil to make sure the results are trustworthy.

Table 1 Soil Quality Test Results in Post-Mining Land

Parameter	Unit	Test Result	Environmental Standard
Soil pH	–	4.8	6–7
C-Organic	%	1.25	≥ 2
Nitrogen (N)	%	0.08	–
Phosphorus (P)	mg/kg	8.5	–
Potassium (K)	mg/kg	45.2	–

The lab test results show that the soil in the area where mining used to happen has become much worse. The soil has a pH level of 4.8, which means it is quite acidic. Also, the amount of organic carbon is not very high, at 1.25%, which is less than the suggested minimum of 2% or more. The soil in the area after mining has low levels of nutrients like nitrogen, phosphorus, and potassium, which shows that the soil is not very fertile.



2.5. Water Quality Analysis

They checked the water quality to see how much pollution was present in the area after mining happened. Several important parameters were analyzed, including:

1. pH
2. Total Suspended Solids (TSS)
3. Iron (Fe)
4. Manganese (Mn)

Water samples were tested in the lab using standard methods for checking water quality.

Table 2 Water Quality Test Results in Post-Mining Area

Parameter	Unit	Test Result	Environmental Standard
pH	–	4.2	6–9
Total Suspended Solids (TSS)	mg/L	356	200
Iron (Fe)	mg/L	9.8	7
Manganese (Mn)	mg/L	5.1	4

The test results for the water show that some measurements are higher than the allowed limits set for the environment. The water has a pH level of 4.2, which means it's quite acidic. The level of TSS in the water is 356 mg/L, which is higher than the allowed maximum of 200 mg/L, showing that there is a lot of suspended particles in the water. Additionally, the levels of iron (Fe) and manganese (Mn) are also higher than allowed, which suggests that mining activities may be causing some environmental pollution.



2.6. Vegetation Observation

Vegetation observation was carried out to evaluate the ecological recovery of the post-mining environment. Field observations showed that vegetation growth in the study area remains limited and is dominated by pioneer plant species that are able to survive in nutrient-poor and acidic soil



conditions. The limited vegetation cover indicates that the ecological recovery process has not yet fully developed. In addition, physical conditions of the land such as surface instability and potential soil erosion were observed in several locations within the study area.



Figure 3 Vegetation conditions on post-mining land

2.7. Environmental Evaluation

After checking the soil, water, and plants, the area that used to be a mine is still having problems with the environment. This condition shows up through poor soil fertility, polluted water, and not much plant growth. Therefore, it is necessary to have sustainable environmental management strategies, including :

1. soil quality improvement
2. water quality management
3. revegetation programs
4. post-mining land reclamation

These steps are important to bring back the health of the environment and help the ecosystems stay strong and healthy after mining is done.

RESULT AND DISCUSSIONS:

3.1. Soil Quality Condition in Post-Mining Land

Soil quality is a key sign of how much the environment has been damaged in areas where mining has happened. Mining usually takes away the top layer of soil, which has important nutrients and organic material that plants need to grow. After mining is done, the soil left behind often goes through major changes in its physical and chemical makeup. The results from the lab tests on soil samples taken from the study area are shown in Table 1. The test results show that the soil has a pH level of 4.8, which means the soil is acidic. This value is lower than the best soil pH level for farming, which is usually between 6 and 7. Soil that is too acidic can make it harder for plants to get the nutrients they need, which can slow down their growth.

Also, the soil had an organic carbon level of 1.25%, which is below the suggested minimum of at least 2%. Organic matter helps keep the soil fertile, makes the soil structure better, and improves how well the soil holds onto nutrients. The soil in the area after mining has very little organic matter, which means it doesn't have much nutrients and can't help plants grow very well. The levels of important nutrients like nitrogen (0.08%), phosphorus (8.5 mg/kg), and potassium (45.2 mg/kg) were also not very high. These nutrients are important for plants to grow, and if they are missing,



it can greatly slow down the recovery of plants in areas where the land has become damaged. The findings show that mining has greatly lowered the amount of nutrients in the soil because when they dig, they take away the top layer of soil that is rich in nutrients.

These results match what earlier research has shown, which is that soil fertility and the amount of nutrients available drop a lot in areas that used to be mined. If proper steps aren't taken to improve the soil, it may take a very long time for the natural environment to heal and recover in those areas.

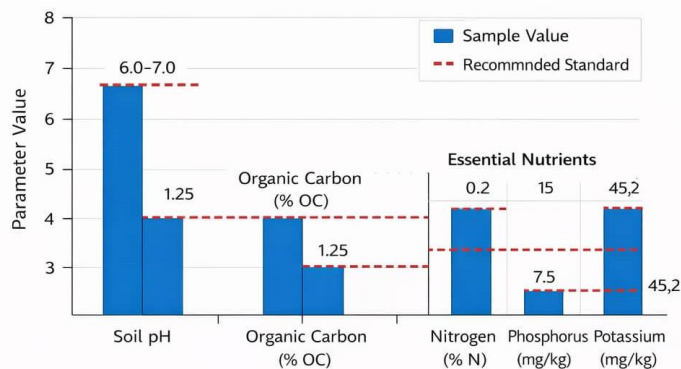


Figure 4 soil parameters in Post-Coal Mining Area

3.2. Water Quality in the Post-Mining Area

Checking the quality of water is important for understanding how mining affects the environment. Mining activities can create acid mine drainage, which usually has a lot of dissolved metals and tiny particles floating in it. The water quality test results from the study area are shown in Table 2. The test results show the water has a pH level of 4.2, which means the water is very acidic. This value is lower than the safe environmental range of 6 to 9, which means the water in the study area has been polluted by mining.

The level of total suspended solids (TSS) was 356 mg/L, which is higher than the allowed environmental limit of 200 mg/L. High levels of TSS mean there are a lot of small particles floating in the water, which could come from dirt getting washed into the water, leftover materials from mining, or soil moving into rivers and streams. Additionally, the amount of iron (Fe) was found to be 9.8 mg per liter, and manganese (Mn) was measured at 5.1 mg per liter. Both values are higher than the environmental quality standards, which are 7 mg/L for iron and 4 mg/L for manganese. High levels of these metals could harm the environment and damage aquatic ecosystems.

The area where mining happened may still be experiencing acid mine drainage because there is acidic water and high levels of metals present. If not handled correctly, this condition can lead to ongoing harm to the environment and damage to ecosystems.

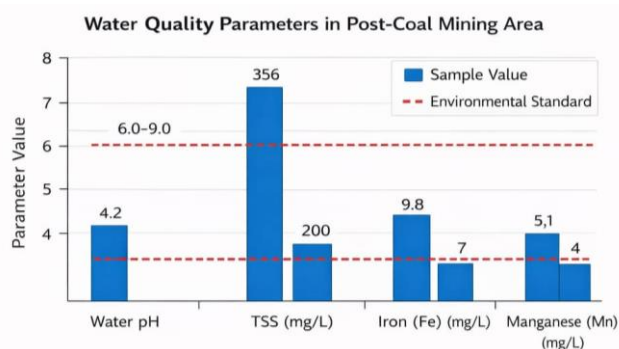


Figure 5 Water Quality Parameters in Post-Coal Area



3.3. Vegetation Condition and Ecological Recovery

Vegetation is very important in helping to restore ecosystems in areas that have been damaged or destroyed. The variety of plants in an area can show how well the ecosystem is healing after mining. Fieldwork in the study area showed that plant growth is still not very heavy. The current plant cover is mainly made up of pioneer species, which are plants that can live in tough environments, like soils that are too acidic and areas with not much nutrients.

The presence of pioneer species shows that the process of ecological succession is still in its early phase. Also, parts of the land after mining have weak soil and clear signs of erosion on the surface. These physical conditions also make it harder for a wider variety of plant communities to form. Limited vegetation cover makes it harder for the ecosystem to hold soil in place, keep moisture in the ground, and support a variety of living things. So, if there are no good reclamation and plant-growing programs, the natural healing of the environment might take a very long time.

3.4. Environmental Condition Evaluation

When looking at the combined results from checking the soil, water, and plant life, it's clear that the area after mining is still facing major environmental problems. The soil is too acidic, has not enough nutrients, and lacks sufficient organic material, which shows that the soil is not very fertile. At the same time, poor water quality with low pH and high levels of metals shows that mining activities are still causing environmental problems.

The low amount of plant growth in the area after mining shows that the environment is still in the early stage of healing and rebuilding. The plants in the area studied are mostly early-growing species that can handle tough conditions like soil that is too acidic and has few nutrients. Even though pioneer species are important in starting the process of ecological recovery, their presence shows that the ecosystem is still in the early stages of healing and hasn't fully restored itself yet. Not having many different types of plants can also make the soil less stable and lead to more erosion.

Because of these environmental conditions, it's important to use combined reclamation methods to help the ecosystem recover faster in areas that have been mined. There are several ways to make the environment better. One way is to add organic materials to the soil to improve its quality. Another method is to use lime to make the soil less acidic. Also, plants can be used to help remove heavy metals from the soil. In addition, programs that plant species of plants that can grow in poor soil conditions may help bring back plant cover and make the soil better over time. So, to properly care for the environment after mining is done, you need to use a full plan that includes fixing the soil, keeping the water clean, and bringing back the natural ecosystems. Creating sustainable reclamation programs is important to repair the environment and help keep nature healthy for a long time in areas that used to be mines. The slow growth of plants shows that the environment in the study area hasn't fully recovered yet. These results show that we need to use combined approaches to manage the environment in order to improve the quality of the environment in areas that were once used for mining. Recommended environmental management strategies include :

1. soil fertility improvement through organic amendments
2. water quality management and treatment of mine drainage
3. revegetation programs using adaptive plant species
4. implementation of systematic land reclamation practices



By using these strategies, the environment and natural functions of land after mining can slowly get better over time.

3.5 Results achieved

The results achieved in this study include :

1. Data on environmental conditions in post-coal mining areas were collected based on soil quality, water quality, and vegetation status.
2. Information on the level of environmental damage in post-coal mining areas was obtained.
3. Recommendations for sustainable environmental management were formulated as a basis for restoring environmental quality in post-mining land.
4. Preparation of research reports and scientific publications on the analysis of environmental conditions in post-coal mining land.

CONCLUSIONS :

This study looked at the environmental conditions in an area that used to have coal mines by checking the soil, water, and plant life. The results show that the land after mining is still going through a lot of environmental damage. The soil test shows it is acidic, with a pH level of 4.8, and has very little organic matter, only 1.25%, which means the soil isn't very fertile and doesn't have enough nutrients for plants to grow well. Testing the water shows it is very acidic with a pH level of 4.2. Also, there is a high amount of tiny particles in the water, called total suspended solids, which measures 356 mg per liter. This is higher than the standard set for good water quality. Besides that, the levels of iron (Fe) and manganese (Mn) are also higher than what is allowed, which suggests that mining activities might be causing pollution in the environment.

The observations of plants show that not many plants are growing, and the ones that are growing are early-stage plants that appear first in an area, which means the environment in the study area is still in the beginning phase of healing. So, to help the land heal after mining and keep it healthy long-term, we need to use plans that include improving the soil, cleaning the water, and carefully planting new vegetation. This will help restore the environment and make sure the area can be used in a sustainable way.

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