



The Impact of Andesite Mining Activities on Environmental, Social and Economic Conditions of the Community in Karangjati Village, Bergas District, Semarang Regency

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Abstract

Mining activities, which play a vital role in fulfilling Indonesia's mineral resource needs, are expected to contribute to the improvement of community welfare. According to Law No. 3 of 2020, the management of mineral and coal resources is aimed, among other objectives, at increasing the income of local communities, regional governments, and the state, as well as creating job opportunities through the implementation of Community Development and Empowerment (PPM) programs. However, in practice, the involvement of mining companies in Semarang Regency remains limited and tends to focus on short-term economic interests that lack sustainability. This study employs a descriptive quantitative method to evaluate the impact of andesite mining activities on the environmental, social, and economic conditions of communities in the ring I area, specifically in Karangjati Subdistrict, Bergas District, Semarang Regency. Data were collected through the distribution of questionnaires to 44 respondents and analyzed using the Likert scale. The research findings indicated that the average scores for the environmental, economic, and social aspects were 3.29, 3.21, and 3.14, respectively. These results suggest that community perceptions of the impacts of mining activities fall within a moderate category. It can be concluded that the community does not perceive significant negative environmental impacts from mining activities, reflecting that the company has carried out environmental management and monitoring (UKL-UPL) optimally, in accordance with environmental quality standards and applicable regulations. In terms of the social aspect, the community tends not to experience noticeable changes as a result of mining operations.

Introduction

According to Agustina & Latte (2023) and Veronica & Fasa (2022), Natural resources are everything that exists in nature and can be used in efforts to fulfill human needs and welfare. Some examples of natural resources are water resources, forest resources, land resources, mining resources, and mineral resources. God created nature to fulfill human needs on earth to be processed as well as possible so that benefits are created and the preservation of nature and its sustainability are maintained (Muhamad et al., 2020; Yahman & Setyagama, 2023).

Indonesia has many natural mineral resources that can be used as raw materials for industry and production. Therefore, mining materials are minerals. According to Ali & Frimpong (2020), the extraction of mining materials, which is carried out either mechanically or manually, is called mining. As explained in the Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia No. 26 of 2018, mining is part of the Mining Business activity to produce Minerals and/or Coal and its associated Minerals (Darman &

Riyanti, 2023; Listiyani et al., 2023). Therefore, the existing resources have economic potential that must be optimized to improve the welfare of the community.

However, it should be remembered that our natural resources will run out over time, and that wealth also belongs to our children and grandchildren. In the vision of mineral and coal policy by the Ministry of Energy and Mineral Resources of the Republic of Indonesia, the goal of the state is to control non-renewable natural resources of minerals and coal to improve the welfare and prosperity of the community. Align with research from Dědeček & Dudzich (2022), National income per capita is a measure of the level of welfare and prosperity, therefore, national income and population influence each other's per capita income of a country. In addition, the national development index (HDI) indicator can also be seen.

But the main goal of mineral and coal management in Indonesia is to increase the number and quality of human resources by optimizing the implementation of national mineral and coal management, increasing the independence, resilience, and growth of the mineral and coal-based industrial sector throughout the country, increasing the role and economic benefits of minerals and coal, and overall improving the welfare and prosperity of the people. In addition to these goals, of course, references, standards, and agreements must be considered when formulating policies. Another thing that must also be considered is the changes that occur both at the national and international levels.

Law Number 3 of 2020 concerning Amendments to Law Number 4 of 2009 concerning Mineral and Coal Mining in Article 2 (Paragraph) d, requires that mineral and coal mining must be managed sustainably and environmentally friendly. Meanwhile, Article 3 emphasizes that the objectives of mineral and coal management include ensuring the benefits of mineral and coal mining in a sustainable and environmentally friendly manner (Paragraph b) and increasing the income of local, regional and state communities, as well as creating jobs for the greatest possible welfare of the people.

(Paragraph) e, it is stated that in realizing the social aspects in the mining industry as required in Article 2 and Article 3 of Law Number 3 of 2020 above, mining companies are required to: (1) Implementing local community development and empowerment programs (Article 95d); (2) Comply with environmental carrying capacity tolerance limits (Article 95e); (3) Management and monitoring of the mining environment, including reclamation and/or post-mining activities (Article 96b); (4) Prioritize the use of local labor, domestic goods and services in accordance with the provisions of laws and regulations (Article 106); (5) Involving local entrepreneurs in the area in accordance with the provisions of laws and regulations (Article 107); (6) Prepare community development and empowerment programs; must allocate funds for the implementation of community development and empowerment programs, the minimum amount of which is determined by the Minister; Preparation of community development and empowerment programs is consulted with the Minister, regional governments, and the community (Article 108); (7) Prioritize the use of local contractors and local labor (Article 125).

From the explanation above, the existence of mining activities must be able to meet these points in order to provide a positive impact, in this case research will be conducted on the impact on environmental, social and economic conditions of the community, especially those around the mining activity location. Mestanza-Ramón et al. (2022) said that, this is because in the process of mining activities from start to finish, there must be changes and an impact on the abiotic and biotic environment. Related to the impact on the biotic environment, in order to restore the initial function of ex-mining land when mining activities have been completed which will cause

flora and fauna to grow and reproduce, mining business actors are required to carry out a reclamation program.

Meanwhile, related to the impact on the abiotic environment, mining business actors are required to implement environmental management and monitoring as stated in the UKL and UPL documents (Environmental Management Efforts and Environmental Monitoring Efforts). The mandate of Law No. 3 of 2020 concerning the implementation of the PPM (community development and empowerment) program, companies engaged in mining can implement the program to the local community. The goal is for mining companies to ensure future development and provide long-term sustainability of local communities' livelihoods and also aim to form local social and cultural independence and sustainability (Githiria & Onifade, 2020; Amoah et al, 2020; Liu & Agusdinata, 2020).

In Central Java Province, especially in Semarang Regency, there are 15 (fifteen) companies engaged in the mining industry with various commodities, including andesite, fill soil, limestone and sirtu. These mining activities are located in several sub-districts, namely Bergas, Bawen, Pringapus and East Ungaran. Companies with andesite commodities themselves number 9 (nine) companies whose mining activities are located in several sub-districts, namely Bergas, Bawen and East Ungaran.

Of the 9 (nine companies), the largest production to date is still occupied by the company where the researcher will conduct research, with a large-scale classification (> 150,000 tons/year) using the open pit mining method (quarry) located in Karangjati Village, Bergas District, Semarang Regency. Related to the Community Development and Empowerment (PPM) program, researchers found that in Karangjati Village, Bergas District, Semarang Regency, where andesite mining activities are taking place, they have not implemented the implementation as mandated by Law No. 3 of 2020.

Although there has been a slight increase in the economy of the community around the mine with the opening of job opportunities for residents around the mining location, the sustainability of the long-term livelihoods of the local community and also the contribution to the independence and sustainability of local social and culture in an unlimited period of time are felt to have not been implemented. This can be seen among others as follows: (1) Environmental Aspects: causes changes in raw water quality, ambient air quality, noise; (2) Social Aspect: influences the social dynamics of the local community, including only certain people with certain specifications who get job opportunities in the company; (3) Economic Aspect: there are no other job opportunities outside of mining activities that can improve the local economy.

In implementing the Community Development and Empowerment (PPM) program, mining business actors in Karangjati Village actually have the opportunity to create an empowered and independent community by utilizing ex-mining land for cultivating productive plants that are suitable for planting in locations around the mining area. In addition, seen from the environmental aspect, ex-mining land can also be utilized for the community to contribute if the company provides opportunities to open employment opportunities other than ongoing mining activities and can be sustainable even though the mine life has expired.

This is a form of implementation of PPM, namely opening employment opportunities for the surrounding community in a sustainable manner without relying on mining activities that one day the reserves of natural resources in this case andesite stone will run out which are environmentally friendly. Based on the description above, the purpose of this study is to evaluate how andesite stone mining activities in Karangjati Village, Bergas District, Semarang

Regency have an impact on the environmental, social and economic conditions of the surrounding community.

Methods

In this research study, a descriptive quantitative research method is utilised to conduct an orderly evaluation of natural, societal and economic effects and consequences of andesite mining business on the community. Community perceptions are objectively analyzed in the quantitative methodology because they can be gathered and interpreted in form of structured and numerical data. The qualitative insights were incorporated to supplement the statistical results and gain a contextual finer understanding, which was realised by using Focus Group Discussions (FGDs). Such a mixed-methods approach will help generate an integrated evaluation between empirical rigor and lived experiences of affected groups.

Study Area and Population

The study took place in Karangjati Village which is in Bergas District of Semarang Regency, Central Java Province, Indonesia. Karangjati Village is the village in the center of enormous andesite mines, so this region is of high interest regarding the investigation of the direct effects of the extractivism activities. The village is located in the so-called “Ring I” impact zone- a term which is used to describe the area of the greatest exposure to environmental and socio-economic alterations caused by mining. Karangjati has 14 neighbourhood units (Rukun Tetangga or RTs), 8,800 families and is divided administratively. This was because of physical closeness of this location to the mining site as well as the magnitude of activities performed by a quarry which falls under the category of an annual volume of over 150, 000 tons. The existence of such industrial-scale operation is what qualifies Karangjati to be a representative of a case study in viewing the multidimensional effects of mining in a highly populated area of the rural dissemination.

Sampling Technique and Sample Size

To ensure that the investigation achieved the methodological rigor as well as the ability of being externally validated, the current inquiry was based on the simple random sampling. This process was used because it gives equal chances of selection to all the members of the target population hence eliminating selection bias. The target population was considered to be the ones who were within the age range of 20-60 in their productive age which is the group mostly prone to be impacted directly or indirectly by the mining related developments, e.g. changes in employment, morbidity/mortality, income and access patterns to resources.

The necessary amount of people to be sampled was estimated using the Slovin formula, which is applicable where it is estimated that the total population is known and that a margin of error is specified. Seizing the margin of error to 15 February the population of 8,800 families would mean that at least 44 respondents will be needed. Proportional representation was observed by selecting the participants according to the number of the 14 resolution territories (RTs) in the village with the number of respondents picked in proportion to the number of the entire population of the village represented by the number of the RTs. Each RT was randomly sampled through a table created at random and the resulting sample was essentially diverse both demographically and geographically based on the village.

Data Collection Methods and Instruments

In order to obtain both the qualitative and quantitative data, the research resorted to structured questionnaires, semi-structured interviews, direct field observation, and Focus Group Discussions (FGDs). The purpose of the guided questionnaire, which aimed at assessing

community perception on three impact categories; environmental, social and economic, was based on the country mining regulations as given in Law No.3 of 2020 regarding Mineral and Coal Mining and the previously conducted research works on mining impacts as empirical evidence. Questions were rated using 5-point Likert scale with items including answers as strongly disagree, strongly agree and other intermediate results indicating that the perception can be measured by using a simple numerical form and subjective feelings can be converted into numerical values so that they can be analysed with simple statistical tools.

To identify the complicating effects of the mining activities, semi-structured interviews with a sample of the community members, local leaders, and the mining company representatives, were conducted to clear up the complex effects of mining activities. The interviews were done to support and contextualise the quantitative findings. Site visit complementary field observations was conducted by conducting viewing of the sites and recording of the environmental surroundings, community infrastructural framework, and corners of degradation or development connected with mining. This was then cross-verified with observations and results of the respondents. Focus Group Discussions (FGDs) were arranged to obtain more opinions, and stakeholders, including local government members and mining staff, community members, and inhabitants, affected by the crisis, were consulted. The FGDs helped in establishing common priorities of the community, strengthened quantitative findings, and helped in providing recommendations that were possible to be acted upon.

Research Tools and Materials

The study process required a set of both paper and electronic tools, and relevant secondary literature. Primary data was collected using stationery, voice recorders, cameras, clip boards, and printed questionnaires. There were voice recorders that allowed interviews and FGDs to be well transcribed and photographic evidence registered the developments on the environment and the infrastructure. The administration of questionnaires was also practical at the investigational level using clipboards, and one could record constant notes to give qualitative annotations. Regarding secondary information, the research team took advantage of government reports, environmental management plans of mining companies (UKL-UPL), environmental quality data (e.g. water, air, and noise samples), statistics data available in the Central Bureau of Statistics (BPS), and scientific articles. Such materials provided a critical contextual information, corroborated primary data and triangulation. These data were analysed and arranged using SPSS and Microsoft Excel to perform the statistical calculation. The following measures were taken in the present study to determine the reliability and validity of the measurements involved, engage descriptive analyses, test the data on normality with the help of Shapiro-Wilk test, and compare the groups with independent t-tests or Mann-Whitney U tests, depending on the normalcy of the variables in question.

Results and Discussion

Validity Testing

Validity test is used to determine whether the questionnaire is valid or not. Pearson Product Moment correlation test (r) is used to measure the validity of the questionnaire.

Table 1. Results of Pearson Product Moment Validity Test (r)

Statement	r count	r table	Information
Environmental Aspects			
Environment 1	0.733	0.316	Valid

Environment 2	0.783	0.316	Valid
Environment 3	0.717	0.316	Valid
Environment 4	0.730	0.316	Valid
Economic Aspects			
Economy 1	0.608	0.316	Valid
Economy 2	0.670	0.316	Valid
Economy 3	0.590	0.316	Valid
Economy 4	0.635	0.316	Valid
Economy 5	0.386	0.316	Valid
Economy 6	0.658	0.316	Valid
Economy 7	0.696	0.316	Valid
Social Aspects			
Social 1	0.658	0.316	Valid
Social 2	0.639	0.316	Valid
Social 3	0.811	0.316	Valid
Social 4	0.676	0.316	Valid
Social 5	0.845	0.316	Valid

Source: Processed Data, 2025

Based on the table above, it shows that there are 3 (three) variables that are the subject of research, from the three variables studied, there are an average of 5 (five) question items. From each question item in each variable, it turns out that the calculated r value is greater than the r table, so the data obtained in the field can be declared valid.

Reliability Testing

Reliability testing is to measure a questionnaire which is an indicator of a variable. A questionnaire is said to be reliable if a person's answers to it are statements are consistent or stable over time. A variable is said to be reliable if it provides a value *Cronbach Alpha* > 0.60.

Table 2. Results of Pearson Product Moment Correlation Test (r)

Variables	Cronbach's Alpha	Critical Point	Information
Environmental Aspects	0.723	0.7	Reliable
Economic Aspects	0.718	0.7	Reliable
Social Aspects	0.774	0.7	Reliable

Source: Processed Data, 2025

Based on the table above, this test uses variables rather than question items. The results show that each variable can be considered reliable if its Cronbach's Alpha value is greater than 0.6.

Characteristic Distribution Test

Table 3. Distribution of Data Characteristics Based on Intervention and Control Groups

Variables	Group		p
	Intervention	Control	
Gender			
Woman	13 (39.4%)	20 (60.6%)	0.186

Man-man	31 (56.4%)	24 (43.6%)	
Age	47 (23 – 60)	43.5 (20 – 53)	0.019*
Education			
SD	2 (50%)	2 (50%)	0.125
JUNIOR HIGH SCHOOL	6 (30%)	14 (70%)	
High School/Vocational School	24 (50%)	24 (50%)	
D1	1 (100%)	0 (0%)	
D3	1 (100%)	0 (0%)	
S1	9 (81.8%)	2 (18.2%)	
S2	1 (33.3%)	2 (66.7%)	
Work			
Student	1 (100%)	0 (0%)	0.257
Private	25 (42.4%)	34 (57.6%)	
Self-employed	9 (60%)	6 (40%)	
civil servant	1 (100%)	0 (0%)	
Etc	8 (66.7%)	4 (33.3%)	
Length of stay (years)			
1 – 5	2 (33.3%)	4 (66.7%)	0.432
6 – 10	1 (100%)	0 (0%)	
>10	41 (50.6%)	40 (49.4%)	

Description: * Significant ($p < 0.05$)

From the results of the data characteristic distribution test based on the intervention and control groups on age, a p value of <0.05 was obtained, so it can be concluded that there is a significant difference in age based on the intervention and control groups. In this case, it can be concluded that the age group that is active in participating in a social event in Karangjati Village is in the age range of 50-60 years, while in Wringinputih Village it is in the age range of 20-30 years.

Normality Test and Difference Test

Using the Shapiro-Wilk test, this normality test is used to determine whether the collected data is normally distributed or comes from a normal population. The Mann Whitney or Mann Whitney U difference test is a non-parametric test used to measure the difference in medians between two independent groups. This test is used in cases where the scale of the dependent variable data is ordinal, interval, or ratio but is not normally distributed. This shows that the Mann Whitney U test requires ordinal, interval, or ratio scale data. If the data is ordinal or ratio scale, the distribution is considered abnormal. The data was taken from two different groups, in this case the Karangjati Village Community and the Wringinputih Village Community, where each individual studied is a different individual from each other.

Environmental Aspect Normality Test

Table 4. Descriptive and Normality Test of Environmental Aspects Based on Intervention and Control Groups

Group	Mean \pm SD	Median (min – max)	p
Intervention	13.16 \pm 2.50	13 (8 – 18)	0.095*

Control	10.32 ± 2.54	10 (7 – 16)	0.002
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Description: * Normal ($p > 0.05$)

From the results of the environmental aspect normality test using the Shapiro-Wilk test on the control group, the data was found to be not normally distributed, so the next step was to test the difference using the Mann-Whitney test.

Table 5. Differences in Environmental Aspects Based on Intervention and Control Groups

Group	Median (min – max)	p
Intervention	13 (8 – 18)	<0.001*
Control	10 (7 – 16)	

Description: * Significant ($p < 0.05$)

From the results of the test of differences in environmental aspects based on the intervention and control groups using the Mann-Whitney test, a p value of <0.001 ($p < 0.05$) was obtained, so it can be concluded that there is a significant difference. In this case, the intervention group is Karangjati Village, which is located close to mining activities, and the control group is Wringinputih Village, which is relatively far (± 4 km) from mining activities. Based on the test results, it can be concluded that there are differences in the company's treatment of environmental aspects in the two villages. This difference is influenced by variations in geographical distance between Karangjati Village and Wringinputih Village to the location of mining activities, which indirectly affects the intensity of environmental impacts and interventions carried out by the company.

Normality Test of Economic Aspects

Table 6. Descriptive and Normality Test of Economic Aspects Based on Intervention and Control Groups

Group	Mean ± SD	Median (min – max)	p
Intervention	22.50 ± 3.42	22 (17 – 32)	0.038
Control	16.27 ± 5.20	16.5 (7 – 29)	0.006

From the results of the normality test of economic aspects using the Shapiro-Wilk test in the intervention and control groups, the data were obtained with an abnormal distribution, so the next step was to test the difference using the Mann-Whitney test.

Normality Test of Economic Aspects

Table 7. Differences in Economic Aspects Based on Intervention and Control Groups

Group	Median (min – max)	p
Intervention	22 (17 – 32)	<0.001*
Control	16.5 (7 – 29)	

Description: * Significant ($p < 0.05$)

From the results of the test of differences in economic aspects based on the intervention and control groups using the Mann-Whitney test, a p value of <0.001 ($p < 0.05$) was obtained, so it can be concluded that there is a significant difference. In this case, the intervention group is Karangjati Village, which is located close to mining activities, and the control group is Wringinputih Village, which is relatively far (± 4 km) from mining activities. From the results of the test, it can be concluded that there is a significant difference in economic aspects between the two.

This is due to the different distance factors between Karangjati Village and Wringinputih Village from the mining activity location, thus affecting the different economic activities and growth between the two groups. The difference can be seen from the economic activities and growth in Karangjati Village which are higher than Wringinputih Village.

Social Aspect Normality Test

Table 8. Descriptive and Normality Test of Social Aspects Based on Intervention and Control Groups

Group	Mean ± SD	Median (min – max)	p
Intervention	15.70 ± 2.64	15 (8 – 22)	0.077*
Control	10.09 ± 3.00	10 (5 – 17)	0.036

Description: * Normal ($p > 0.05$)

From the results of the normality test of social aspects using the Shapiro-Wilk test on the control group, it was found that the data was not normally distributed, so the next step was to test the difference using the Mann-Whitney test.

Table 9. Differences in Social Aspects Based on Intervention and Control Groups

Group	Median (min – max)	p
Intervention	15 (8 – 22)	<0.001*
Control	10 (5 – 17)	

Description: * Significant ($p < 0.05$)

From the results of the test of differences in social aspects based on the intervention and control groups using the Mann-Whitney test, a p value of <0.001 ($p < 0.05$) was obtained, so it can be concluded that there is a significant difference. The results of the research analysis from the results of the difference test in this case the intervention group is Karangjati Village, which is the closest location to mining activities and the control group is Wringinputih Village, which is another location that is relatively far from mining activities, it can be concluded that there is a significant difference between the two in social aspects.

This is because the distance factor of Karangjati Village is closer to the mining activity location than Wringinputih Village, this has an impact on the ease of access for the community in carrying out social activities such as adequate road access for the community to reach public service facilities, as well as other CSR programs carried out by the company such as providing nutritious food assistance to students who attend schools in the Karangjati Village area.

Table 10. Descriptive and Normality Test of Total Score Aspects Based on Intervention and Control Groups

Group	Mean ± SD	Median (min – max)	p
Intervention	51.36 ± 5.69	50.5 (42 – 65)	0.233*
Control	36.68 ± 9.26	37 (19 – 60)	0.053*

Description: * Normal ($p > 0.05$)

From the results of the normality test of the total score aspect using the Shapiro-Wilk test in the intervention and control groups, the data were normally distributed so that the next step was to test the difference using the Independent-t test.

Table 11. Differences in Total Score Aspects Based on Intervention and Control Groups

Group	Mean ± SD	p
Intervention	51.36 ± 5.69	<0.001*
Control	36.68 ± 9.26	

Description: * Significant ($p < 0.05$)

From the results of the test of differences in total score aspects based on the intervention and control groups using the Independent-t test, a p value of <0.001 ($p < 0.05$) was obtained, so it can be concluded that there is a significant difference. This proves that the CSR or PPM program provided by the mining company to the two community groups, namely the community in Karangjati Village and Wringinputih Village, seen from the environmental, social and economic aspects, there are significant differences between the two. Karangjati Village received CSR from the mining company while Wringinputih Village did not receive it.

Table 12. Descriptive and Normality Test of Age, Environmental Aspects, Economic Aspects, Social Aspects and Total Score

Variables	Mean ± SD	Median (min – max)	p
Age	41.72 ± 11.63	44.5 (20 – 60)	<0.001
Environmental aspects	11.74 ± 2.88	12 (7 – 18)	0.005
Economic aspects	19.39 ± 5.38	19 (7 – 32)	0.193*
Social aspects	12.90 ± 3.98	13 (5 – 22)	0.038
Total score	44.02 ± 10.62	45 (19 – 65)	0.005

Description: * Normal ($p > 0.05$)

From the results of the normality test using the Kolmogorov-Smirnov test on age, it was found that the data was not normally distributed, so the next step was to test the relationship using the Spearman's correlation test.

Test for Confounding Relationships

Spearman's correlation test is used to measure the relationship between two ordinal or interval variables. In this context, the test is conducted to determine whether there is a significant relationship between age and environmental, economic, and social aspects.

Table 13. Results of the Test of the Relationship between Age and Environmental Aspects, Economic Aspects, Social Aspects and Total Score

Variables	Age	
	p	r
Environmental aspects	0.356	0.100
Economic aspects	0.204	0.137
Social aspects	0.121	0.166
Total score	0.091	0.181

Information: p (statistical significance value); r (correlation coefficient)

The p-value in the Spearman's correlation test shows that the probability of the relationship between age and the three aspects (environmental, social and economic aspects) is > 5% so it can be concluded that there is no significant relationship. So the age factor of the community in this study related to mining activities carried out has no impact on environmental, social or economic aspects. This is because most of the population in all age classifications do not have significant mobility in their daily lives. This can be seen from the average educational

background of most of the community which is equivalent to SMA (Senior High School), both from the productive age classification of 20 to 30 years and 51 to 60 years.

Environmental Management and Monitoring

The results of coordination with mining companies regarding the implementation of environmental management and monitoring referring to the UKL and UPL documents are as follows:

Table 14. Laboratory Test Results for Raw Water Quality, Ambient Air and Noise

No.	Types of Impact	Company Laboratory Test Results	Impact Measurement
1.	Raw Water Quality		(Minister of Health Regulation Number 02 of 2024)
	Polluterrun and decline in raw water quality	Temperature: 28.5°C Dissolved Solids Total : 85.0 mg/L pH : 7.15 ChromeHexavalent : 0.004 mg/L Color : 5.07 TCU Flavor : - Odor: Odorless Turbidity : <1.94 NTU Iron : <0.12 mg/L Fluoride : - mg/L Manganese : <0.059 mg/L Nitrate : <0.01 mg/L Nitrite : <0.012 mg/L Sulfate : - mg/L Zinc : - mg/L Cyanide: - mg/L Hardness : - mg/L Total Coliform : <1/100 mL E. Coli : <1/100 mL	Temperature: air temperature ± 3 °C Total Dissolved Solids : <300 mg/L pH : - Hexavalent Chromium: 0.01 mg/L Color : 10 TCU Flavor : - Odor: Odorless Turbidity : <3 NTU Iron: 0.2 mg/L Fluoride : - mg/L Manganese: 0.1 mg/L Nitrate : 20 mg/L Nitrite : 3 mg/L Sulfate : - mg/L Zinc : - mg/L Cyanide : -mg/L Hardness : - mg/L Total Coliform : 0 CFU/100 mL E. Coli : 0 CFU/100 mL
2.	Ambient Air Quality		(PP No. 22 of 2021)
		Nitrogen Dioxide (NO ₂): <14.2 µg/m ³ Sulfur Dioxide (SO ₂): 42.09 µg/m ³ Oxidant (O ₃) : <2.69 µg/m ³ TSP : 36.72 µg/m ³ Carbon Monoxide: <1,000 µg/m ³ NMHC : <8 µg/m ³ PM10 : 31 µg/m ³	Nitrogen Dioxide (NO ₂) : 200 µg/m ³ Sulfur Dioxide (SO ₂) : 150 µg/m ³ Oxidant (O ₃) : 150 µg/m ³ TSP : 230 µg/m ³ Carbon Monoxide: 10,000 µg/m ³ NMHC : 160 µg/m ³ PM10 : 75 µg/m ³ PM2.5 : 55 µg/m ³

		PM2.5 : 25 µg/m ³ Pb : 0.01 µg/m ³ NH ₃ : 0.03 ppm NMHC : <8 µg/m ³	Pb : 2 µg/m ³ NH ₃ : 2 ppm
3.	Noise Quality		Decree Number KEP.48/MENLH/XI/1996
		Noise : <54 dB(A)	Noise : 70 dB(A)
4.	Domestic Solid Waste or Non B3 (Hazardous and Toxic Materials)		
		Non-B3 domestic solid waste generated by additional production capacity in mining areas.	Domestic solid waste can managed properly and correctly and does not pollute the environment; PP Number 81 2012 on Management of Household Waste and Similar Household Waste; Law Number 18 of 2008 on Waste Management.

The table above contains laboratory results from several types of impacts with the following evaluations: Raw water quality: the results of the examination of the quality of raw/clean water closest to the mining activity location show concentrations that meet the quality standards in accordance with the provisions of the Regulation of the Minister of Health of the Republic of Indonesia Number 02 of 2023. Ambient air quality: the trend in ambient air quality concentrations as a result of mining activities still meets environmental quality standards in accordance with PP No. 22 of 2021.

Noise quality: noise measurement is carried out by direct measurement using a sound level meter, the results of laboratory analysis of noise quality concentration trends as an impact of mining activities still meet the applicable environmental quality standards in accordance with Decree Number KEP.48/MENLH/XI/1996. Domestic solid waste or non-B3 (hazardous and toxic materials): this waste has been managed well to avoid the impact of decreasing groundwater quality, the impact of decreasing environmental aesthetic quality, and can also be dangerous for the surrounding environment and workers.

Scientific Evaluation of Mining Impacts on Human-Environmental Systems in Andesite Quarry Zones

Mining is a revolutionary land use activity with immense biophysical and socio-ecological implication. Exegesis of empirical results of the Karangjati Village, where huge-scale andesite quarrying has become operational must, therefore, go beyond perceptions of community and enter into existing constructs of environmental science, namely landscape degeneration, hydrological strain, ecological enduring power, and economic decoupling. According Hofstetter et al. (2021), these frameworks position the local patterns in the broader transdisciplinary discourse on effects of the extractive industries. Whereas the respondents tend

to assess the environmental conditions as moderately impacted, this is the form of appraisal that conceals latent and run up ecological risks.

This constant remarkability in ambient air, noise level, and raw water quality however does not rule out instability in the future unless there is a full coverage of monitoring of the ecosystem. Based on empirical findings, it has been found that quarry performances, and especially volcanic masses dominated by andesitic rocks, may induce the dynamic destabilization of the soil structure and the loss of infiltration capacity, thus modifying the dynamics of groundwater recharging (Liu & Bai, 2024; Sun et al., 2025; Theron et al., 2022). The presence of such geomorphological and hydrogeological changes often are non-linear in nature and they might not be noticed till it is too late (Vogel et al., 2024). In addition, the conditions of mining disturbance are generally characterized by enhancements in the surface runoff and sediment conveyance, which can degrade the downstream aquatic habitats due to the rising turbidity, pH variation, or expelled trace metals without apparent chemical pollution (Wang et al., 2023; Ouma et al., 2022).

Biogeochemically, concentration of Hexavalent chromium, nitrate and iron within the regulatory limits is in no way an antecedent of ecological apprehension. At any dose, even small, hexavalent chromium remains in aquatic sediments and biological organisms with time and can create ecological latent effects that cannot be easily noticed (Mohanty et al., 2023; Sharma et al., 2022). The compliance without safety rule within the environmental toxicology further illustrates the fact that regulatory standards usually depict socio-political compromises as opposed to the ecosystem safety thresholds (Barone, 2025). Therefore, permanent biomonitoring and ecotoxicological evaluation are requested, and dynamic processes are to be found between weathering, runoff, and anthropogenic contributions in mineral-extraction regions.

The social aspect, which in the number of those surveyed does not become a significant violation of the lives of the locals, should be considered in the light of system science, not only subjective feeling. Economically, it is beneficial to develop infrastructure like pavement and grants of building materials which however split ecological networks and distorts land use patterns in a manner which breaks the functional integrity of rural ecosystems (Ige et al., 2024; Xu et al., 2024). Empirical research has indicated that in the absence of incorporating spatial planning in the process such adaptations decrease the connectivity of the habitats and impact wildlife corridors (Newell et al., 2022) and this factor is of interest to the semi-rural area of Karangjati.

Moreover, this countervailing argument of CSR interventions with environmental loss overlooks the so called ecological debt, which is an ever growing cumulative exposure of risks among the ecosystem and the human society as a result of the asymmetrical distribution of costs and benefits over periods of time (Williamson et al., 2025; Gayo et al., 2022). On the economic front, lack of perception of gain despite the extensive withdrawal is consistent with the state of affairs experienced in the world where extractive industries have been found to demonstrate poor multiplier effect of income to rural economies. It is stressed in many studies that modern mining processes are and will remain capital-intensive and technology-intensive, providing stationary local job opportunities and having no significant benefits to the knowledge transfer (Sun et al., 2023; Abid, 2025).

The fact that even in regions close to high levels of natural resource endowments but not directly linked with its vast wealth, an enduring economic stagnation prevails can be explained by such notion of Korinek & Stiglitz (2021), who speak about the decoupling of the metabolic flows and defines it as an insufficient supporting effect of the extractive processes to the

regional resilience due to the absence of locally based vertically integrated production systems. Such a state of affairs is even compounded by the fact that mines are not complemented by backward or forward chains, and by regional supplier networks, internal mineral processing, or even holistic development planning (Franken & Schütte, 2022; Malik, 2024).

Another major implication of the current research is space gradient of impact. The theoretical expectation of an inverse exponential relationship between pollutant concentration, acoustic disturbance, and anthropogenic disruption relative distance to the source are consistent with statistical differences seen between both the mining proximate village of Karangjati and the control village of Wringinputih. This however does not mean that proximity in linear convergence can guide the allocation of corporate social responsibility or developmental allocation. Equity planning, based on science, means that ecological vulnerability and social exposure indices should be taken into consideration at the same time when compensation and investment priorities will be established (Loh & Kim, 2021; Berke et al., 2023; Rosa et al., 2023). Sedimentation or change of microclimates that occur as a result of land cover change due to mining can also be felt even by communities that are further down stream, though spatially far.

These trends speak to the need to retire the straightforward distance-based zoning in favor of ecosystem service mapping to achieve a more equitable and environmental friendly intervention planning (Ruiz-Apilánez et al., 2023). The lack of land-use planning of the post-mining land can also be important, especially the fact that no such coherent planning occurs in the realm of study can be considered as a significant missed opportunity when it comes to the sustainable development. According to the empirical data, agroforestry, soil remediation, and phytostabilization measures have proved to be successful in restoring the rehabilitation of degraded quarry sites, particularly in tropic volcanic regions (Jinger et al., 2023).

The restoration of carbon and nitrogen cycling, soil microstructure, and pollinator diversity has been demonstrated to be achieved by native-species revegetation (Raupp et al., 2024). The incorporation of specified restoration measures in a PPM framework namely Community Development and Empowerment, illustrates that it is possible to achieve the synergistic interaction of ecological rehabilitation and occupation creation, broadening the post-mining values of mined land. Environmental education and ecological consciousness also become of the essence. The paper suggests the emphasis on local outreach programs and the related capacity-building projects that can motivate the local population to participate in conservation-related activities. These actions are in line with those of ecosystem stewardships that advocate co-management between communities in a particular area and extractive companies, practices that have been observed to improve compliance and encourage long-term sustainability.

The mining industry can be rewritten into the story of a destructive agency to a source of environmental resilience and scientific literacy among resource-reliant populations due to the provision of structured workshops and practical demonstrations, as well as, knowledge-sharing platforms. Even though the various environmental and socio-economic realities in Karangjati are not as critical at this point in the present time, the implications in the long-term, since care has not been taken to monitor them and ensure that they are scientifically dealt with, are very challenging to the well-being of individuals as well as the stability of an ecosystem. This calls therefore, a science-based, proactive, and ecologically integrated strategy of redefining mining no longer as an economic practice, but a highly transformational process in the coupled human-environment system.

Conclusion

In research using quantitative methods and Focus Group Discussion (FGD) methods on mining activities carried out in Karangjati Village, the following conclusions were obtained: The environmental aspect obtained an average value of 3.29, which reflects that the community does not feel the negative impact on the environment due to mining activities. This condition shows that mining companies have implemented environmental management and monitoring efforts (UKL-UPL) optimally, with results that meet environmental quality standards in accordance with applicable laws and regulations. The social aspect obtained an average value of 3.14, indicating that the community did not feel any changes in their social life as a result of mining activities. This finding contradicts the results of the FGD, which revealed that the company has implemented a Corporate Social Responsibility (CSR) program, including through road paving and providing nutritious food for school students around the mining area, as an effort to improve access and social welfare of the community. The economic aspect obtained an average value of 3.21, indicating that the economic impact of mining activities is less felt by the community around the operational area. This is due to the low need for labor in the mining process, considering that the activities carried out are relatively simple and do not require the involvement of large numbers of human resources.

Meanwhile, companies engaged in the non-mining sector around Karangjati Village are able to absorb a larger number of workers. This is due to the high need for human resources in the company's operations, as well as the characteristics of the business life cycle which tends to be longer or even unlimited compared to the mining industry. In the study using the FGD method, it was found that the mining company had implemented the PPM (Community Development and Empowerment) program in Karangjati Village in accordance with the mandate of Law Number 3 of 2020. It is necessary to hold seminars or outreach activities for the local community in order to form a constructive mindset regarding the importance of developing self-capacity in environmental conservation efforts. This aspect is closely related to food security, which is an urgent need, especially on a micro scale, such as at the household level. Thus, the Community Empowerment and Development (PPM) program initiated by the mining company can provide benefits in environmental, social and economic aspects that are more optimal and sustainable for the lives of the surrounding community.

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