



Analysis of the impact of coal mining on small-scale fishing communities in West Aceh Regency, Indonesia

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Abstract. Coal mining in West Aceh has become one of the significant industrial sectors, contributing to economic growth and job creation. However, the negative impacts of this activity are increasingly concerning, especially for small-scale fishing communities that rely on marine ecosystems. This research aims to analyze the social, economic, and environmental impacts experienced by small-scale fishermen due to coal mining. The methodology used in this study is a mixed-methods approach, integrating both qualitative and quantitative data. The research was conducted in the Meureubo District of West Aceh, focusing on five villages located around the mining area. Primary data were obtained through structured interviews and questionnaires distributed to 120 respondents, consisting of small-scale fishermen. Secondary data were collected from government documents, company reports, and relevant literature. Data analysis was performed using descriptive analysis for quantitative data and thematic analysis for qualitative data. The results indicate that mining activities lead to water pollution, habitat destruction, and a decline in environmental quality, which directly affects fish catches and fishermen's income. Additionally, the opening of mining land disrupts fishermen's access to traditional fishing areas, worsening their socio-economic conditions. The fishing community has developed various adaptation strategies to cope with these changes, including modifying their fishing gear and seeking new locations. This study recommends the need for more inclusive and participatory policies to mitigate the negative impacts of mining and enhance the well-being of small-scale fishing communities in West Aceh.

Key Words: coal mining, economic impacts, environmental impacts, small-scale fishermen, social impacts, West Aceh.

Introduction. Coal mining has become a significant sector in the global economy. Coal provides an essential energy source for power generation and various industrial processes around the world (Higginbotham et al 2010; Cowell et al 2011; Rosyid & Adachi 2016). On one hand, coal mining contributes to economic growth and job creation; on the other hand, the negative impacts of this activity have come under increasing scrutiny, particularly regarding local communities, the environment, and public health (Mori 2018; Wu & Chen 2018; Kurniawan et al 2020). The issue becomes more complex with the emergence of social injustices, where local communities often do not receive benefits commensurate with the losses they experience due to coal mining.

Indonesia is one of the largest producers and exporters of coal in the world (Bian et al 2010; Finkelman et al 2021; PwC Indonesia 2023). The contribution of the mining and quarrying sector to Indonesia's economic growth has increased in recent years. According to data from the Central Statistics Agency, the mining and quarrying sector contributed 12.22% to national economic growth in 2022 (Badan Pusat Statistik 2024). One of the regencies in Aceh Province with significant coal resources is West Aceh Regency.

Based on data from the West Aceh Mining Office, the potential coal resources in this area reach 1.7 billion tons. Of this amount, the known coal resources are estimated at 600 million tons, with total reserves of 400 million tons. The coal found in West Aceh Regency generally has a low calorific value but is spread across several sub-districts. The sub-

districts with coal potential include Meureubo, Woyla Induk, Woyla Barat, Woyla Timur, Kaway XVI, Samatiga, and Pante Ceuremen.

On the other hand, West Aceh Regency is also one of the areas in Aceh Province with substantial marine resource potential. Capture fisheries serve as a primary livelihood for small-scale fishing communities in this region. The socio-economic life of these small fishermen heavily relies on the condition and availability of marine resources. In recent years, the government has developed coal-fired power plants (PLTU) in several locations within West Aceh Regency. The primary source for the development of these power plants is coal. The presence of these power plants is expected to meet the electricity needs of the local community and stimulate regional economic growth. The significant coal resource potential in West Aceh Regency has a considerable impact on the socio-economic life of the community, particularly small-scale fishermen in coastal areas.

Coal mining activities often lead to serious environmental issues, including water, soil, and air pollution. Water contamination can occur due to runoff of harmful chemicals from mining sites, which pollutes clean water sources and disrupts aquatic life. Additionally, soil erosion caused by mining operations can diminish soil fertility and destroy natural habitats. Air pollution, resulting from coal dust and harmful gas emissions, not only negatively impacts air quality but also poses health risks to communities and surrounding ecosystems. All these adverse effects contribute to the decline of coastal ecosystem sustainability and threaten vital fish resources, which are crucial for the livelihoods of coastal communities that rely on fishing for their income (Crain et al 2009; Higginbotham et al 2010; Cowell et al 2011; Rosyid & Adachi 2016; Andrews et al 2021; Malone et al 2021; Junaidi et al 2024). These changes have resulted in decreased fish catches, worsening the socio-economic conditions of small fishermen in West Aceh Regency.

This research aims to assess the social, economic, and environmental impacts of coal mining on small fishing communities in West Aceh Regency and propose policy recommendations to mitigate these effects and improve community welfare.

Material and Method. This research employs a descriptive research design with a mixed methods approach. This approach integrates both qualitative and quantitative data to provide a more comprehensive understanding of the impacts of coal mining. The study is conducted in West Aceh Regency, specifically in the Meureubo sub-district, which includes five villages: Sumber Batu, Buloh, Pucok Reudep, Reudep, and Balee. The selection of these locations is based on their proximity to mining areas and the predominance of fishing communities. These villages are the first ring directly affected by coal mining operations and are classified as first-ring villages in the Corporate Social Responsibility (CSR) program. Data collection was conducted from January to February 2024, aiming to gather both primary and secondary data. Primary data was obtained through interviews guided by a structured questionnaire aligned with the research objectives. Relevant secondary data was sourced from library research, including books, journals, government documents, corporate reports, and stakeholder information. Data analysis in this study encompasses two main approaches: quantitative and qualitative. For the quantitative analysis, data from the questionnaires will be used to apply and illustrate descriptive percentages. Meanwhile, qualitative analysis will be conducted on data collected from interviews and focus group discussions (FGD) using a thematic analysis approach.

Results

Characteristics of the fishing community. The fishing community plays a crucial role in the economy and culture of coastal areas. Their livelihoods are highly dependent on marine resources and closely linked to environmental changes. However, in recent years, the fishing community in West Aceh has faced serious challenges that threaten their sustainability. Therefore, understanding the characteristics and challenges of the fishing community is essential for ensuring that policies are inclusive and responsive to the needs of fishermen.

The data on the characteristics of the fishing community (Table 1) indicates that the majority of respondents are of productive age, with 32.0% aged 31-40 years and 25.4% aged 20-30 years, while all respondents are male. Education levels vary, with 30.2% having

completed junior high school (SMP) and 29.0% having completed senior high school (SMA), while 10.7% hold a diploma or bachelor's degree. Most respondents work as fisherman (70.5%) and have varying levels of work experience, with 35.0% having 11-20 years of experience. Monthly income shows inequality, as 27.5% earn above Rp 4,500,000, while 24.2% earn below Rp 1,500,000. Additionally, 40.2% receive supplementary income from side businesses, but 30.8% do not have any other sources of income. In terms of fishing gear, nets (39.17%) are the most commonly used. Social conditions reveal that 60.2% live in simple housing, and 50.4% are active in fishermen's organizations. The survey results show that 95.83% of respondents feel that the marine environment is deteriorating, while only 4.17% do not perceive any changes. Regarding proximity to mining areas, 22.73% of respondents live very close (0-1 km), 50.91% are at a medium distance (2-3 km), and 26.36% live further away (4-5 km). Communities living near mining operations are likely to experience more significant environmental impacts. This situation warrants attention to environmental and public health issues within the fishing community.

Table 1

Characteristics of fishermen in West Aceh

<i>Characteristics</i>	<i>Number of respondents</i>	<i>Percentage (%)</i>
<i>Age</i>		
20-30 years old	31	25.4
31-40 years old	39	32.0
41-50 years old	31	25.4
51-65 years old	19	15.2
<i>Gender</i>		
Male	120	100
Female	0	0
<i>Education</i>		
No formal education	13	10.7
Elementary school	25	20.3
Middle school	37	30.2
High school	36	29.0
Diploma/Bachelor's degree	13	10.7
<i>Main occupation</i>		
Fisherman	85	70.5
Freelancer	25	20.5
Others	11	9.0
<i>Work experience</i>		
1-5 years	17	14.2
6-10 years	38	31.7
11-20 years	42	35.0
21-40 years	23	19.2
<i>Monthly income</i>		
< Rp 1,500,000	29	24.2
Rp 1,500,000 - Rp 3,000,000	33	27.5
Rp 3,000,000 - Rp 4,500,000	25	20.5
> Rp 4,500,000	33	27.5
<i>Additional income source</i>		
Side business	49	40.2
Social assistance	35	29.0
None	37	30.8
<i>Fishing gear used</i>		
Gill Nets	47	39.17
Hooks and lines	33	27.50
Trammel nets	28	23.33
Traditional traps (bubu)	12	10.00

<i>Social condition</i>		
Simple house	73	60.2
Permanent house	47	39.8
<i>Involvement in organizations</i>		
Active in fishermen groups	61	50.4
Not involved	59	49.6
<i>Perception of the environment</i>		
Marine environment is deteriorating	115	95.83
No change in the environment	5	4.17
<i>Distance to mining area</i>		
0-1 km	25	22.73
2-3 km	56	50.91
4-5 km	29	26.36

Impact of coal mining on the environment. Environmental degradation is an increasingly urgent and complex issue that affects various aspects of community life. Amidst the rapid pace of industrial development and the ongoing exploitation of natural resources, numerous new challenges have emerged that threaten the sustainability of ecosystems. One particularly concerning aspect is the operation of coal-fired power plants (PLTU). While these plants play a crucial role in meeting the increasing energy demands of society, they also contribute significantly to environmental degradation. The emissions and waste generated by these facilities lead to air and water pollution, which adversely affects local ecosystems and the health of surrounding communities. It is essential to clarify the connection between industrial development, resource exploitation, and the role of coal-fired power plants in this environmental degradation. As industries expand and natural resources are extracted at an unsustainable rate, the impacts of these activities become increasingly evident. Coal-fired power plants, in this context, serve as both a necessary energy source and a significant contributor to ecological harm. Addressing these issues requires a comprehensive approach that balances energy needs with environmental protection to ensure a sustainable future for both communities and ecosystems.

The case of coal pollution in West Aceh highlights serious issues related to mining and coal processing activities that directly affect the surrounding water environment. One of the most evident impacts is the turbidity of seawater and rivers, which disrupts water quality for communities and aquatic habitats. Waste generated by PLTU is often discharged into water bodies, leading to pollution that damages marine ecosystems and threatens the livelihoods of small-scale fishermen. Additionally, industrial activities frequently contribute to flooding.

The increase in dust and noise from PLTU operations also directly affects public health, diminishing the quality of life for residents. Furthermore, waste runoff into agricultural lands from PLTU activities can harm agricultural productivity and food security. Damage to infrastructure, such as public roads, and the presence of unfilled mining pits exacerbate the situation, increasing safety risks for local communities. Moreover, pollution disrupts mangrove ecosystems and surrounding marine biota, significantly impacting fishermen's livelihoods and the tourism sector. This situation underscores the necessity for stringent oversight and regulation of coal mining activities, as well as remediation efforts to restore polluted environments, in order to minimize long-term impacts.

Based on the data in Table 2, it is noted that the environmental damage reported by respondents highlights several significant issues faced by the community. The most prominent problem is the murkiness of river water (20.20%), which affects the quality of water for daily needs and health. Additionally, 13.53% of respondents identified certain activities as causing floods, indicating an increased risk due to poor water resource management. Dust (19.00%) and noise pollution (15.36%) were also reported, both of which can negatively impact public health and well-being. The effects of mining activities are evident with the entry of mining waste into agricultural land (10.70%), harming crop yields, and damage to public roads (13.53%) disrupting accessibility. Lastly, the presence of uncovered mining pits (8.68%) indicates a lack of proper management, posing safety risks to the community. FGDs with fishermen revealed that coal mining has resulted in spills into the sea, and coal washing processes to separate sulfur have polluted both river and sea

waters in the region. Studies show that coal washing waste contains hazardous substances such as sulfur, mercury, cyanide acid, manganese, sulfuric acid, and lead. Heavy metals like mercury and lead can cause skin diseases, including cancer, in humans who consume contaminated water.

Table 2

Percentage of environmental damage due to coal mining

No.	Environmental damage	Percentage (%)
1	River water becomes murky	19.20
2	Causes of flooding	13.53
3	Increase in dust	19.00
4	Increase in noise levels	15.36
5	Entry of mining waste into agricultural land	10.70
6	Damage to public roads	13.53
7	Presence of uncovered mining pits	8.68

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Impact of coal mining on the socio-economic conditions of small-scale fishermen.

Coal mining activities significantly affect small-scale fishermen. The presence of these operations complicates the fishermen's ability to operate their fishing gear. The establishment of PLTU forces fishermen to venture farther out to sea because areas that were previously fishing zones have now become restricted zones. If they continue to fish in these areas, the catch is often suboptimal due to the pollution from waste discharged by the PLTU, which contaminates the surrounding waters. Below is a table showing the number and percentage of respondents who provided feedback regarding the impact of PLTU activities on small-scale fishermen.

Based on Table 3, the research results indicate that water pollution has the most significant impact on small-scale fishermen, with 60 respondents (50%) reporting negative effects on their fishing activities. This pollution reduces both the quantity and quality of their catch, directly affecting their income, as 55 respondents (45.8%) noted a decline in their catch. Additionally, 50 respondents (41.7%) experienced difficulties operating their fishing gear and felt that fishing areas were becoming increasingly restricted, forcing them to venture farther out to sea. Fish health is also a concern, with 40 respondents (33.3%) observing a decline in fish quality, while 30 respondents (25.0%) expressed worries about health risks associated with pollution.

Table 3

Impact of coal mining on the socio-economic conditions of the community

No.	Impact	Number of respondents	Percentage (%)
1	Difficulty operating fishing gear	50	41.7
2	Need to fish farther out	45	37.5
3	Decrease in catch	55	45.8
4	Water pollution	60	50.0
5	Decline in fish health	40	33.3
6	Health risks for fishermen	30	25.0
7	Reduction in fishing areas	50	41.7

Source of thermal waste comes from power plants. This thermal waste, disseminated throughout marine waters, poses dangers to the marine environment and its biota (Naik et al 2019; Kumar et al 2022). Consequently, fish tend to avoid areas around the PLTU, which are critical habitats for the target species of small fishermen. FGDs revealed that the number of barges has been increasing daily, complicating operations for fishermen. Interviews with several fishermen using various methods - such as longlines, payang, rampus nets, and trammel nets - indicated incidents where fishing boats were struck by coal barges, resulting in damage to the vessels and gear, and even fatalities among crew members. Although the PLTU provides compensation to the families of affected fishermen, the process is cumbersome and lengthy. To date, several fishermen whose nets were damaged have not received replacements and must bear the costs of making new nets themselves. Furthermore, coal exposed to sunlight for extended periods on barges can undergo oxidation with flammable gases, causing the coal to ignite. This leads to frequent coal fires during transport, producing smoke that irritates the eyes and causes shortness of breath, particularly for fishermen at sea, making it difficult for them to catch fish. Miroshnichenko & Kaftan (2017) state that coal is generally self-combustible. Self-combustion of coal is defined as the slow heating and oxidation of coal initiated by the absorption of oxygen at low temperatures (Andrews et al 2021). This property can lead to coal fires, resulting in environmental damage.

Fishermen's attitudes toward coal mining. Mining activities, particularly open-pit mining, have significant impacts on the environment, economy, and society. This process begins with large-scale land clearing, often resulting in deforestation and changes in land use. Land clearing not only destroys local ecosystems but also disrupts the habitats of various species, potentially leading to a decline in biodiversity. The environmental impacts of these mining activities are particularly felt by fishing communities that rely on marine resources. When land is cleared, sedimentation and waste from mining operations can pollute water bodies, directly affecting water quality and marine life. This leads to decreased fish catches, which are a primary source of income for fishermen. In this context, understanding the perceptions and attitudes of fishermen toward mining is crucial.

Based on Table 4, the survey results indicate that the majority of fishermen hold a negative perception of environmental conditions, with 80% of respondents feeling that the situation is deteriorating. This reflects deep concerns about the impacts of mining, such as pollution and ecosystem damage that affect their livelihoods. Conversely, attitudes toward mining activities show that 65% of respondents support these operations. This support may stem from expectations of short-term economic benefits derived from mining, despite an awareness of its negative impacts. Additionally, 26.67% of respondents expressed neutral attitudes, indicating ambivalence or uncertainty, while only 8.33% opposed mining activities. The low level of opposition may be related to limited economic alternatives for fishermen. FGDs with fishermen revealed that they are often not involved in employment opportunities at PLTU, lack representation in discussion forums, have minimal knowledge and access to information about licensing processes, and face the dominance of large economic interests that overlook their voices. Furthermore, social and economic stigma position small-scale fishermen as a less influential group, while existing policies rarely adopt participatory mechanisms.

Fishermen's perceptions and attitudes toward mining

Table 4

<i>Aspect</i>	<i>Category</i>	<i>Number of respondents</i>	<i>Percentage (%)</i>
Perception of the environment	Deteriorating condition	96	80.00
	Stable condition	14	11.67
	Improving condition	10	8.33
Attitude towards mining	Support	78	65.00
	Neutral	32	26.67
	Oppose	10	8.33

Community adaptation strategies in response to environmental changes. The impacts of coal mining in West Aceh have far-reaching and significant consequences for the fishing communities that rely heavily on marine ecosystems for their livelihoods. These communities depend on the health of the waters and the abundance of marine life to sustain their economic activities. However, the mining activities in the region often result in severe water pollution, habitat destruction, and a general decline in environmental quality. As coal mining operations expand, they frequently release harmful substances into nearby water bodies, which can contaminate the water and disrupt the delicate balance of aquatic ecosystems. This pollution not only affects the health of the fish populations but also poses serious risks to the fishermen and their families who consume these fish. As a result, the quality and quantity of fish catches have diminished, leading to economic instability for those who depend on fishing as their primary source of income.

In light of these challenges, the fishermen of West Aceh have shown remarkable resilience and resourcefulness. They have developed a range of effective adaptation strategies to cope with the adverse effects of coal mining on their livelihoods. These strategies may include diversifying their income sources, such as engaging in alternative forms of fishing, aquaculture, or even tourism-related activities. Additionally, some communities are actively involved in advocacy and environmental conservation efforts, seeking to raise awareness about the importance of protecting marine ecosystems.

Based on Table 5, it is showed that among the total respondents, 41.7% reported that they are primarily seeking new fishing locations. This reflects an urgent need to explore alternative waters due to declining catches in traditional areas that may be affected by pollution and habitat destruction. Additionally, 33.3% of respondents reported changing their fishing gear to be more efficient and environmentally friendly, which not only helps improve catch yields but also contributes to sustainability. Collaboration with local organizations has also emerged as an alternative, with 29.2% of fishermen relying on collaborative support to advocate for their rights and obtain necessary information in the face of environmental changes caused by coal mining. Furthermore, 25.0% of respondents are diversifying their livelihoods to reduce dependence on fish catches, demonstrating an awareness of the importance of creating additional income sources amid uncertainty. Although only 16.7% have participated in skills training, there is a desire to enhance their abilities and knowledge in better fishing techniques.

Adaptation strategies of fishing communities facing environmental changes

Table 5

<i>Category</i>	<i>Number of respondents</i>	<i>Percentage (%)</i>
Changing fishing gear	40	33.3
Finding new fishing locations	50	41.7
Business diversification	30	25.0
Skills training	20	16.7
Collaboration with local organizations	35	29.2

Conclusions. The impact of coal mining on small-scale fishing communities in West Aceh has significant and complex consequences, affecting various environmental, social, and economic aspects. Research findings show that 19.20% of respondents reported turbidity in river water, while 50% identified water pollution as the most detrimental effect, disrupting water quality and aquatic habitats. Additionally, 41.7% of respondents experienced difficulties operating their fishing gear, and 45.8% reported a decline in fish catches, directly affecting their income and well-being. Despite 65% of respondents supporting mining activities due to perceived economic benefits, they also acknowledge the negative consequences associated with these operations. There is a negative perception of deteriorating environmental conditions, with 80% of respondents expressing concern that environmental damage is worsening. As a recommendation, there is a need for collaboration, stringent oversight, and policies that protect the environment while enhancing the welfare of fishing communities. It is also essential to involve the community in decision-making processes to ensure their voices and needs are considered.

Conflict of interest. The authors declare that there is no conflict of interest.

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