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Clean Water Management in Settlements Around the Gebe Island Nickel Mining as an Effort for Sustainable Environmental Education

Pengelolaan Air Bersih di Permukiman Sekitar Tambang Nikel Pulau Gebe Sebagai Upaya Edukasi Lingkungan Berkelanjutan

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Abstract

This study is motivated by the fact that the limited availability of clean water in residential areas around the Gebe Island nickel mine has the potential to cause health risks and environmental degradation due to nickel mining activities in residential areas. This occurs due to the lack of a sustainable education strategy, so a scientific approach is needed in clean water management based on community participation. This study aims to analyze the relationship between environmental education and clean water management based on community empowerment to improve the quality of life and the resilience of water ecosystems in a sustainable manner. This research was conducted using a mixed-method approach. Data were collected through questionnaires, interviews, pretest-posttest and FGD, while data analysis was carried out quantitatively and qualitatively. The results of the research and environmental education training were able to improve community knowledge and behavior in maintaining water quality. The success of this program was influenced by social, economic, and institutional factors as well as the synergy between the government, community and companies in creating a participatory and sustainable water management system.

Article Information

Keywords:
clean water management, sustainable environmental education, nickel mining

Kajian ini dilatarbelakangi oleh fakta terbatasanya ketersediaan air bersih di permukiman warga sekitar tambang nikel Pulau Gebe yang berpotensi menimbulkan risiko kesehatan serta degradasi lingkungan akibat adanya aktivitas pertambangan nikel di wilayah pemukiman warga, hal ini terjadi karena kurangnya strategi edukasi berkelanjutan terkait pengelolaan air bersih yang menjadi kebutuhan warga setempat. Cara yang dapat dilakukan adalah diperlukan metode atau pendekatan ilmiah dalam pengelolaan air bersih berbasis partisipasi masyarakat. Penelitian ini bertujuan menganalisis hubungan antara edukasi lingkungan dan pengelolaan air bersih berbasis pemberdayaan masyarakat guna meningkatkan kualitas hidup dan ketahanan ekosistem air secara berkelanjutan. Penelitia ini dilakukan dengan menggunakan pendekatan mix-method. Data dikumpulkan melalui kuesioner, wawancara, pretest-posttest dan FGD, sedangkan analisis data dilakukan secara kuantitatif dan kualitatif. Hasil penelitian dan pelatihan edukasi lingkungan mampu meningkatkan pengetahuan dan perilaku masyarakat dalam menjaga kualitas air. Adanya keberhasilan program ini dipengaruhi oleh faktor sosial, ekonomi, dan kelembagaan serta sinergi antara pemerintah, masyarakat dan perusahaan dalam menciptakan sistem pengelolaan air yang partisipatif dan berkelanjutan.

Kata kunci:
pengelolaan air bersih, edukasi lingkungan berkelanjutan, pertambangan nikel

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A. INTRODUCTION

The availability of clean water is a basic human need that is crucial for supporting health, social life, and sustainable development. In Indonesia, access to clean water remains a challenge, especially in remote areas or areas impacted by extractive industry activities such as mining. One area facing a similar problem is Gebe Island, a small island in Central Halmahera Regency, North Maluku Province. This island is known to have substantial nickel reserves, making it a site for industrial-scale mining activities. Unfortunately, mining activities on Gebe Island have significantly impacted the quality and quantity of clean water available to the local community (Arifin, M., & Hidayati, 2021).

Field evidence indicates that communities living around the Gebe Island mining area face various clean water-related challenges, including declining groundwater quality due to heavy metal contamination, limited clean water sources, and a lack of adequate water treatment facilities and infrastructure. Data from the local Health and Environmental Services Agency indicates that levels of heavy metals, such as nickel and iron, in several water sources exceed the threshold set by Minister of Health Regulation No. 32 of 2017 concerning Environmental Health Quality Standards. A community survey indicates that most residents lack an adequate understanding of the importance of clean water management and the long-term environmental impacts of mining activities(Rahmawati, N., & Yuliana, 2021).

The gap between the need for quality clean water and the actual conditions on the ground gives rise to various health and social issues. The absence of a structured clean water management system further exacerbates the situation. On the one hand, communities are heavily dependent on groundwater and natural sources, while on the other, mining activities continue to expand exploration areas, shrinking community living spaces and disrupting water resources. The hope for the future is the creation of a clean water management system that is not only technically feasible but also capable of serving as an environmental education tool that fosters collective awareness and community participation in sustainably maintaining the island's ecosystem. Addressing this gap requires an integrative, empowerment-based effort, namely the development of a community-based clean water management system equipped with an environmental education component. This approach is expected to not only improve access to clean water but also encourage changes in community behavior toward environmental protection, particularly in the context of coexisting with extractive industries. Environmental education embedded in the clean water management process can serve as a medium to increase community ecological literacy and strengthen the position of policymakers in decision-making concerning survival and the environment (Suryani, A., & Febrianti, 2021).

Efforts will include identifying potential clean water sources, developing simple water treatment technologies (such as biofilters or activated carbon-based purification systems), providing community training on water source maintenance and management, and providing environmental education tailored to the characteristics of the Gebe Island community. This approach is participatory, involving the local community as the primary actors. Furthermore, the involvement of local government and mining companies in corporate social responsibility (CSR) programs is crucial to ensuring the program's sustainability (Hakim, L., & Lestari, 2022).

The rationale for choosing this approach is based on the principles of sustainable development, which emphasize the integration of environmental, social, and economic aspects. Clean water management based on environmental education is believed to have a dual impact: first, improving the community's quality of life through adequate access to clean water; second, strengthening community capacity to protect the environment from the threat of damage caused

by natural resource exploitation. This also aligns with the Sustainable Development Goals (SDGs), particularly goals 6 (Clean Water and Sanitation) and 13 (Climate Action), which emphasize the importance of sustainable water management and adaptation to environmental change (Firmansyah, R., & Dewi, 2021).

The novelty of this research lies in the integration of clean water management and environmental education into a single, participatory and contextual model. To date, most approaches to clean water management in mining areas have tended to be top-down and technocratic, resulting in less active involvement of local communities. This research offers an inclusive model where education is not merely a complement, but rather a core strategy for sustainable water resource management. Furthermore, this research will produce a learning document that can be replicated in other regions with similar characteristics, thus contributing to the development of best practices in environmental management in mining-impacted areas by addressing local issues with global implications. This research is expected to provide scientific and practical contributions to environmental conservation efforts and improve the quality of life of communities surrounding mining areas. Furthermore, the results of this study are also expected to serve as a reference for policymakers in formulating more equitable and sustainable water and environmental management policies in vulnerable areas such as Gebe Island (Nugraha, B., & Fitriani, 2023). This study was conducted with the aim of: 1) assessing the level of knowledge, effectiveness of socialization, and community participation in environmental protection in island Gebe District; 2) exploring community perceptions of water quality, the health risks posed, and clean water management efforts around mining areas; 3) analyzing significant differences between the pre-test and post-test results of environmental education training participants; and 4) evaluating and integrating the training results into sustainable clean water management and pollution control strategies on Gebe Island.

B. METHODS

This study used a quantitative and qualitative (mixed-method) approach to obtain a comprehensive overview of community knowledge, perceptions, and participation, as well as the effectiveness of environmental education training in Pulau Gebe District. A mixed-method approach is effective for comprehensively understanding social phenomena through the integration of quantitative and qualitative data(Lestari, S., & Nugroho, 2021). Regarding knowledge, socialization, and community participation in environmental protection, data were collected through a structured questionnaire distributed to the local community. The questionnaire was designed to measure basic environmental knowledge, exposure to socialization, and community involvement in environmental conservation activities. In-depth interviews and a perception survey were used to assess community perceptions of water conditions, health risks, and clean water management around the mine. Informants were selected through purposive sampling from the community living near the mine. Informants were selected using purposive sampling from the community living around the mine. These informants included community leaders, mine workers, local traders, and local residents relevant to the research. Interview results were analyzed using thematic techniques. Thematic analysis is carried out by revealing patterns, themes, and the deep meaning of interviews, in order to provide a comprehensive understanding of the phenomena being scientifically researched. Furthermore, a quasi-experimental method was used to compare the pretest and posttest results of the environmental education training. Training was provided to community groups, followed by a pretest before the training and a posttest after the training. Data analysis used a paired sample t-

test to determine the significance of changes. Finally, the integration of training outcomes with clean water management and pollution control strategies was analyzed descriptively through focus group discussions (FGDs) with local stakeholders. The data were analyzed to formulate collaborative strategies based on participation and local knowledge that integrated the training outcomes.

C. RESULTS AND DISCUSSION

Knowledge, Socialization, and Community Participation in Environmental Protection

The analysis of knowledge, outreach, and community participation (Figure 4.1) in environmental protection was compiled based on the analysis stages of primary data obtained through in-depth interviews with local communities, village leaders, and mining company representatives on Gebe Island. Furthermore, these findings were reinforced by questionnaire data distributed to heads of families and direct field observations, providing a comprehensive picture of water conditions, management efforts, and the involvement of various parties in protecting the environment around the mining area. The issue of river water quality and clean water management in residential areas around the Gebe Island mine is a strategic issue that requires the attention of various parties. The mind map that has been compiled identifies several important interrelated aspects, ranging from the physical condition of the water source, potential pollution, impacts on public health, to stakeholder involvement in water management. This overview clarifies the complexity of the challenges faced by mining activities and environmental changes that affect the sustainability of local water sources. Mining activities have been shown to impact water quality and environmental sustainability around the mining area (Hidayat, A., & Lestari, 2022). The involvement of communities, governments, and companies is very important in collaborative clean water governance, especially through participatory approaches and integrated monitoring (Wijaya, K., Ramadhani, M., & Anwar, 2023).

Furthermore, the interaction between environmental and social factors is key to understanding the dynamics of water management in this region. Efforts by communities, the government, and mining companies to maintain clean water quality and accessibility are reflected in various initiatives, including routine monitoring, the provision of clean water infrastructure, and water management education and training. Disseminating information and increasing environmental awareness also strengthen community resilience in the face of pollution and water scarcity, particularly during the dry season. Collaboration between communities, the government, and the private sector is crucial in building water resilience in pollution-prone areas. Environmental education, clean water infrastructure, and adaptive strategies to seasonal changes are key factors in the success of sustainable water management (Mulyani, S., & Prasetyo, 2020).

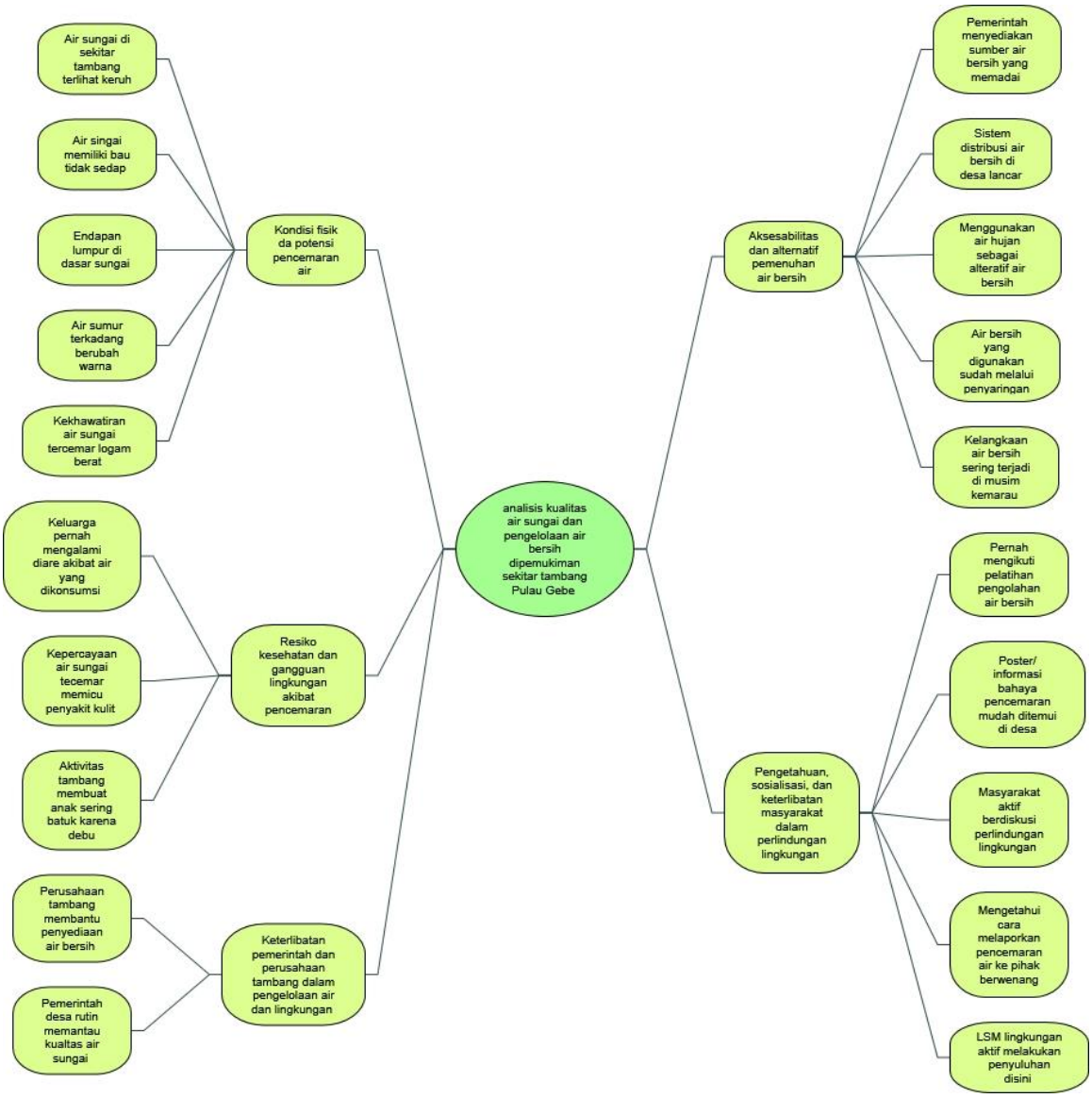

Figure 1. Mind map of River Water Quality Analysis and Clean Water Management in Settlements Around the Gebe Island Mine

The mind map above describes several important aspects related to water conditions and management efforts, including:

1. In terms of physical conditions and potential water pollution, several indications of pollution were found, such as cloudy river water around the mine, an unpleasant odor, and the presence of mud deposits on the riverbed. Furthermore, well water sometimes changes color, raising public concerns about heavy metal contamination in the river.
2. The health risks and environmental disruptions caused by pollution are a public concern. There have been reports of families experiencing diarrhea from consuming contaminated water, and there's a widespread belief that river water causes skin diseases. Mining activities also cause frequent coughing in children due to dust.
3. In terms of stakeholder involvement, mining companies reportedly assist in the provision of clean water, and village governments routinely monitor river water quality. This

demonstrates the involvement of both the government and mining companies in water and environmental management.

4. To ensure accessibility and alternatives to clean water, the government has provided adequate clean water sources, and the clean water distribution system operates smoothly in the village. Communities also use rainwater as an alternative. The clean water used is generally filtered, although clean water shortages still occur during the dry season. Some residents have also participated in clean water management training.
5. In terms of knowledge, outreach, and community involvement in environmental protection, it appears that people actively discuss environmental issues, know how to report pollution to authorities, and frequently receive information from environmental NGOs conducting outreach in the village. Posters and information about the dangers of pollution are also readily available.

Overall, this mind map demonstrates that despite challenges related to water quality caused by mining activities, there are also joint efforts from the community, government, and companies to ensure the availability and management of clean water and protect the environment around Gebe Island. Mining activities can cause water quality degradation through heavy metal pollution and sediment waste, which impacts community health and well-being (Ardiansyah, M., & Ramadhani, 2022). Collaboration between the community, government, and industry sectors in providing clean water, monitoring water quality, and increasing capacity through education and training is a crucial strategy for maintaining the sustainability of water resources (Nugroho, H., Putri, A. R., & Yuliani, 2023).

Public Perceptions of Water Conditions, Health Risks, and Clean Water Management Around the Gebe Island Mine

Community perceptions of river water conditions and clean water management around the Gebe Island mine were evaluated using a questionnaire that addressed various aspects related to physical quality, accessibility, and health risks. The frequency data in the following table provides an objective overview of the views and experiences of residents in the area.

Table 1. Public Perception of Water Conditions, Health Risks, and Clean Water Management Around the Gebe Island Mine

	Frequency (n)				
Physical conditions and potential for water pollution	**STS**	**TS**	**N**	**S**	**SS**
The river water around the mine looks murky	2	0	1	10	12
The river water has an unpleasant odor	2	2	2	11	8
Mud deposits at the bottom of the river	0	4	3	15	3
Well water sometimes changes color	0	9	3	9	2
Concerns about river water being contaminated with heavy metals	1	0	2	12	8
Accessibility and alternatives for fulfilling clean water needs					
The government provides adequate sources of clean water	1	14	2	5	5
The clean water distribution system in the village is running smoothly	0	11	5	7	3
Using rainwater as an alternative to clean water	0	9	1	13	2
The clean water used has been filtered	1	10	3	11	0
Scarcity of clean water often occurs in the dry season	0	0	1	17	7
Health risks and environmental disturbances due to pollution					
The family has experienced diarrhea due to the water they consumed.	0	3	14	6	1
The belief that polluted river water triggers skin diseases	1	2	0	17	5

Mining activities often cause children to cough due to dust.	1	1	1	15	6
Knowledge, outreach, and community involvement in environmental protection					
Have attended clean water processing training	0	8	3	15	3
Posters/information about the dangers of pollution are easy to find in villages.	2	5	14	13	2
The community actively discusses environmental protection	0	2	12	9	2
Know how to report water pollution to the authorities	0	2	5	16	3
Environmental NGOs actively conduct outreach here	3	15	0	1	6
Involvement of government and mining companies in water and environmental management					
Mining companies help provide clean water	1	13	1	5	5
The village government routinely monitors the quality of river water	1	14	1	4	5

Based on the data in Table 1, the following interpretation can be drawn up:

1. Physical Conditions and Potential for Water Pollution

The majority of respondents agreed (S) or strongly agreed (SS) that the river water around the mine appeared cloudy (10 S, 12 SS) and had an unpleasant odor (11 S, 8 SS). This indicates that the community is aware of visual and olfactory indications of pollution. Regarding silt deposits on the riverbed, the majority also agreed (15 S), although some disagreed (4 TS). Changes in the color of well water showed more diverse views, with many disagreeing (9 TS), indicating that perceptions of groundwater pollution are not yet very strong. However, concerns about heavy metal contamination are quite high (12 S, 8 SS). Community perceptions of water pollution, such as changes in color, odor, and the presence of sediment, are important early indicators in identifying water quality around mines(Syahrul, M., & Dewi, 2022).

2. Accessibility and Alternatives to Clean Water Supply

Informant were quite critical of the government's role in providing clean water, with many disagreeing (14 TS), as well as the clean water distribution system (11 TS). However, the use of rainwater as an alternative received significant approval (13 S). The water used was reported to have been filtered by a majority of respondents, although not overwhelmingly. The scarcity of clean water during the dry season was strongly acknowledged, with 17 respondents agreeing and 7 strongly agreeing, indicating a significant seasonal problem. Clean water availability in mining-prone areas is often hampered by inadequate infrastructure, forcing communities to rely on alternatives such as rainwater, especially during the dry season (Fadli, R., & Maulida, 2023).

3. Health Risks and Environmental Disturbances

Most respondents were neutral (14 N) regarding their experiences with water-related diarrhea, indicating uncertainty or a lack of direct evidence. However, many agreed or strongly agreed that river water triggers skin diseases (17 S, 5 SS) and that mining activities cause frequent coughing in children (15 S, 6 SS), indicating community concern about the health impacts. Water and air pollution from mining activities has been linked to increased cases of skin diseases and respiratory disorders in children in settlements surrounding industrial areas (Latifah, R., & Haryono, 2022).

4. Knowledge, Socialization, and Community Involvement

Water treatment training has been attended by some residents (15 S), although some disagree (8 TS). Pollution information through posters is quite well known (13 S). Community activity in environmental protection discussions also appears quite good (9 S, 2 SS). Most residents know how to report pollution (16 S). However, perceptions of the role of environmental NGOs tend to be negative, with a predominance of "disagree" (15 TS), indicating that the presence or activities of NGOs may not be perceived as significant. Community

participation in environmental management has increased through training, outreach, and access to information, but the effectiveness of NGOs' roles is often questioned when communication and field presence are deemed suboptimal (Wulandari, D., & Setiawan, 2023).

5. Government and Mining Company Involvement

Community perceptions of the contributions of mining companies and village governments to water management tended to be negative, with the majority stating "disagree" (13 TS and 14 TS, respectively). This reflects a lack of trust or tangible evidence of the direct involvement of these two parties in water quality management. This lack of community trust in government and companies in environmental management is often caused by a lack of transparency, communication, and tangible evidence of programs implemented at the local level (Saputra, H., & Yuniarti, 2022).

The Gebe Island community is generally aware of and feels the impacts of water pollution caused by mining activities, both physically and on health. However, perceptions of the role of government and companies in providing and managing clean water remain low. Public education and participation in environmental activities are already in place, but need to be strengthened, particularly through training and the active presence of NGOs. Alternatives such as rainwater harvesting are well-received, but clean water distribution and availability remain challenges, particularly during the dry season. Public awareness of the impacts of mining pollution is crucial for successful water management, but its effectiveness depends on concrete support from the government, companies, and the active role of NGOs and the strengthening of local capacity (Hasanah, U., & Ridwan, 2023).

Comparison of Pre-Test and Post-Test Results of Environmental Education Training on Clean Water Management and Pollution Mitigation in Pulau Gebe District

To assess the effectiveness of the environmental education training entitled "Increasing Community Capacity in Sustainable Clean Water Management and Environmental Pollution Mitigation in Gebe District," participants' knowledge was measured through a pre-test before the training and a post-test after the training. The following comparison of pre-test and post-test scores illustrates the increase in community understanding and capacity on the topic of clean water management and environmental pollution mitigation efforts.

Table 2. Comparison of posttest scores with pretest scores Paired Samples Statistics

	Mean	N	Std.Deviation	Std.Error
Pair 1 Nilai postest	81,625	24	3,4365	,7015
Nilai Pretest	73,958	24	3,9615	,8086

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 Post Test Score-Pretest Score	7,66	675,2640	1,0745	5,4439	9,8895	7,135	23	,000

Based on the results of the Paired Samples T-Test, it was found that there was a difference in the average scores between the pretest and posttest scores of 24 respondents. The average pretest score was 73.96 with a standard deviation of 3.96, while the average posttest score increased to 81.63 with a standard deviation of 3.44. The average difference between the posttest and pretest scores of 7.67 indicates an improvement in results after the intervention. An increase in posttest scores after an intervention indicates the effectiveness of an educational program, where the Paired Samples T-Test is often used to measure significant differences in training or outreach evaluations (Permatasari, D., & Wijayanti, 2021).

The statistical test results showed a t-value of 7.135 with 23 degrees of freedom (df) and a significance value of 0.000. Since the significance value is less than 0.05, it can be concluded that there is a significant difference between the pretest and posttest scores. Thus, the intervention or treatment provided has proven effective in improving learning outcomes or participant understanding, as reflected in the increase in scores after the intervention was carried out.

A significant increase in posttest scores compared to pretest scores also indicates that the intervention method or material implemented significantly improved respondents' mastery of the material or competencies. This suggests that the learning or training strategy implemented is worthy of consideration as an effective approach in the same context or with a similar population. The consistent decrease in standard deviation from pretest to posttest also strengthens this interpretation, as it indicates a smaller variation in scores between participants after the intervention, indicating more equitable learning outcomes.

Furthermore, the results of the Paired Samples T-Test, with a very low significance level, strengthen scientific evidence that the changes were not simply the result of chance or random variation, but rather a real impact of the intervention. These findings can serve as a basis for organizers to evaluate and further develop training or learning programs, while also recommending the implementation of similar methods on a broader scale to achieve optimal results. The Paired Samples T-Test is effective for evaluating the impact of educational interventions, where a significant increase in posttest scores and a decrease in standard deviation indicate the success of the learning strategy in improving understanding and equity of participant outcomes (Rohmah, S. N., & Santoso, 2022).

Integration of Environmental Education Training Results with Clean Water Management and Pollution Control Strategies

The comparison of pretest and posttest scores from the environmental education training showed an increase in community understanding of sustainable clean water management and environmental pollution mitigation. This improvement provides a crucial foundation for strengthening community participation, as illustrated in the mind map, particularly in the areas of solutions and strategies for water pollution control. The knowledge and capacity developed through the training support more effective collaboration between the community and the government in efforts to reduce pollution and maintain the sustainability of clean water sources.
Furthermore, the increased community understanding gained from the training also directly contributes to the interaction of ecology and human activities on water quality, as a more educated community will be more aware of the impact of their daily activities, including mining activities, on aquatic ecosystems. Therefore, integrating the training outcomes into clean water management and pollution control strategies, as outlined in the mind map (Figure 4.8), strengthens community preparedness and participation in addressing challenges and obstacles in clean water management in areas surrounding mines.

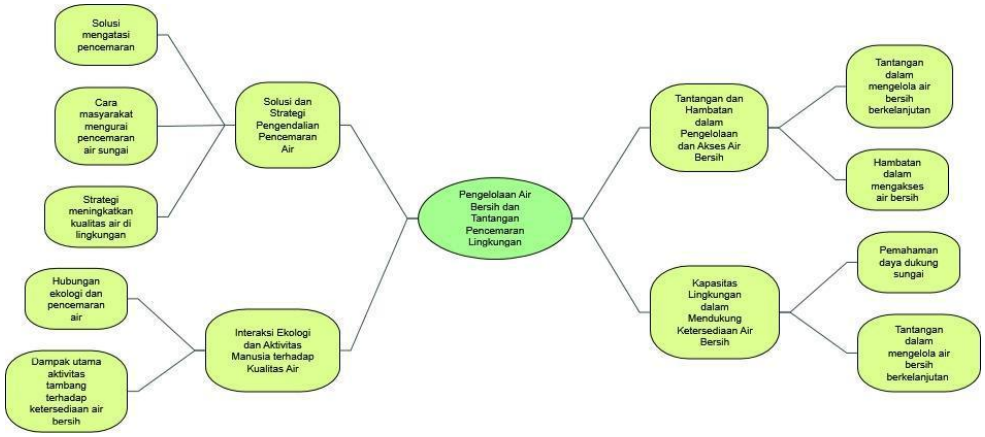

Figure 2. Mind map "Clean Water Management and the Challenges of Environmental Pollution"

Based on the displayed mind map, the main theme is "Clean Water Management and the Challenges of Environmental Pollution." It covers three major interrelated aspects: solutions and strategies for controlling water pollution, the interaction of ecology and human activity on water quality, and the challenges and obstacles in managing and accessing clean water.

In the first aspect, namely solutions and strategies for controlling water pollution, several approaches to addressing pollution are discussed. This includes various solutions offered to address pollution, community participation in reducing river water pollution, and strategies for improving water quality in the environment. These efforts demonstrate the importance of collaboration between the community and the government in maintaining water quality. Water pollution control strategies require collaboration between the community and the government through a participatory approach, strengthened regulations, and the application of appropriate technology to improve water quality and maintain environmental sustainability (Kusumawardani, R., & Prabowo, 2021).

Furthermore, in terms of the interaction between ecology and human activities on water quality, it is emphasized how human activities, particularly mining, have a major impact on clean water availability. The link between ecology and water pollution is evident, indicating that ecosystem balance plays a significant role in determining the quality and sustainability of clean water resources. Human activities such as mining significantly impact water quality degradation and ecosystem imbalance, ultimately affecting the availability and sustainability of clean water sources in the surrounding environment (Hutabarat, R., & Maulina, 2023).

The third aspect addresses challenges and obstacles in clean water management and access. These challenges include difficulties in managing clean water sustainably and barriers to access, particularly in remote areas. Furthermore, the environmental capacity to support clean water availability is also highlighted, including the importance of understanding river carrying capacity and limitations in long-term water management. Clean water management and access in remote areas face various challenges, including limited infrastructure, poor understanding of environmental carrying capacity, and weak long-term sustainable management systems (Susanti, D., & Firdaus, 2022).

Overall, this mind map illustrates that clean water management requires not only technical strategies but also an ecological approach and active community participation to address pollution and ensure the sustainability of water resources. Effective clean water management requires an integration of technical approaches, ecological awareness, and active community participation to maintain water quality and ensure resource sustainability amidst the pressures of human activity (Anindita, R., & Wardana, 2023).

D. CONCLUSION

1. The Gebe Island community has a relatively good level of knowledge and participation in environmental protection. Active community involvement, easy access to information, and participation in training are key indicators. Although mining pollution persists, collaboration between the community, government, and companies has promoted more sustainable, inclusive, and participatory clean water management.
2. The people of Gebe Island have a strong perception of declining water quality, which has resulted in health risks from mining activities, such as skin diseases and respiratory problems. Despite efforts to manage clean water through filtering and utilizing rainwater, the community still believes that clean water distribution and the active role of the government and companies are not yet optimal.
3. This study demonstrated a significant improvement between the pre-test and post-test scores of environmental education training participants. The results of the Paired Samples T-Test, with a significance value of 0.000, indicated the effectiveness of the intervention in significantly improving participants' understanding.
4. The results of the environmental education training can be effectively integrated into clean water management and pollution control strategies on Gebe Island. This integration strengthens participatory approaches, ecological awareness, and community understanding of environmental challenges, thus supporting the development of a sustainable water management system amidst the pressures of mining activities.

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