

Decision Analysis for The Best Alternative Sedimentation Normalisation Management Method in Sediment Ponds

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ABSTRACT

The sediment pond normalization process plays a crucial role in maintaining environmental compliance and operational sustainability in open-pit coal mining. However, the conventional method used at PT BIB—relying heavily on trucks, excavators, and material blending—is often constrained by equipment inefficiencies, workforce limitations, weather disruptions, and environmental risks. This study aims to identify the root causes of these inefficiencies and propose an optimal alternative normalization method. Employing a qualitative approach, data were collected through semi-structured interviews with experts and analyzed using the Fishbone Diagram and Simple Multi-Attribute Rating Technique (SMART). The findings indicate that the Geotube method offers the most effective solution, eliminating the need for material blending, enabling operations during rainfall, reducing reliance on heavy equipment, and maintaining consistent sludge density. The implementation plan prioritizes high-volume sediment ponds and is supported by a structured budget, schedule, and risk management framework. The study contributes to improving mine wastewater management strategies and offers a replicable model for other industrial sectors aiming for sustainable sludge treatment practices.

Keywords: : Decision Making, Fish Bone Diagram, Simple Multi-Attribute Rating Technique (SMART), Sludge Normalization.

INTRODUCTION

The coal commodity is still one of the important natural resources used in various industrial sectors. Coal commodity is still one of the important natural resources used in various industrial sectors. Based on the projection results, the BaU scenario primary energy mix in 2025 for renewable energy is 21%, gas 24%, coal 34%, and oil 21%, and in 2050 the share of renewable energy rises to 29%, gas 23%, coal 32%, and oil 16% (Metanol, 2019). Meanwhile, according to Government Regulation NO. 79 of 2014 concerning national energy policy that in 2025 the role of coal is at least 30% and in 2050 at least 25% of the projected primary energy mix in Indonesia. Thus, coal is still the main energy in Indonesia.

According to the Ministry of Energy and Mineral Resources (ESDM), the coal sector still supports state revenue (Lung, 2020). The target realisation of Non-Tax State Revenue (PNBP) in

2024 is IDR 113.5 trillion. The Ministry of Energy and Mineral Resources (ESDM) approved the total tonnage of domestic coal production in 2024 to reach 922.14 million tonnes. This value is the result of the Work Plan and Budget (RKAB) for 2024 - 2026 which is determined for 587 companies. Meanwhile, the total tonnage of coal production in 2025 was 917.16 million tonnes, and in 2026 was 902.97 million tonnes.

In 2024, the coal mining industry both in Indonesia and globally is in a transition phase, with an emphasis on improving efficiency, reducing environmental impacts, and adjusting to global energy policies. Despite facing challenges from the shift to renewable energy, coal still plays an important role in fulfilling energy needs in many countries, especially in developing countries. The Indonesian government's determination to become one of the countries that play an important role in sustainability and ESG (Environmental, Social, and Governance) reporting. ESG is becoming one of the important priorities for investors in doing business (Bondarenko et al., 2023). Coal mining companies are required to focus and contribute to this government policy. This effort is to invite participation and corporate responsibility, one of which is to protect and maintain the global environment. The Company can make a greater positive contribution to the environment and society as a whole. Coal mining management policies that are oriented towards environmental concerns to realise the sustainability of environmentally sound development and realise the Sustainable Development Goals (SDGs) programme launched by the United Nations (UN) (Bandyopadhyay & Maiti, 2022). Material topics related to the mining industry that are associated with Sustainable Development Goals (SDGs) aim to mitigate negative impacts and increase positive impacts in line with SDGs.

PT BIB is a coal mining company that conducts mining activities with open-pit mining. The open-pit mining method has a large environmental impact. This method, which involves excavating soil and rock at the surface to extract minerals, often creates a range of serious environmental problems. Large-scale land clearing and excavation can cause soil degradation and increase the risk of sedimentation erosion. Exposed soil can be easily washed away by water and cause sedimentation in rivers or other surface waters.

In 2024, PT BIB has a coal production target of 46.8 million tonnes with a land clearing plan of 1,383 hectares. This target will continue to increase by 54 million tonnes with a total cumulative land clearing plan of 10,465 Ha. To anticipate wastewater and sediment due to mining activities and the vast land clearing, the company has several environmental management and monitoring mitigation measures based on the AMDAL environmental document, one of which is environmental management by making a sediment pond.

A sediment pond is a pond made to accommodate and settle runoff water particles originating from mining sites or temporary material stockpiles before the water is discharged into the river body. The function of the settling pond is to settle mud or solid material from mine water before it flows into public waters and as a place to control water quality before it flows out of the settling pond. Currently, the number of sediment ponds is 29 units, and based on the 54

Million tonnes BIB Feasibility study document the cumulative number of sediments until 2036 is 58 units.

To keep the sediment pond functioning optimally, it is necessary to carry out periodic maintenance to normalise the sedimentation sludge in the sediment pond. Sediment pond normalisation is the maintenance of the storage pond and draining of the settling pond.

The sludge normalisation method currently used is the conventional method, using truck and loading units to retrieve the sludge sedimentation in the sediment pond and then the sludge is discharged to the waste dump area. The current conventional method is less effective because there are often delays due to operational constraints such as the need for relatively many truck units, limited sources of material for blending, long mud disposal distances, the number of loading and truck units is not suitable if the unit is damaged so that productivity becomes low, normalisation activities cannot run if it is raining, and limited waste dump areas for mud materials.

Some of these operational constraints, can cause potential environmental pollution and disrupt coal mining operations in the pit due to the inability to pump mine wastewater to the sediment pond. Based on this, a decision-making analysis is needed to find the best alternative sediment pond normalisation method as a repair of the current conventional method that can eliminate some of these obstacles.

The open-pit mining method carried out by PT BIB has a large environmental impact, one of which is the problem of sedimentation. In 2024, PT BIB has a coal production target of 46.8 million tonnes with a land clearing plan of 1,383 hectares. This target will continue to increase until 2036, which is 54 million tonnes with a cumulative total land clearing of 10,465 Ha. Figure 1 is a graph of coal production and land clearing based on the 54 Million Tonnes BIB Feasibility Study document.

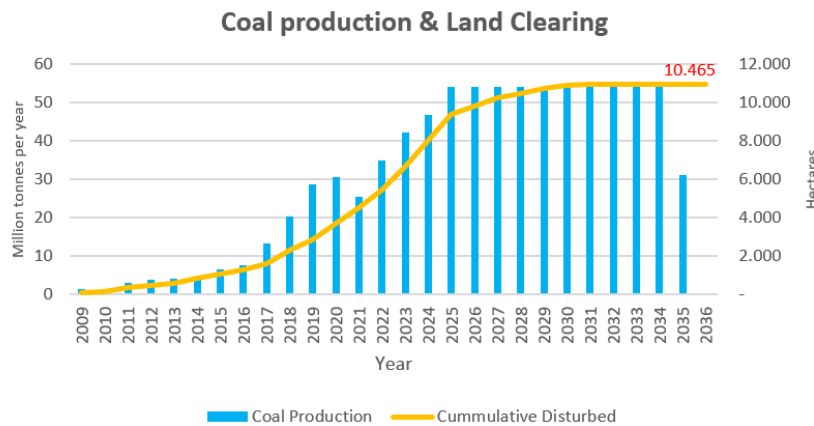


Figure 1. Coal production and land clearing for the period 2009 – 2036

Source: FS BIB 54 Jt tonnes

Along with the progress of the mine opening sequence, it can cause a reduction in water absorption areas which causes erosion and sedimentation which has an impact on high TSS (Total

Suspended Solid) in runoff water during rainfall. The high TSS in the water body reduces the supply of Dissolved Oxygen (DO) in the waters which endangers the life of aquatic biota. Based on South Kalimantan Governor Regulation No. 36 of 2008 the maximum TSS value for coal mining is 200 mg/Litre. Meanwhile, based on the Decree of the Minister of Environment No.113 of 2003 the maximum TSS value for coal mining is 400 mg/Litre. To anticipate wastewater and sedimentation due to mining activities and extensive land clearing, the company has several environmental management and monitoring mitigation measures by the AMDAL document, one of which is wastewater and sediment management by making a sediment pond. Currently, the number of sediment ponds is 29 units, and based on the BIB Feasibility study document 54 Million tonnes the cumulative number of sediments until 2036 is 58 units. Figure 2 is a graph of the number of sediment ponds at PT BIB:

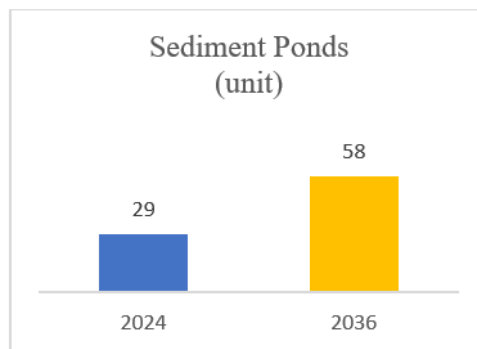


Figure 2. Total Sediment Pond

Source: FS BIB 54 Jt tonnes

Figure 3 is a table of data on the amount of sediment ponds currently and those that will be built until 2036.

Decision Analysis for The Best Alternative Sedimentation Normalisation Management Method in Sediment Ponds

SEDIMENT PONDS - EXISTING			Pit	SEDIMENT PONDS - PLAN		
No	Name	m2		No	Name	Width [m2]
1	SP 01 PSP	32,655.59	PASOPATI	1	SP 04 PSP	40,611.94
2	SP-02 PSP	29,140.95		2	SP 05 PSP	39,486.80
3	SP-03 PSP	25,732.64		3	SP 07 PSP	7,342.96
4	SP 06 PSP	48,409.35				
	Total sediment pond area in pasopati pit	135,938.53		Total sediment pond area in pasopati pit (Plan)	87,441.70	
5	SP 04 GRM	129,590.69	KUSAN GIRIMULYA	4	SP 03 GH	69,791.64
6	SP 03 GRM	1,321.54		5	SP 04 GH	107,095.69
7	SP 06 GRM	105,708.10		6	SP 05 GH	73,008.45
8	SP 02 GRM	1,176.76		7	SP 02 APL	31,233.44
9	SP 05 GRM	161,536.47		8	SP 03 APL	29,851.11
10	SP 08 KSN	3,260.32		9	SP 04 APL	64,833.12
11	SP 10 KSN	71,506.43		10	SP 07 GRM	155,066.88
12	SP 09 KSN	12,752.69		11	SP 06 GRM Extension	157,330.75
13	SP 14 KSN	10,269.60		12	SP 17 KSN	248,021.78
14	SP 12 KSN	90,718.38		13	SP 18 KSN	187,328.31
15	SP 15 KSN	132,161.60		14	SP 19 KSN	150,038.90
16	SP 04 KSN	7,103.40		15	SP 20 KSN	1,515,471.96
17	SP 02 KSN	14,096.83		16	SP 21 KSN	419,577.96
18	SP 03 KSN	2,519.89		17	SP 22 KSN	631,307.74
19	SP 16 KSN	23,716.12	18	Add SP 13 KSN	45,852.16	
20	SP 10 KSN	98,044.06	19	SP 01 ACL	196,236.72	
21	SP 01 APL	10,913.91	20	SP 02 ACL	420,806.34	
22	SP 1 GH	105,708.12	21	SP 03 ACL	110,600.65	
23	SP 2 GH	123,589.96	22	SP 01 GRW	539,432.65	
			23	SP 02 GRW	483,386.30	
			24	SP 03 GRW	201,264.74	
	Total sediment pond area in Kusan - Girimulya pit	1,095,884.87		Total sediment pond area in Kusan - Girimulya pit (Plan)	5,937,531.97	
24	SP 01 MKR	8,699.65	SEBAMBAN	25	SP 01 SBB Utara	134,583.91
25	SP 02 SBB Utara	136,808.81		26	SP 05 SBB	55,200.01
26	SP 03 SBB Selatan	89,304.63		27	SP 04 SBB Selatan	60,323.08
	Total sediment pond area in Sebamban pit	235,012.29		Total sediment pond area in Sebamban pit (Plan)	250,107.00	
27	SP 07 BTL	218,300.00	BATULAKI	28	SP 09 BTL	81,100.00
28	SP 08 BTL	66,600.00		29	SP 11 BTL	18,110.56
29	SP 10 BTL	18,255.28				
	Total sediment pond area in Batulaki pit	303,155.28		Total sediment pond area in Batulaki pit (Plan)	99,210.56	
	Total existing sediment pond area	1,819,990.00		Total Plan sediment pond area	6,374,291.23	
	Total sedimen pond area PT. Borneo Indobara	8,194,282		Total sedimen pond area PT. Borneo Indobara		

Figure 3. Amount of Sediment Pond PT. BIB

Source: FS BIB 54 Jt tonnes

Figure 4 is a map of the sediment pond location:

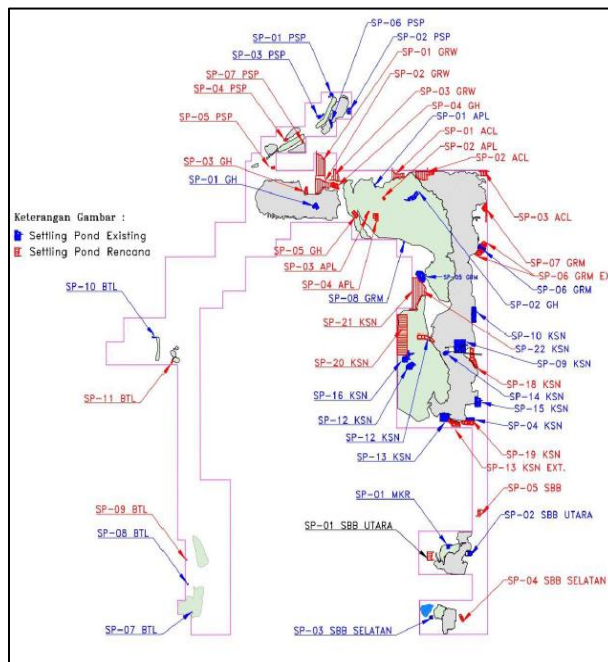


Figure 4. Sediment pond location map

Source: FS BIB 54 Jt tonnes

Figure 5 is a photo of the sediment pond:



Figure 5. Sediment Pond

Sediment ponds need to be maintained periodically so that the capacity of the sediment pond can be optimal to accommodate wastewater and sedimentation by carrying out normalisation activities. The method of normalising sludge in the sediment pond that is currently used is the conventional method, using truck and excavator units to take sludge in the sediment pond and then the sludge is disposed of in the disposal area.

The conventional method still cannot be effective because there is often a non-achievement of the sludge volume target due to several operational constraints such as limited availability of source material blending or a long distance from the location of sediment pond normalisation activities, sludge normalisation activities cannot run if it rains, the need for relatively many truck and loading units, the number of loading and truck units does not match if the unit experiences breakdown, lack of unit operators, the risk of landslides in the disposal dumping area if the viscosity of the sludge material is not suitable and the limited disposal area for sludge material. The conventional method also has a high safety risk because the unit works in the area near the mud. Figure 6 shows the non-achievement of sludge normalisation in sediment ponds 01, 02, 08, 09, and 10:

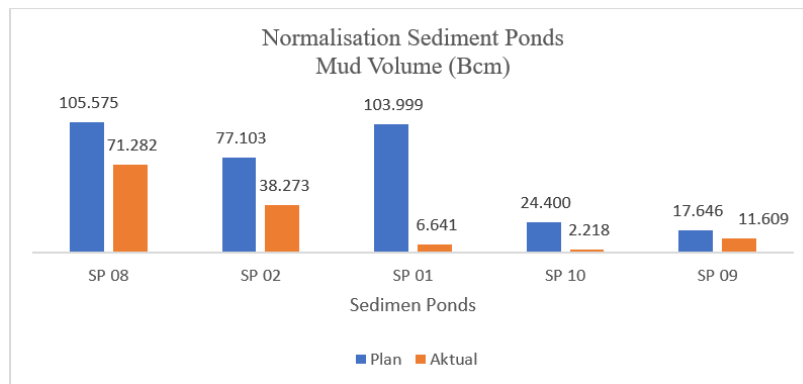


Figure 6. Normalisation activity sludge volume realisation data

Source: Internal company data

The target volume of sludge in normalisation activities using the truck transport method was not achieved as planned, due to the following reasons:

- a. High rainfall resulted in sediment pond normalisation activities not being able to continue.

- b. Non-optimal unit performance due to unit damage so that the match factor is not suitable between the number of loading and truck units
- c. Limited source of material for blending and long distance of material source.

This can lead to potential environmental pollution and disrupt coal mining operations in the pit because it cannot pump mine wastewater to the settling pond. Figure 1.10 is a fishbone diagram analysis to find and regenerate potential improvements to the existing conventional method with truck and excavator units as a basis for finding alternative improvement methods:

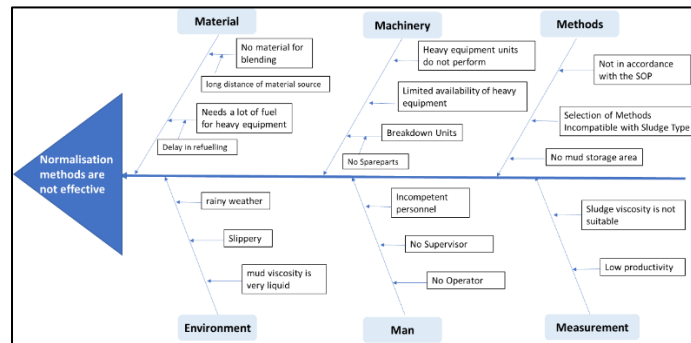


Figure 7. Fishbone Diagram Analysis

Based on the analysis of this fishbone diagram, some of the potential problems identified need to be improved by conducting a decision analysis to find alternative options for a more effective normalisation method, which is not constrained by several major problems such as no source of material for blending, limited availability of heavy equipment, rainy weather, no operator and sludge viscosity is not suitable and machinery along with land clearing and the number of sediment ponds that continue to grow until 2036, so as not to cause potential environmental pollution and interfere with mining operations. This sediment pond management activity is a very important concern for the management of PT.BIB because it will have a very broad impact on the environment and several stakeholders such as Government Agencies, Communities, Contractors, buyers, investors, social community institutions, and environmental observers. This will greatly affect the sustainability of the company's mining activities. Figure 8 is a rich picture of sediment pond normalisation activities that are not carried out effectively.

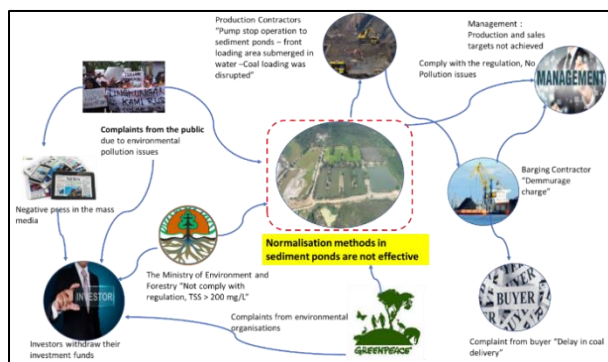


Figure 8. Rich Picture

Environmental issues are very important in the sustainability of mining operations. Companies must be committed to compliance with environmental management regulations set by the central and local governments (Jazuli, 2017). If normalisation activities are not carried out effectively, it will have an impact on environmental pollution. The company will receive strict sanctions from government agencies in the form of closing mining operational licenses. This will also cause complaints from the community, community social organisations, and environmental supervisory organisations and will be exposed by the mass media. This will affect the company's image and will have a direct impact on investors and buyers.

The current sediment pond normalisation method requires that wastewater pumping activities from the mine cannot be pumped continuously to the sediment pond, because it can interfere with normalisation activities. Not being able to do this continuous pumping, will make the pit area waterlogged and will have an impact on disrupting coal exposure activities. This will interfere with coal production and coal shipment to buyers. Therefore, an improvement solution is needed to find the best alternative normalisation method so that problems that can affect the environment and several stakeholders can be avoided and sustainable coal mining activities can run well.

Based on the above background, the purpose of this study is to analyze the causes of the ineffectiveness of the sedimentation pond normalization method currently used at PT BIB and evaluate and determine alternative normalization methods that are more effective, efficient, and sustainable. The benefits of this research are expected to make a practical contribution to the management of PT BIB in making strategic decisions related to sedimentation pond management, as well as making a theoretical contribution to the development of studies in the field of mine environmental management, especially in the management of water and solid waste that is environmentally friendly and supports the achievement of sustainable development goals (SDGs).

RESEARCH METHOD

Data Collection

Primary Data

Primary data was obtained based on interviews with people and or functions related to and experienced with the implementation of this pond sediment normalisation method. The interview method is semi-structured interviews, which are qualitative research interviews, involving direct and in-depth interaction between researchers and participants starting with a list of predetermined themes and possibly with key questions. The interview starts from the issues covered in the interview guide. The sequence of questions was not the same for each participant depending on the interview process and individual responses. However, the interview guide ensures that the researcher can collect the same type of data from the participants. Next, it is necessary to identify and select potential respondents or relevant participants. The data that has

been obtained from the results of the interview is then filtered and checked for quality, if there are deficiencies or lack of clarity, a follow-up interview is carried out or an additional list of questions is made

Secondary Data

Secondary data is obtained based on internal company reports and public documents such as journals, books, case study reports, and government regulations related to the research. Every data and information needs to be reviewed and controlled so that it is relevant to the research question.

Research Design

This research uses qualitative research. The qualitative method in this research is carried out to provide a detailed explanation of business problems at PT BIB, especially related to the ineffective normalisation of sludge in the sediment pond which can cause environmental pollution and disruption of mining operations.

RESULT AND DISCUSSION

Define Business Problem and Generate Improvement Area

The business problem in this study was identified based on primary data, namely by conducting interviews with respondents who are experts and or functions related, competent, and experienced with the implementation of this pond sediment normalisation method. The interview method is semi-structured interviews, which are qualitative research interviews, involving direct and in-depth interaction between researchers and participants starting with a list of predetermined themes and possibilities with key questions and secondary data obtained based on internal data company reports and public documents such as journals, books, case study reports, best practices and government regulations related to this study.

A fishbone diagram is a causal diagram that shows the causes of a particular event (Coccia, 2018). Fishbone diagrams are used to identify and categorise areas for improvement in the existing method (Ilie & Ciocoiu, 2010). Figure 9 describes the fishbone diagram as the result of the interview process with a team of experts to generate improvement areas:

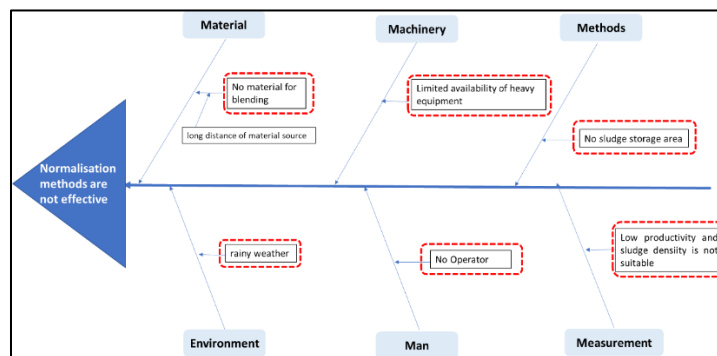


Figure 9. Fish Bone Diagram - Generating Improvement Areas

The following is an explanation of each of these aspects that need improvement:

- a. Material Aspect = This aspect needs to be improved because the availability of material sources for blending is very limited and sometimes has a long distance that requires many dump truck units to adjust the distance. This can make normalisation activities ineffective and costly. An alternative method that does not require material for blending is needed.
- b. Machinery aspect = This aspect needs to be improved because the availability of dump truck units is limited, heavy equipment units do not perform, breakdown units, and no match factor between excavator and dump truck units which will affect productivity. A method that does not require a large number of dump trucks and excavators units is required.
- c. Environment aspect = Conventional sludge normalisation activities cannot be carried out in rainy weather because it will make the sludge material liquid and it will be difficult to do the blending. If it rains, there is a risk of environmental pollution to public waters due to the overflow of sludge water from the sediment pond. This aspect needs to be improved because this existing method cannot be implemented continuously if it rains. A normalisation method is needed that can operate even in rainy weather conditions and minimise the occurrence of environmental pollution.
- d. Method aspect = This conventional method requires a lot of effort if the mud material is very liquid because it requires a lot of hard material for blending. And this method requires specialised sludge storage disposal sites, which are sometimes not available or with limited disposal capacity. Alternative methods are needed for the type of mud to be normalised, the existing method is only well implemented if the mud density is very high, whereas if the mud density is low, it requires blending material, which is ineffective. A normalisation method is needed for all types of sludge, especially low-density or relatively liquid sludge.
- e. Man aspect = Requires a lot of manpower to run heavy equipment units dump trucks and excavators and has a high safety risk for manpower because heavy equipment units work near the mud area and crowded work area traffic. This needs to be improved because this method uses a lot of dump truck operators, causing high costs and sometimes there is a shortage of operators at the time of implementation, causing productivity not to be achieved. A normalisation method that does not require many operators or manpower is needed.
- f. Measurement aspect= The blended mud output discharged to the disposal area has the potential for density that is not by the standard due to errors in the blending process and if rainy conditions the mud density cannot be controlled. This will cause potential landslides in the dumping area and this method has low productivity especially when the heavy equipment unit is not performing, there is no operator, and during the rainy season. This needs to be improved with a normalisation method that can control the density of the mud produced remains high even in rainy weather and has high productivity.

Based on historical data on the normalisation of the company's sediment ponds in several sediment ponds as previously explained in Chapter 1, the target volume of sludge in

normalisation activities using the truck transportation method was not achieved according to the predetermined plan due to several things that have been mentioned above. Meanwhile, the total number of sediment ponds will increase in 2036 by 58 sediment ponds. This can cause potential environmental pollution and disrupt coal mining operations in the pit which can interfere with coal production targets.

Determine Alternative Solution to Business Problems

Based on the analysis of fishbone diagrams to identify and regenerate areas to be improved in the existing method, and based on the results of interviews, journals, and best practices, two alternative methods of normalising sediment ponds are obtained that do not require material blending, do not require dump truck units, do not require many operators, normalisation activities can still be operated even in rainy conditions, and the density of the resulting mud output is denser and more controlled:

1. Geotextile tubes are generally used in hydraulic and marine applications such as coastal protection and flood control. They are also used to dewater sludge from sewage treatment plants and dredged materials. Geotextile tubes are made from strong and flexible textile materials that are capable of retaining fine-grained materials though permeable enough to allow the excess water from the hydraulically filled slurry to dissipate (Silva et al., 2021). Geotextile tubes or Geotubes are defined as geotextile sheets that are glued, heated, or sewn on the sides so that they become tubular and then filled with slurry (Liu & Silvester, 1977). This method has been applied by a coal mining company in South Kalimantan in a case study project - cleanout of coal mine settling ponds as part of a cleanup effort to normalise the sludge in the sediment ponds, Geotextile tube dewatering facilities were constructed to contain and dewater the sediment extracted from the ponds ((Geosynthetics, 2014). Geotextile technology was the first successful use of geotextile tubes for beneficial use in the USA to dewater sewage sludge from farms, paper mill waste, fly ash, mining waste, and several other wastes. This sewage sludge containment concept has proven to be practical in construction, technically and economically feasible, and environmentally acceptable (Fowler et al., 1996). The layout of the mud normalisation trial that has been carried out by the company with the geotextile tube method can be seen in Appendix C.
2. Geotextile pools or Geopools methods are an innovative way of dewatering and processing dredged material that could point the way to a future of dredged material disposal and reuse. It is described as a 'giant coffee filter' and looks like a very large above-ground swimming pool. Unlike the traditional method of draining dredged material, this method is scalable and customisable. It requires less land and can save a lot of time and money compared to existing methods (Murray, 2020). Geopool is a technological method of cleaning water bodies from sediments using filter basins. Geopool and Geotube technologies are viable alternative methods for sediment dewatering. The principle of operation of the filter pond is based on the use of gravity and the filtering capacity of polymer fabrics, Geopool is easy to disassemble

after the dehydration process is complete (Афанасьева et al., 2019). This method was carried out in a case study project in Ohio in 2022 in the black river dredged material reuse facility project (Weyer, 2022). The layout of the mud normalisation trial that has been carried out by the company with the geotextile pool method can be seen in Appendix D.

Business Solution

Decision Analysis using the SMART Method

The decision-making process will be performed by using multi-criteria with Simple Multi-Attribute Rating Technique (SMART). This method is used in this research due to ease of use in practice to perform faster decision-making. SMART is one of the methods for decisions involving multiple criteria or objectives with a finite set of alternatives. The performance of each alternative is expressed in grades on numerical scales, which are evaluated through a direct-rating procedure. By using this methodology, the decision maker from many different backgrounds can easily apply the method and understand its recommendations. Figure IV.2 describes the model used in SMART has several stages (Goodwin & Wright, 1998), to get the best alternative solutions and recommendations, the SMART method is used in detail.

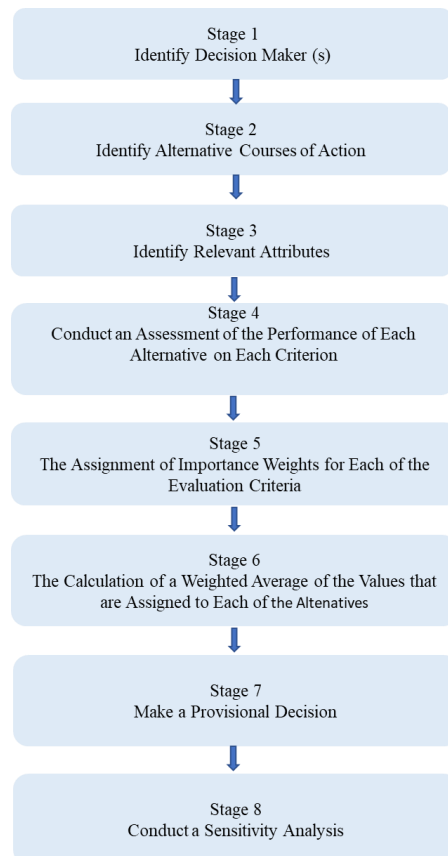


Figure 10. Step in SMART Analysis

Justification of Implementation Plan

The final stage of this research is to make a plan for the best solution chosen so that the best solution can be implemented effectively. The implementation plan is to normalise the sludge sediment ponds more effectively through the alternative solution method determined, namely the geotextile tube method.

This sediment pond normalisation activity is the task and responsibility of the environmental department led by the Environment & Reclamation Department Head. Regarding the implementation plan of the results of this study, the decision-makers gave recommendations to make a short-term plan and a long-term plan using the geotextile tube mud normalisation method, which is a method selected from the results of this study. The following are the short-term and long-term plans:

1. The short-term plan is to conduct further trials with the selected method from the results of this study, namely the geotextile tube method with a target mud volume capacity greater than the previous 200,000 m³ located in the North Kusan Girimulya Pit which is the largest pit location. The location of the planned mud normalisation activities can be seen in Figure 11.



Figure 11. Geotextile Tube Location Plan

The location plan of the sludge source that will be normalised can be seen in Figure 12.



Figure 12. Source Location Kusan Pit Sludge North Girimulya

The planned schedule for the implementation of mud normalisation with the geotextile tube method can be seen in Figure 13.

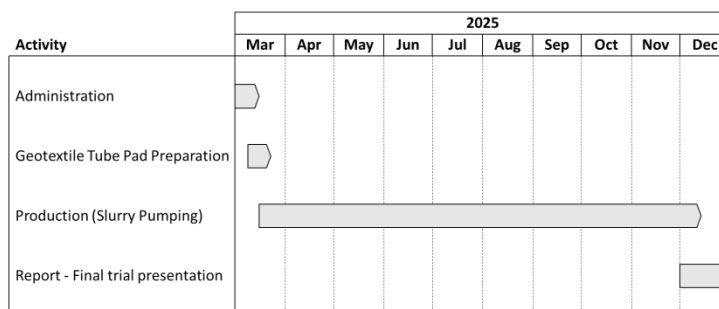


Figure 13. Schedule Plan for Sludge Normalisation with Geotextile Tube Method

The estimated cost required for normalisation activities using the geotextile tube method with a target sludge volume of 200,000 m³ can be seen in Table IV.20.

Table 1. Estimated Cost Plan for Normalisation of Geotextile Tube Method

Item	Mudcake Volume (m ³)	Rate (IDR/m ³)	Total Cost (IDR)
Normalisation	200.000	294.947	58.989.305.351

2. Long-term Plan

Planning mud normalisation activities throughout the sediment pond in the pit area on a priority scale with the following stages:

- a. Mapping the sediment pond to be normalized and estimating the volume of mud

This sediment pond normalisation activity is the task and responsibility of the environmental department led by the Environment & Reclamation Department Head. The environmental department conducted sediment pond mapping identified in all mining pits, namely the Kusan Girimulya Pit, Pasopati Pit, Sebamban Pit, and Batulaki Pit. The results of the sediment pond mapping identification can be seen in Table 2.

Table 2. Sediment Pond Normalisation Plan

Pit Location	Amount of Sediment Pond	Estimated Sludge Volume	Pit Status	Waste Pumping from Pit	Priority
Pasopati	4	271,877	Not Active	Not Active	Priority 4
Kusan Girimulya	19	2,191,770	Active	Active	Priority 1
Sebamban	3	470,025	Active	Active	Priority 3
Batulaki	3	606,311	Active	Active	Priority 2

Normalisation activities using the geotextile tube method will be carried out in 2026 with the priority being carried out at the Kusan Girimulya Pit because this pit is the largest compared to other pits with the largest amount of coal production. Sediment pond normalisation activities at the sebamban and batulaki pits will be carried out in the second semester of 2026 according to priority.

1) Technical and Administrative Review

The environmental department creates terms of reference (TOR) to determine technical reviews related to location, and area requirements based on volume, preliminary design,

standard specifications, project duration, and owner estimate. Preparation of budget according to owner estimate and submitting to management for approval. Coordination with the procurement team to search for competent and professional vendors, and commercial negotiation to get the best offer through a tender process. Preparation of work contract with winning tender vendor.

2) Timeline

The schedule of the long-term work plan for sludge normalisation using the geotextile tube method can be seen in Table 14.

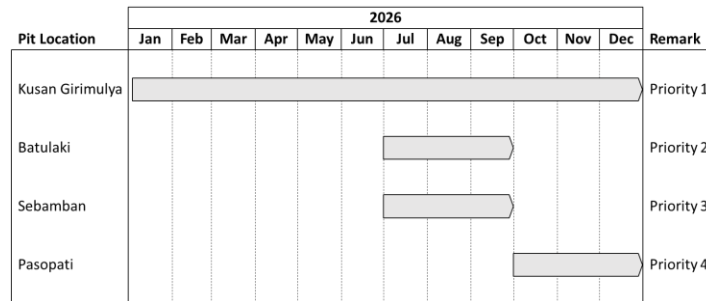


Table 14. Long-term Work Plan Schedule

3) Project Execution

Conduct a kickoff meeting with the winning vendor by the terms of reference (TOR) and work contract so that this project runs effectively and efficiently. The environmental department team conducts periodic monitoring and evaluation during the project until the end of the project.

CONCLUSION

Based on the analysis of the problems and proposed alternative solutions, this study successfully identified the main weaknesses of the conventional sediment pond normalisation method, such as material limitations, equipment efficiency, environmental impact, and operational constraints during rainy conditions. Through the use of a fishbone diagram approach, expert interviews, and the SMART method, it was found that the Geotube method is the most effective alternative compared to both the conventional and Geopool methods. This is because it eliminates the need for material blending, reduces reliance on heavy equipment and operators, can operate during rainfall, and enhances efficiency and controlled sludge density. These findings not only provide practical solutions for more sustainable sediment pond management but also open opportunities for further research on polymer dosage optimization in sludge drying processes and risk analysis for implementation. Thus, this study makes a significant contribution to improving wastewater management efficiency and supporting operational sustainability in the mining sector and other industries.

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