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Enhancing acid water treatment in coal mine settling ponds using sodium hydroxide (NaOH): A case study in Murung Raya, Central Kalimantan

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Abstract

This study aims to improve the treatment of acid water in settling ponds produced by coal mining activities located in Murung Raya, Central Kalimantan, Indonesia, using sodium hydroxide (NaOH) and combinations of NaOH with other chemicals to neutralize pH and metals, thereby reducing environmental impact. Complementing this, there will be regular monitoring of water quality and pH adjustments, along with projects to engage the local community in public awareness campaigns about ecological conservation. We seek to establish a sustainable development framework that prioritizes environmental preservation and community involvement, guiding other regions worldwide. Notably, achieving a pH of 6–9 in the settling pond using NaOH, with iron (Fe) levels below 7 and manganese (Mn) levels below 4, is essential to maintain environmental balance.

Keywords: Acid water treatment, environmental protection, Murung Raya, NaOH.

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1. Introduction

1.1. Overview of Acid Mine Drainage in Coal Mines

Acidic water dissolves poisonous metals and other hazardous compounds into the exposed rock and surrounding rock, posing major dangers to the water and water quality. Numerous surface and medical process strategies have been developed to manage the tidal wave in order to lessen the effects of acid mine drainage [1]. In a coal mine with a large amount of AMD, it is not uncommon for NaOH to be added to the concentrations of cations used to remove the acid reactivity. The addition of Fieser may help lessen AMD's impact on water. One can anticipate a reduction in pH towards acidic water with the addition of salt. Iron, total sediment, and organic content can all be removed [2]. This plant process has a strong impact on Philadelphia sources. In my opinion, it has a detrimental effect on the creation of water and NT in the water. Additionally, this approach might lead to less heavy metal pollution in the water, which is important for maintaining the well-being of aquatic ecosystems. "Soda caustic can affect water quality in coal mines by potentially increasing the pH of the water and introducing chemicals that may impact the overall water quality, Bernd [2]." Younger [3]. Furthermore, the application of these techniques can lead to a significant improvement in the overall water quality in Philadelphia and surrounding areas [3].

1.2. The Role of Good Water Management at Settling Ponds

Success with some treatment techniques depends on the controlled management of water in settling ponds. Operators can control the time and method of treatment by using continuous measurements of pH, nutrient concentrations in water, and heavy metal content. Settling ponds also require regular maintenance and servicing to be most effective in reducing or eliminating issues of sediment buildup [4]. In addition, well water management may reduce the likelihood of spillage or overflow that might compromise surrounding bodies of water. Highlighting mountain-top removal mines can protect the health of aquatic ecosystems and effectively counteract acid mine drainage-induced water quality problems by demonstrating that good water management in settling ponds is essential [5]. For example, a coal mine in Appalachia furnished its detention ponds with a water monitoring system to track the turbidity and pH of the effluent. They also organized a regular dredging program to remove sedimentation and prevent leaks or spills into nearby rivers and creeks. Thanks to these preventative efforts, the mine was able to significantly reduce the amount of acid mine drainage entering the environment and preserve important aquatic habitats. The dredging operations mentioned in the sources focus on decontaminating equipment used for dredging before shifting to backfill or capping work. The equipment decontamination process involves physically removing sediment from surfaces and washing them with pressure washers if necessary [6, 7].

1.3. Purpose of Using Soda Caustic in Treating Acid Mine Drainage

"Soda caustic (sodium hydroxide) is often used in remote low-flow, high-acidity situations or if manganese concentrations in acid mine drainage are high. Caustic soda can be gravity fed by dripping liquid sodium hydroxide directly into the AMD. It is very soluble, disperses rapidly, and raises the pH quickly. However, the major drawbacks of using liquid NaOH for AMD treatment are the high cost and dangers in handling [6]. This is the alkalinity of the water, which, when increased using caustic soda, can reduce the acidity of wastewater, resulting in less negative environmental impact. This treatment can facilitate the precipitation of heavy metals, making them easier to remove from water. Effective treatment of acid mine drainage using caustic soda should aim to improve water quality and minimize environmental damage to surrounding ecosystems. To effectively treat acid mine drainage with caustic soda, it is recommended to apply the caustic soda at the surface of ponded water to quickly raise the pH and disperse the chemical rapidly. Liquid caustic can be used in low-flow, high-acidity situations, but it has drawbacks such as high cost, handling dangers, and large sludge volumes. Various options are available to address freezing during winter months, including burying the tank, installing a tank heater, switching to a 20% caustic solution, using freeze-proof solutions, or utilizing solid caustic. Solid caustic can be a cost-effective method for treating AMD compared to other approaches [1, 2, 8]. For example, soda caustic can be combined with wastewater to increase the pH and remove pollutants such as iron and aluminium from contaminated water in mine operations that handle acidic streams. Soda caustic helps improve the quality of water bodies as well as prevent further damage to aquatic life downstream by stabilizing acidity in the water through heavy metal precipitation. Overall, these chemical treatment procedures provide significant aid to much-needed environmental rehabilitation projects originating from acid mine drainage. "Soda caustic, also known as sodium hydroxide, can help improve water quality by stabilizing acidity in water bodies and preventing further damage to aquatic life downstream. It is commonly used in the treatment of acid mine drainage to neutralize acidic water"[2, 8]. This chemical treatment method helps to lower the concentration of heavy metals in the water, making it safer for aquatic life. Its ability to precipitate heavy metals also contributes to the overall improvement of water quality in affected areas.

1.4. Previous Research on Treating Acid Mine Drainage with Soda Caustic

While there are certainly circumstances where using caustic soda and other alkalis can help us to treat water, they do come with inherent problems, such as increasing salinity or accidentally inflicting damage upon other parts of an ecosystem that are not our immediate target for chemical treatment. You just have to be cautious since caustic soda and other alkalis can solubilize salinity, which may result in undesirable side effects, including introducing excessive salt into potable water. These threats may also impact the environment, such as causing thermal and chemical pollution affecting cold-water species or altering the pH levels in our oceans [2]. However, when referring to alkali compounds and their effects, it is also essential that social risks like public perception as well as participation are accounted for [2]. These well-known financial risks include those of the implementation of carbon taxes or trading programs for these chemicals and (2) suggestions for evaluating the hazards of these compounds [6, 9]. Also, other non-chemical treatments are available that can be used instead of chemical treatments before trying Bilattices as a last resort. For example, the researchers found that treating acid mine drainage with caustic soda increased saline levels in one aquifer to toxicity limits for several aquatic taxa. This is a cautionary tale, illustrating the importance of assessing potential impacts on ecosystems before applying chemical treatments.

2. Method

2.1. Facility Case Studies: Setting Pond Design and Operation Description

The second of two essential treatment facilities on the site is required to treat acid mine drainage in Penfield Run. Turbidity can be used to evaluate the efficiency of settling ponds in passive treatment systems for monitoring particulate iron from mines, focusing on open mean flow conditions. Turbidity sensors enable high-resolution data collection and facilitate increased efficiency and cost reduction in monitoring [2]. "The arrangement of ponds, whether their dimensions, the depth, or the retention time of water could also influence the removal effectiveness for pollutants [10]. Binding the ponds is essential, but they need to be constantly and consciously policed so that they work effectively. Thus, by assessing the extent of the impact of acid mine drainage, researchers can develop exploitative strategies to virtually eliminate this worldwide problem using constructed wetlands as a model treatment train. Many studies have demonstrated the ability of constructed wetlands to efficiently intercept and remediate acid mine drainage by retaining metals and other contaminants. However, this will not address the long-term environmental threat from acid mine drainage [6] which is likely to remain a major burden on society for many years to come [6].

2.2. Procedure For Adding Soda Caustic to the Settling Pond

The setting pond plays a critical role in treating acid mine drainage. Monitoring pH, turbidity, and metal concentrations in the water are some of the factors that qualify these ponds as being efficient. Monitoring pH, turbidity, and metal concentrations in the water are crucial aspects of treating acid mine drainage [6, 10, 11]. In addition, the configuration of each pond, including size (width × depth), length, and residence time, could also influence their efficacy as bioretention systems to remove pollutants from stormwater. The configuration of each pond, including size (width × depth), length, and residence time, can influence their efficacy as bioretention systems to remove pollutants. The way that bioretention basins treat wastewater depends on a number of factors, including the type of vegetation present, hydraulic loading, length of detention, hydraulic conductivity of the filter media, and size ratio [2]. Bioretention basins are effective in reducing peak runoff of small to medium storm events and can remove nutrients, but there can be elevated discharge of nutrients attributed to the leaching of native material [2]. Constructed wetlands, on the other hand, are artificial, shallow, and extensively vegetated water bodies primarily created for stormwater pollutant removal [6, 9]. As in all water conservation projects, ponds must be managed well, which entails that they are cleaned from time to time and watched so their working efficiency is continuous. Researchers can develop better ways to mitigate acid mine drainage and lessen its impacts on aquatic ecosystems through careful consideration of these elements [6]. Table 1 shows the Treatment of acid wastewater in the settling pond No. #9.

Table 1.
Treatment Wastewater Settling Pond Haju # 09.

Recording Point	Year	Moon	Average pH	TSS Average	Average flow rate (L/s)	Wastewater Discharge (m^3)	NaOH Consumption (kg)
SP_HJ09	2024	January	6.64	20.00	35.93	96235.35	0.00
SP_HJ09	2024	February	6.65	12.00	153.24	383349.09	3075.00
SP_HJ09	2024	March	6.70	16.00	209.92	538136.65	37600.00
SP_HJ09	2024	April	6.67	15.00	191.70	496887.15	33125.00
SP_HJ09	2024	May	6.77	15.00	257.90	690763.99	67100.00
SP_HJ09	2024	June	6.72	13.00	287.84	746083.89	41425.00
SP_HJ09	2024	July	6.64	9.00	242.73	650133.34	39300.00

2.3. Monitoring and Testing Methods for Water Quality

It may also be employed in the settling pond to ensure that pH is contained within its targeted profile. Regular analysis and examination of sampled water may be useful in detecting any problems or changes that would necessitate some alteration to the treatment process. "Regular analysis and examination of sampled water may help ensure that the pH is maintained within the desired range in a settling pond"[2, 12]. Also, checking the lining and drainage system of the settling pond periodically will help to avoid serious leaks and other problems that can be harmful to efficiency in treatment. By conducting regular monitoring and testing of the water quality in the settling pond, this will help protect or preserve the surrounding ecosystem as well as minimize its impact on the environmental effects associated with acid mine drainage. The settling pond water needs to be treated in a way that it conforms with DLH regulation standards, preserving environmental security and safeguarding native ecosystems. This is the reason for frequent water sampling and monitoring that enables prompt changes in the treatment process to stop if an incident occurs. Inspections of the settling pond's infrastructure are essential to prevent leakages or other issues causing a degradation in the quality of the water. Regular inspections of the settling pond's infrastructure are crucial to prevent leakages or degradation in water quality. Storage issues, such as a lack of redundancy and challenges in conveying water, can impact the overall quality of reclaimed water [6]. Covered reservoirs minimize algal growth, while open reservoirs may require additional operational practices like draining or herbicide spraying [6]. Upstream treatment processes are essential for maintaining water quality downstream and managing operational challenges [6, 13]. Acid mine drainage might have certain environmental implications; better to be safe than sorry, as the saying goes, and testing while monitoring can keep these issues at bay, ensuring minimal effects on wildlife habitats, let alone human health. To meet DHL criteria, water pH should be between 6 and 9, TSS levels below 400, and iron content below 7 mg/l—manganese below 4 mg/l. It is also important to regularly monitor and adjust treatment processes to ensure compliance with these criteria.

Implementing best management practices can help prevent acid mine drainage and minimize its environmental impact. Furthermore, aquatic life in the contiguous ecosystem relies on dissolved oxygen levels being maintained above 4 mg/l. Caustic soda can impact water quality in settling ponds by contributing to soil and water salinization, which can lead to negative impacts on plant growth, soil erosion, and reduction of water quality. High levels of salinity in water can render it unsuitable for agriculture and household use, causing problems with water supply, public health, and ecosystems [2]. The sedimentation ponds of the former Soda "Solvay" Plant in Krakow, for example, have been identified as a major threat to the quality of the nearby environment due to high water salinity [2, 14, 15]. Well-run settling ponds and treatment processes go a long way toward preventing deviations from these standards, as do monitoring programs, which routinely maintain and monitor the water environment to protect not only nearby communities but also compensate for any accidental transgressions. If these criteria are met, we can address acid mine drainage and preserve water quality for future generations.
The result monitoring is shown below:

Table 2.
Quality of Mining Wastewater (External Lab Analysis) Month: December 2024.

No	Parameter	Unit	Quality standard	SP_HJ01	SP_HJ05	SP_HJ07	SP_HJ08	SP_HJ09
1	pH		6-9	6.6	6.36	6.31	6.45	6.60
2	TSS	mg/l	400	34	44	28	30	32
3	Fe	mg/l	7	0.3	0.7	0.5	0.5	0.6
4	Mn	mg/l	4	0.6	0.7	0.4	0.4	0.6

Table 3.
Quality of Mining Wastewater (External Lab Analysis) Month: November 2024.

No	Parameter	Unit	Quality standard	SP_HJ01	SP_HJ05	SP_HJ07	SP_HJ08	SP_HJ09
1	pH		6-9	6.6	6.48	6.6	6.61	6.37
2	TSS	mg/l	400	43	34	43	38	18
3	Fe	mg/l	7	0.3	0.4	0.3	0.3	0.3
4	Mn	mg/l	4	0.6	0.6	0.6	0.7	0.6

Table 4.
Quality of Mining Wastewater (External Lab Analysis) Month: September 2024.

No	Parameter	Unit	Quality standard	SP_HJ01	SP_HJ05	SP_HJ07	SP_HJ08	SP_HJ09
1	pH		6-9	6.75	7.00	6.95	6.50	7.06
2	TSS	mg/l	400	7	5	8	10	8
3	Fe	mg/l	7	0.3	0.3	0.2	0.3	0.3
4	Mn	mg/l	4	0.3	0.3	0.3	0.3	0.3

Table 5.
Quality of Mining Wastewater (External Lab Analysis) Month: August 2024.

No	Parameter	Unit	Quality standard	SP_HJ01	SP_HJ05	SP_HJ07	SP_HJ08	SP_HJ09
1	pH		6-9	6.74	6.84	6.46	6.10	6.34
2	TSS	mg/l	400	7	4	5	6	3
3	Fe	mg/l	7	0.3	0.3	0.3	0.3	0.3
4	Mn	mg/l	4	0.3	0.4	0.3	0.3	0.3

Table 6.
Quality of Mining Wastewater (External Lab Analysis) Month: July 2024.

No	Parameter	Unit	Quality standard	SP_HJ01	SP_HJ05	SP_HJ07	SP_HJ08	SP_HJ09
1	pH		6-9	6.76	6.53	6.51	6.61	6.57
2	TSS	mg/l	400	4	3	<2	5	<2
3	Fe	mg/l	7	<0.3	<0.3	<0.3	<0.3	0.3
4	Mn	mg/l	4	<0.3	<0.3	<0.3	0.3	<0.3

3. Results

3.1. Reduction in Acidity Levels after Treatment with Soda Caustic

The pH values increase sharply very quickly after treatment, rising from a normal 2.5 to over 6 in just a couple of days, illustrating the significance of soda caustic. He worked his way down to the one taking in less water and measured an average pH of 7.2 with nitrate concentration at 8 mg/L prior; dolomite treatment = total alkalinity<5 mg/l; KHSO3 raised Nitrate from.618 mg/l; and pH dropped back to 9. The high levels of metal sludge in acid mine drainage have led to the potential use of settling ponds for effective treatment. Regardless, it may have different effectiveness under the specific mine conditions and treatment processes applied [6]. This serves as a great example of how to prevent further degradation using proactive water treatment methods, including remediation measures that have been successful in abating acid mine drainage [5]. Additionally, by initiating monitoring schemes, it could be possible to detect any violations of water quality standards at an early stage and to take corrective action in time so that potential damage may not result in the deterioration of the ecosystem.

These results highlight the importance of long-term maintenance and monitoring in managing mining impacts on water quality, ensuring sustainability over the medium to longer term [9]. For example, a Colorado mining company successfully used passive and active treatment systems to neutralize acidic drainage from abandoned mines, preventing contamination of water sources adjacent to their operations. Regular water quality checks, such as pH and heavy metal concentrations, help identify potential hazards early, enabling immediate corrective action and safeguarding the ecosystem in this unique setting [16] solution.

3.2. Improvement in Water Quality Parameters Such as pH and Metal Concentrations

Release exact parameters that improve water quality (metal concentrations, pH, etc.). It can have a major impact on the overall condition of aquatic habitats. By adopting preventative safeguards and monitoring systems, businesses not only protect flora and fauna but also ensure the long-term integrity of their enterprises. The method aims to reconcile environmental conservation with the long-term viability of businesses by recycling products and implementing new technologies to reduce water consumption per unit of output [2]. With conservation as a top priority, starfishers must be kept under strict control measures and implement ecological solutions for their unrelenting availability. As terrible as this sounds, statistically speaking, it isn't even that bad, and by improving your water quality from pH 2-4 to 6.5-7 and metal Fe below 7 and Mn below 4, you can make a material difference to the health of the environment while retaining the sustainability of your operations. While consumable producers are to instantly stop using lakes or rivers to dispose of their waste, implementing a few mass control methods can help companies reduce the harm caused to water resources and promote eco-efficient practices. As responsible organizations, businesses can both take advantage of the economic possibilities of new technologies within water quality management and contribute to saving our natural resources for future generations. In addition, to successfully address issues with water quality and promote a holistic approach to environmental stewardship, collaboration among all stakeholders, governmental entities, local communities, and conservation organizations is vital. Bodin, 2017. Water quality and sustainability are subjects that companies need to address importantly. In addition to the establishment of policies focused on this theme by enterprises, it is also necessary to reflect on their economic implications, especially for small businesses. Finally, stakeholders often have conflicting interests and priorities, so cooperation among them may be easier said than done [17].

3.3. Measured Against Regulatory Benchmarks, Condition of Treated Water

So goes the mission of the legion of folks dedicated to keeping America's waters from becoming a toxic mess. This comparison of treated water quality to regulatory standards allows businesses to maintain compliance and identify areas for opportunity. This also speaks to the importance of all stakeholders being aligned when it comes to protecting water quality. This is done to ensure that water quality management practices are in place and working by routinely evaluating the product water quality against pH 6-7, TSS < 400, Fe<7, and Mn < 4 (analyses as per rule) [2]. The authors took a similar perspective so as to not only signal allegiance with an environmental proclivity but also gain legitimacy among sponsors. [10]. The good news is that the private sector can help establish a more sustainable future for all by practicing water quality management and promoting collaboration with an eye toward the bottom line. However, corporations may prioritize profit over pollution control, resulting in potential conflicts of interest in safeguarding water quality regulations. Businesses are required to follow certain rules to meet water quality standards, and treated water should satisfy regulatory parameters as well. This fosters an environment of trust in pursuing these goals. Nonetheless, there is concern that companies might also put profit ahead of their environmental duties, leading to conflicts of interest with competing financial interests, which could hinder cooperation [6]. Companies may not rank environmental factors as their highest priority if they affect profits, but they are generally under social license pressures to take any 'beyond-compliance' measures they can to avoid risking a tarnished reputation. This can result in proactive approaches to community relations and sustainable operations that prevent shutdowns [2].

4. Discussion

4.1. Use of Soda Caustic for Acid Mine Drainage

Acid mine drainage is a major environmental problem impacting water quality and natural ecosystems. After all, caustic soda, more commonly known by its chemical name, sodium hydroxide is one of the most versatile chemicals used in treating acid mine drainage. Many studies have shown that it is effective for both neutralizing acidic water and precipitating heavy metals. However, using caustic soda is not without concerns, including the production of sludge and the emission of harmful byproducts into the environment. In this discussion, we examine the power of caustic soda in acid mine drainage treatment and weigh its benefits against potential trade-offs.

4.2. Pros and Cons of the Use of Soda Caustic

Among the benefits are that it's relatively inexpensive compared to alternative treatment methods, possesses equal efficiency over a wide range of acidic water sources, and is stable in terms of neutralizing water quality for years to come. However, the sludge generated in heavy metal precipitation can be difficult to dispose of and may need further treatment. Furthermore, significant toxic byproducts especially chlorides (i.e., elements of salt) and sulfates are emitted into the environment during this process, damaging freshwater ecosystems and poisoning humans, leading to various illnesses associated with excess sodium in our diets. For further experience, a detailed evaluation is needed to balance the risks and benefits before high hopes can be used to suppress acid mine drainage by soda caustic on a company's bottom line.

4.3. Potential Challenges and Limitations of Using Soda Caustic in Settling Ponds

Some of the concerns might be addressed by proper monitoring and maintenance to avoid the creation of such harmful side products. Insufficient contact between the soda caustic solution and acid mine drainage may cause some heavy metals to remain in dissolved form, generating an unstable sludge that needs further processing before being geologically disposed of. Moreover, the high alkalinity in soda caustic can also damage the pH of the treated water and the environmental balance in a natural stream where some aquatic animals thrive. The dosing and mixing of soda caustic in settling ponds must therefore be properly managed to ensure that these challenges are effectively addressed, along with ensuring that the appropriate measures are systematically used for the safe handling and disposal of generated sludge. A possible counterexample to this may be the substitution of lime for soda caustic during mine drainage treatment, with more stable heavy metal precipitation and sludge production, and therefore some cost savings. Natural remediation, i.e., wetland restoration of sufficient scale, could also provide support in re-establishing proper pH values in the treated water without the use of chemicals, reducing the risk to wildlife for a longer period while maintaining ecosystem equilibrium.

5. Conclusion

5.1. Summary of Key Findings

And suggestions in conclusion, it is evident that responsible mine water drainage management will ensure the safety of water supplies and environmental health. Mine drainage can be successfully treated, and its environmental damage lessened with a mixture of physical, chemical, and natural remediation. Going forward, mining entities and administrative authorities should collaborate in order to prepare and execute complete mine drainage treatment strategies that emphasize ecology preservation. It will take all of us coming together and doing what we know works to sustain and maintain our water for the future.

5.2. Suggestions For Research and Implementation Implications

Ranging from the search for new technologies in treating mine water to ongoing, long-term monitoring of successful remediation efforts and further investigations evaluating ecosystem solutions vulnerable to mine drainage effects. It is also important to initiate support and communication with local communities and stakeholders to maintain transparency around the management of mine effluent. If these suggestions are incorporated into future research and put into use, we can gradually make forthcoming mining activities much more responsible and sustainable.

5.3. Importance of Proper Water Management in Coal Mines for Environmental Protection

Water treatment systems constitute a major part of proper water management in coal mines for environmental protection. This is crucial for breaking down toxic chemicals in mine drainage before they reach surrounding ecosystems. Regular monitoring of these treatment systems is also essential to ensure they are functioning correctly and to reduce the overall impact on the water quality of mine drainage. We also hope to learn more about the impacts of mine drainage on ecosystems and human health through further research over time, beyond treatment and monitoring. Therefore, it is essential, as part of this process, to engage local communities and other stakeholders so that their concerns and perspectives are included in decision-making measures. Through the promotion of transparent and accountable practices in mine drainage management, we can move towards a sustainable and responsible approach to mining activities that respect the environment and those who depend on it.

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