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Estimating the Formation of Acid Mine Drainage in Open-Pit Coal Mining Operations

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Abstract
"Acid Mine Drainage (AMD)" is one of the major environmental and health issues facing the mining industry. This research focused on evaluating the potential for acid formation in coal mining operations located in Separi, Kutai Kartanegara, East Kalimantan. The study included acid-forming potential tests conducted on core rock layer samples. 24 core rock sample units were collected for ABA and NAG testing. The sample test results using acid-base counting showed that there were 11 samples being potential to produce acid with high capacity, 7 samples produced acid being in a low capacity, and the amount of production varied. The alignment between the results of the acid-forming potential tests confirmed their reliability as effective methods for the preliminary assessment of potential Acid in mining operations across Kalimantan.
Keywords: *Acid Mine Drainage, ABA, NAGpH.*

INTRODUCTION

Undisturbed coal seams in the ground typically do not present a risk to the environment or human health, but coal mining operations are one of the industrial activities that cause environmental problems that can have an impact on health and natural ecological balance at mine sites, especially the decline in air quality, surface water, groundwater, and soil (Finkelman & Greb, 2008). Coal mining operations, especially in surface mining regions, serve as a significant contributor to environmental damage (Myers 2016; Acharya & Kharel 2020; Zhang et al. 2020). Mukhopadhyay et al. (2014) and Quadros et al. (2016) explain that surface coal mining alters the properties and composition of soil and water in the nearby environment. Coal is often linked to the presence of metals that may pollute the soil and hinder plant growth (Pandey, Agrawal & Singh 2014). Changes in water quality and soil composition are among the adverse impacts seen in surface mining areas (Baruah et al., 2016). According to Singh et al. (2007), surface coal mining presents significant challenges to ecosystems, the restoration of vegetation, and the morphology of the land. According to Bradshaw and Chadwick (1980), Wali (1987), and De and Mitra (2002), coal dumps and overburden piles modify the natural landscape, interfere with drainage systems, and restrict vegetation growth. Coal mining activities increase the threat posed by sulfide minerals found in coal, particularly when dealing with coal mine waste. A major concern is the generation of acidity, which can infiltrate soil, surface water, and groundwater through "weathering and percolation". This process is known as mine-induced acidic drainage (Dold 2017; Akcil & Koldas, 2006; Sanliyuksel Yucel, 2019). Studies on the effects of mining activities in coal-producing nations like China, India, Japan, Indonesia, and the United States indicate that mining can lead to the uncontrolled discharge of contaminated waste into nearby surface and underground environments (Sanliyuksel Yucel 2019). The breakdown of metal sulfides, especially pyrite, is a major contributor to the formation of "acid mine drainage (AMD)". Coal wall rocks frequently contain substantial quantities of pyrite and other metal sulfides. The extent of the impact caused by mine-induced acidic drainage depends on the acidity and sensitivity of the affected environment, along with factors like neutralization, dilution, and dissolution rates. According to Myers (2016), Sayoga et al. (2018), Acharya and Kharel (2020), Zhang et al. (2020), and Moreno-González et al. (2022), the primary sources of by mine-induced acidic drainage in mining regions include drainage from mining operations, Runoff from exposed open-pit regions, Leachate and surface runoff originating from waste rock dumps and spoil piles, Mine waste materials, Containment of processing residues, Coal storage piles and processed fine coal storage associated with processing activities. In their article, Ojonimi et al. (2021) stated that while mine-induced acidic drainage naturally forms in coal extraction regions, the process can be accelerated by

Extraction and processing operations that bring pyrite to interaction with oxygen and water The coal mining process accelerates acid formation by exposing "iron-sulfide minerals to exposure from atmospheric conditions" Banerjee (2014). According to Gautama and Hartaji (2004), Brady et al. (1988, 1994), BC-AMD (1989), and Geidel et al. (2000), anticipatory evaluation is employed to determine whether a specific capacity of mine effluent has the potential to generate acidic water and to predict water quality based on observed acid water production rates. "Methods for predicting Acid Mine Drainage (AMD) formation can be categorized into two types: static tests and kinetic tests". "Static tests" evaluate the potential of sulfide minerals to generate AMD and the neutralization capacity provided by minerals like carbonates in the sample. These tests are typically performed in a laboratory setting and require a relatively short duration. On the other hand, kinetic tests are conducted over an extended period and involve leaching to assess formation rates, rock weathering behavior, and metal transportability related to Mine-induced acidic drainage. "Kinetic tests" are primarily used to confirm the results of static tests and are not suitable for identifying rocks on an operational mining scale. Various static testing methods have been developed for predicting AMD, with two widely used approaches being "acid-base accounting (ABA)" and "net acid generation (NAG) testing". Skousen et al. (2002) noted that "The ABA method was first developed by Smith et al. at West Virginia University in 1965". Following its incorporation into the "US EPA" manual in 1978, the " Acid-Base Accounting analysis" procedure gained widespread acceptance for identifying potential Mine-induced acidic drainage (Sobek et al., 2000). Over time, this method has been refined and applied by various researchers (Johnson & Hallberg, 2005; Sanliyuksel Yucel, 2019; Smart et al., 2002; Lowrence & Wang, 1990). "The Acid-Base Accounting technique" typically entails assessing total sulfur and neutralization potential. Total sulfur is determined through elevated-temperature oxidation to estimate the sample's maximum possible acidity (MPA). "The Net Acid Generation (NAG) analysis", first proposed and formulated by Finkelman et al. (1986), employs hydrogen peroxide (H_2O_2) to assess the likelihood of Mine-induced acidic drainage formation from sulfide minerals present in coal and mine overburden. This approach directly measures the "net acid generation (NAG)" in the specimen after adding H_2O_2, a strong oxidizing agent.

In the nineties, "Environmental Geochemistry International (EGI) Pty Ltd.", together with the "Australian Mining Industry Research Association (AMIRA)", carried out studies at Seventeen mining sites distributed across Indonesia, Australia,and Papua New Guinea. The aim was to Create a straightforward and Expense-effective method for assessing the Possibility for Mine-induced acidic drainage formation (Nordstrom & Alpers, 1999). In 2002, EGI and Ian Wark Research collaborated on the AMD Prediction and Kinetic Control Project, Financed by "AMIRA", to Create the Handbook for "Acid Rock Drainage (ARD) Testing". This handbook, utilized in various countries, including Indonesia, aligns with the: Indonesia's National Standard 6597:2011. The ARD Test Manual combines "ABA and NAG methods" to categorize rocks as either Capable of forming acid or incapable of forming acid.

This research aimed to evaluate the acidic water Capacity of rock and coal seams at a mine site in the Separi area, Kutai Kartanegara district, East Kalimantan province, using the static test method. In Indonesia, static testing is performed through two primary methods: "acid-base accounting (ABA) and net acid generation (NAG) tests". For production operations, mining companies in Indonesia typically favor the NAG test due to its simplicity and faster results compared to the ABA method. The NAG test utilizes a fifteen percent "hydrogen peroxide solution serving as a potent oxidizing agent", following the guidelines outlined in the "ARD Test Handbook and the Indonesian National Standard (SNI)". This research contributes valuable data to the field of Mine-induced acidic drainage studies and can play a significant role in addressing environmental degradation associated with mining, both regionally and globally. The findings of this research can be utilized in other mining regions within Indonesia and globally, regardless of scale, to classify mining sites with the likelihood of field of Mine-induced acidic drainage formation.

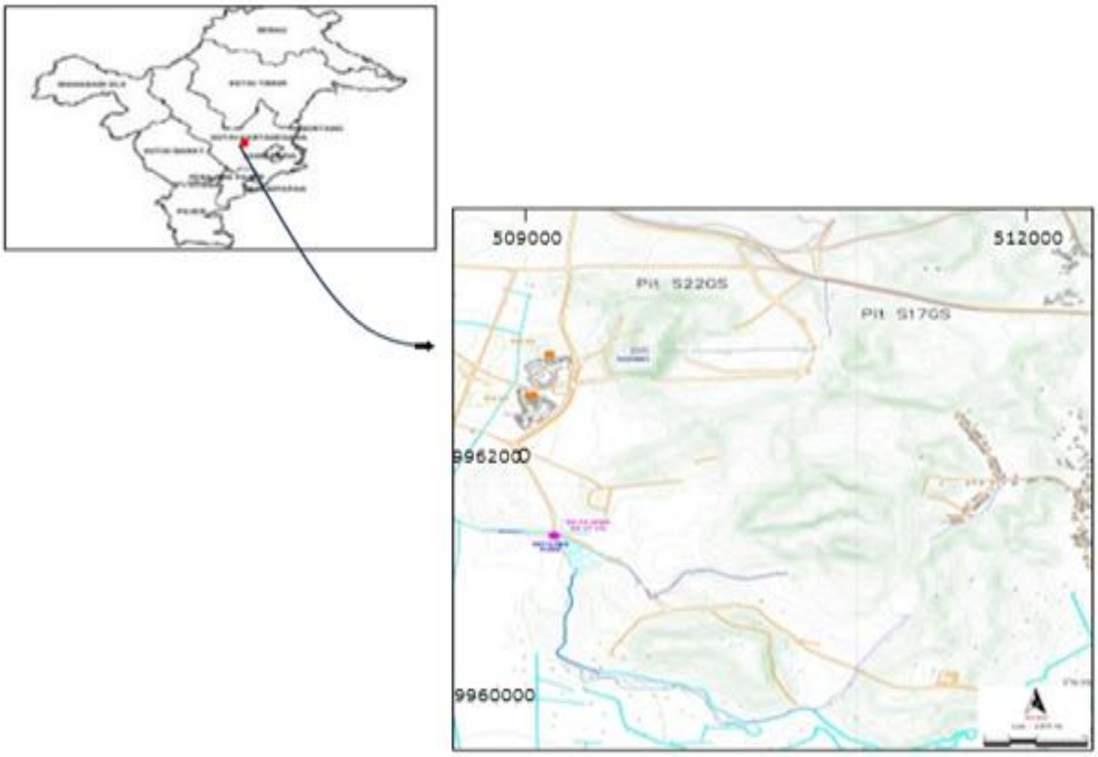

Figure 1. Map location of study area

AREA STUDY

The study area is located at mining pit S17GS in Separi area, Kutai Kartanegara district, East Kalimantan province (Fig.1). This location is part of the Kutai basin. This basin is bounded in the south by the Barito Basin and Meratus Mountains, in the west by the Schwanger Hills and Melawai Basin, while in the north by the Central Kalimantan Strip (Wilson & Moss, 1999). The coal seam-bearing formation belongs to the Balikpapan formation. This formation is a mixture of sandstone and claystone with inserts of siltstone, shale, limestone, and coal. The depositional environment of this formation is delta front to delta plain (van Bemmelen, 1949; Rose and Hartono, 1978; Ott, 1987). Pit SG17GS has a rock slope ranging from 18-25°. The lithology arrangement consists of soil layer, swamp alluvial material, mudstone, siltstone, coal, and sandstone. The soil layer has physical characteristics of brown-yellowish colour, clay grain size, plastic nature, weak hardness, thickness of 3-4 metres. The alluvial swamp layer is characterized by a yellowish colour, liquid mud, with a thickness of about 5 metres. The mudstones are characterized by grey colour, clay grain size, layering and lamination structure, weak to medium hardness, and plastic nature. In this area, the claystone layer is divided into 2 parts, the first part has a thickness of about 17 metres, and is positioned above and below seam 22M. The second section is around roof 22L, with a thickness of about 8 metres. This area has a dip direction of N200ºE, and a dip value of about 10º. The central part of seam 22M shows undulating structure and thinning to pinch out. It has characteristics of black colour, black streak, bright gloss, sub chonchoidal , fragments very hards, average thickness around 4.5-5metres. Seam 22M shows washout and undulating discontinuity with a calorific value of approximately 6,600 Kcal/Kg and 2.21% total Sulphur. Seam 22L has a calorific value of 5,300 Kcal/Kg and total Sulphur of 3.82%.

MATERIALS AND METHODS

Samples of rock cores were obtained from the pit area S17GS, situated in "Kutai Kartanegara Regency, East Kalimantan, Indonesia". 24 specimens, classified as acid-producing and does not produce acid, were derived from exploratory operations and represented various rock types. These specimens were classified according to their potential for acid and the associated coal seam. The core specimens, measuring 6 cm in diameter and having a density range of 2220–2365 kg/m³, reduced in size using a jaw crusher with a 2.5 cm opening. The size-reduced material was divided using a splitter and ground further to a particle size of two hundred mesh (smaller than seventy-five μm). Finally, two -point five-gram samples were prepared following standard static test methods.Static tests were conducted to assess the ability of the rock specimens to produce Acid Mine Drainage (AMD). These tests included paste pH, "Acid Base Accounting (ABA)", and "Net Acid Generation (NAG)" assessments. The NAG test was conducted using a 15% H_2O_2 solution, following standard operating procedures and adhering to the guidelines outlined in the Acid Rock Drainage Test Manual (Smart et al., 2002) and "SNI 6597:2011". Further tests were carried out on the NAG solution after the addition of H_2O_2 to examine the concentrations of metals: iron, manganese, aluminum and sulfate (SO_4). The samples were classified based on their NAG value (kg H_2SO_4/t) into three categories: does not produce acid (NAF), low acid producing (low-PAF), and high acid producing (high-PAF). The NAG categories applied in this study are largely consistent with those established by Miller (1996) and Smart et al. (2002), including categories such as "Non-Acid Forming (NAF)", "Low Potentially Acid Forming (low PAF)", "High Potentially Acid Forming (high PAF)", and uncertain capacity. Additionally, the NAG test was performed at a pH of 4.5 to evaluate the acid-forming potential of the samples. This testing supports rock classification, where samples with pH <4.5 are classified as PAF, and those with pH >4.5 are classified as NAF. The Total Sulfur (TS) test is performed by high temperature heating and does not consider the various forms of sulfur in the sample, such as sulfide minerals (e.g. pyrite), sulfates, and elemental sulfur. Acid Base Accounting (ABA) analysis was conducted to evaluate the potential for Acid Mine Drainage (AMD) formation. The NAG solution was tested to observe changes in the formation and movement of potential contaminants in AMD when mixed with 15% H_2O_2 (Karison et al., 2021). The NAG solution was examined for parameters such as pH, Heat level, Overall, dissolved solids, Oxidative-reductive potential, conductivity, and the Overall concentrations of iron and manganese.

RESULTS AND DISCUSSION

Results of the acid-forming potential tests

The outcomes of the acid-forming potential tests, summarized in Table 1, comprise data from 24 core rock samples classified into three categories: does not produce acid, low acid producing, and high acid producing. As shown in Tables 1 and 2, out of the 24 samples analyzed, 6 were classified as NAF, 7 as low PAF, and 11 as high PAF. The NAGpH values, determined using 15% H_2O_2, ranged from 6.5 to 8.02 for NAF, 4.0 to 5.03 for low PAF, and 2.02 to 3.70 for high PAF. The $NAG_{4.5}$ test results showed that samples classified as NAF had values extending from 0 to 1.94 kg H_2SO_4/t, while those in the low PAF category ranged from 1.94 to 1.96 kg H_2SO_4/t. Samples in the high PAF category had an average capacity ranging from 9.6 to 148.85 kg H_2SO_4/t. This test reflect the potential for H_2SO_4 formation from Sulfide reaction with oxygen and the hydrolysis of dissolved aluminum and iron, as highlighted by Johnson & Hallberg (2005), Sanliyuksel Yucel (2019), Smart et al. (2002), and Lowrence & Wang (1990). The MPA Values varied between 0.2 to 3.5 kg H_2SO_4/t for NAF samples, 1.9 to 44.8 kg H_2SO_4/t for low PAF samples, and 12.3 to 106.6 kg H_2SO_4/t for high PAF samples. The NAGpH results indicated that nearly all core rock samples have the potential to generate Acid. Furthermore, the results of the NAGpH and ABA tests were found to be largely consistent.

Table 1. Rock sample Description

Acid-Base Accounting Test		Classification	
	NAF	PAF(Low Capacity)	PAF(High Capacity)
ANC	8.2 to 26	-5.3 to 26	-39 to 0,7
TS	0.09 to 0.03	0.25 to 1.46	1.18 to 3.65
MPA	0.2 to 3.5	1,9 to 44.8	12.3 to 106.6
NAPP	-23 to -9	-67 to 34	25 to 131
ANC/MPA	-30.5 to 0	-4 to 0.4	-270 to 7.8
Net Acid Generation (NAG) Test			
NAGpH	6.5 to 8.02	4 to 5.8	2.29 to 3.7
$NAG_{4.5}$	0 to 1.94	1.94 to 1.96	9.6 to 148.85

*ANC (Acid Neutralizing Capacity), TS (Total Sulfur), MPA (Maximum Potential Acidity), NAPP (Net Acid-Producing Potential), and NAG4.5 (Net Acid Generation at pH 4.5).

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**Non-Acid Forming; low acid producing - (NAG <2 kg H_2SO_4/t); high acid producing -NAG >10 kg H_2SO_4/t).

Table 2 shows that almost all core rock samples have the potential to form AMD. The 18 samples that have the potential to produce both high capacity and law capacity acid have a sulfur content of 1.36% - 3.75%. The exceptionally high sulfur content in these samples significantly increases the probability of acid formation during the rock's weathering process. The other 6 samples namely G22R_05, G22R_24, G22R_33, G22R_35 and G22R_36 are classified as not having the potential to produce acid in addition to NAGpH values between 6.9 - 8.02 and low sulphur content between 0.03 - 0.11%. The NAG test is an effective method for identifying potential Acid Mine Drainage (AMD) across various scales of mining operations due to its simplicity and rapid execution (Lapakko, 2002). However, it has a limitation in that it cannot account for the neutralizing capacity contributed by carbonate compounds. Research has shown that the presence of substantial quantities of carbonate minerals, like dolomite, calcite, magnesite, and siderite, can result in inaccurate assessments of potential acid capacity (Nordstrom & Alpers, 1999; Gautama & Hartaji, 2004).

Table 2. Results from the Acid Base Accounting and NAGpH Assessments

NO	Sample	Sampel Type	pH NAG	Sulphur (%)	MPA	ANC	NAPP (Kg H_2SO^4/t)	MTA	NTAPP	ANC/MPA ratio	ANC/MTA ratio	Classification	Stratigraphic Position
1	G22R-20	Sandstone	2.31	2.73	48.2	6.9	41	48	41	7.8	1.8	PAF-H	IB23M-22M
2	G22R-21	Sandstone	2.65	1.89	36.0	10.7	25	37	26	1.9	1.9	PAF-H	IB23M-22M
3	G22R_22	Claystone	4.00	1.36	11.0	-5.5	-17	115	121	0.40	0.40	PAF-L	IB23M-22M
4	G22R_23.27	Carbonaceouse Claystone	5.2	1.56	4.8	7.6	-3	22	14	0.03	0.02	PAF-L	Roof 23M
5	G22R_24	Sandy Siltstone	6.9	0.11	3.5	8.2	-5	-7	-15	0.0	0.0	NAF	IB23M-22M
6	G22R_04.39	*Carbonaceouse claystone*	2.29	3.86	49.8	-5.3	55	53	58	1.1	1.1	PAF-H	Roof 22M
7	G22R_05	Sandstone	7.8	0.09	2.7	26.0	-23	-7	-33	-1.73	-6.41	NAF	IB23M-22M
8	G22R_11	Sandstone	5.3	2.55	7.6	74.7	-67	-7	-82	-3.51	-9.08	PAF-L	IB22L-20M
9	G22R_12	Clayey Silstone	5.6	2.40	12.1	26.8	-15	-7	-34	-3.95	-9.74	PAF-L	IB22L-20M
10	G22R_13	Silty Claystone	5.8	2.46	44.8	10.9	34	-7	-17	-4.40	-10.41	PAF-L	IB22L-20M
11	G22R_14	Coaly Shae	2.6	2.34	106.6	-24.2	131	418	442	-4.84	-11.07	PAF-H	IB22L-20M
12	G22R_14.60.	Silty Claystone	3.0	3.86	56.8	-5.9	63	113	119	-2.6	-7.7	PAF-H	Roof 22L
13	G22R_14.80.	Sandy Siltstone	3.5	2.24	68.6	4.9	64	45	40	-27.9	-45.7	PAF-H	Floor 22L
14	G22R_15	Sandstone	2.70	2.78	12.3	-13.2	49	9	22	1.9	1.9	PAF-H	IB22M-22L
15	G22R_16.58	Shale Coal	2.02	2.98	19.5	-39.0	130	54	93	0.9	0.9	PAF-H	Roof 20M
16	G22R_18	Silty Claystone	3.4	3.12	34.4	0.9	33	122	121	-6.17	-13.07	PAF-H	IB22L-20M
17	G22R_19	Coaly Shae	2.6	3.48	106.6	-24.2	131	418	442	-4.84	-11.07	PAF-H	IB22L-20M
18	G22R_16.84	Carbonaceouse Shale	3.70	3.55	47.5	-9.6	57	124	133	0.03	0.02	PAF-H	Floor 20M
19	G22R_32	Silty Claystone	4.21	3.75	53.6	2.5	51	-2	-5	0.03	0.02	PAF-L	IB22L-20M
20	G22R_33	Sandy Siltstone	6.8	0.11	3.4	23.4	-20	-4	-28	-30.59	-49.68	NAF	IB22L-20M
21	G22R_34	Sandy Siltstone	5.03	2.03	1.9	2.1	0	-7	5	0.0	0.0	PAF-L	IB22L-20M
22	G22R_35	Carbonaceouse Claystone	8.02	0.03	0.5	18.3	-18	0	-18	0.0	0.0	NAF	IB 22L-20M
23	G22R_36	Sandstone	6.94	0.09	0.2	10.6	-10	0	-10	0.0	0.0	NAF	IB 22L-20M
24	G22R_37	Sandstone	7.12	0.03	0.5	9.1	-9	0	-9	0.0	0.0	NAF	IB 22L-20M

*Low acid producing, (PAF-H)
*High acid producing (PAF-L)
**Does not produce acid* (NAF)

PAF Stratigraphy and Geometry

In the S17GS Pit mining operation concession, the PAF material is divided into 4 intervals namely, PR22M, PF22M, PR22L and PF22L. PR represents the PAF interval located in the roof of the coal seam, while PF refers to the interval in the floor of the seam. The designations 22M and 22L correspond to the names of seam groups within the S17GS Pit area (Figure 2).

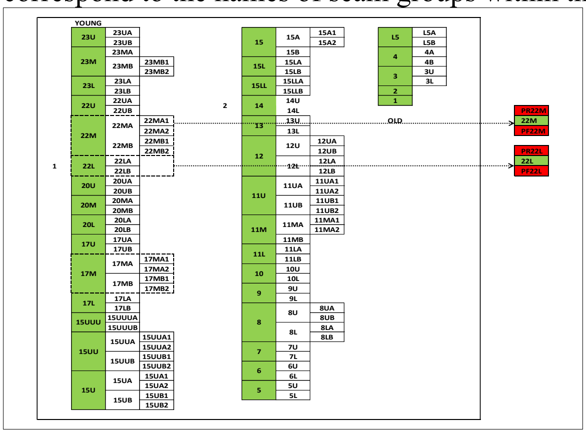

Figure 2. Stratigraphic Position of Coal *Seams* and PAF

Along with the arrangement of rock layers capable of generating acid, the presence of layers 22M and 22L also holds the potential for acid production. Seam 22L is stratigraphically located below the pit floor with a distance of about 3-5 meters if coal mining only takes seam 22M then 22L has no potential to form acid, but if seam 22L is mined then this seam will potentially form acid (Figure 3).

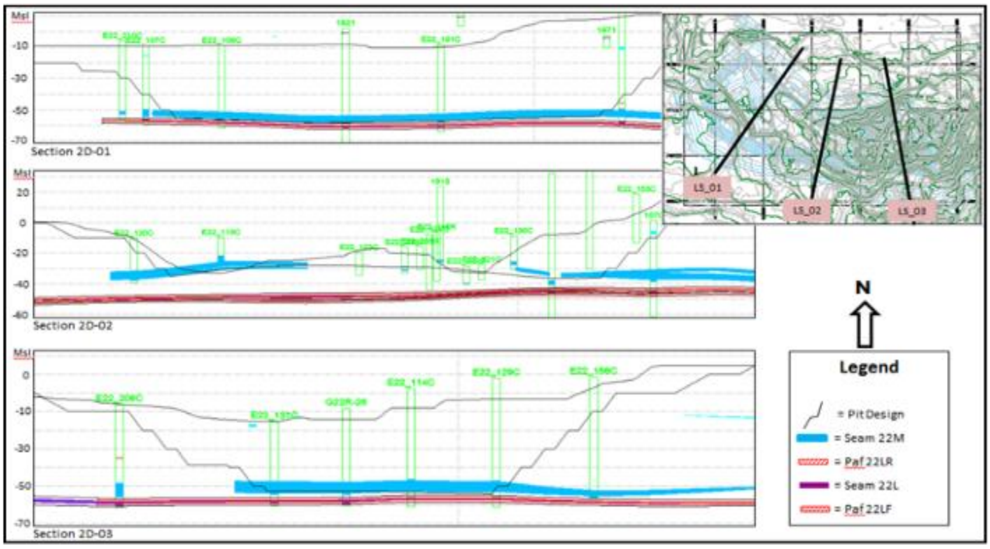

Figure 3. 2 dimensions of PAF material in pit S17GS

CONCLUSIONS

The findings from the acid-forming potential tests indicate that the lithologies at the S17GS pit location have the potential to generate Acid Mine Drainage (AMD) with both high and low capacities. In some samples there are results that are not potentially acid-forming. Table 2 shows that the NAGpH and ABA test results are almost consistent. Both methods generally identified 18 samples that have the potential to produce acid. Coal seams 22M and 22L with sulfur contents of 2.21% and 3.82% have acid producing potential. The study also demonstrated that acid-forming potential tests are effective and complementary methods for evaluating mine waste based on its acid-generating potential. These tools are particularly useful as quick and straightforward approaches for assessing Acidic rock drainage, especially in the context of ecologycal impact assessments for mining operations.

REFERENCES

A. Elghali, M. Benzaazoua, H. Bouzahzah, M. Abdelmoula, J.J. Dynes, H.E. Jamieson, Role of secondary minerals in the acid generating potential of weathered mine tailings: crystal-chemistry characterization and closed mine site management involvement, Elsevier BV, Sci. Total Environ. 784 (2021), 147105, https:// doi.org/10.1016/j.scitotenv.2021.147105.

A. Parbhakar-Fox, B.G. Lottermoser, A critical review of acid rock drainage prediction methods and practices, Elsevier BV, Miner. Eng. 82 (2015) 107–124, https://doi.org/10.1016/j.mineng.2015.03.015.

A.A. Sobek, W.A. Schuller, J.R. Freeman, R.M. Smith, Field and Laboratory Methods Applicabled to Overburden and Minesoil, U.S. Environmental Protection

Abfertiawan, M.S., Palinggi, Y., Syafila, M., Handajani, M. & Pranoto, K., 2023, 'A Comparison dataset on static test using two concentrations of hydrogen peroxide for prediction of acid mine drainage', Data in Brief, 51, 109706.

Acharya, B.S. & Kharel, G., 2020, Acid mine drainage from coal mining in the United States – An overview, Journal of Hydrology, 588.

Banerjee, D., 2014, 'Acid drainage potential from coal mine wastes: Environmental assessment through static and kinetic tests', International Journal of Environmental Science and Technology, 11(5), 1365–1378.

C. Vasilatos, N. Koukouzas, D. Alexopoulos, Geochemical control of acid mine drainage in abandoned mines: the case of ermioni mine, Greece, Procedia Earth and Planetary Science 15 (2015) 945–950, https://doi.org/10.1016/j.proeps.2015.08.151.

D.K. Nordstrom, C.N. Alpers, C.J. Ptacek, D.W. Blowes, Negative pH and Extremely Acidic Mine Waters from Iron Mountain, Web, California, United States: N. p., 2000, https://doi.org/10.1021/es990646v.

Dold, B., 2017, 'Acid rock drainage prediction: A critical review', Journal of Geochemical Exploration, 172, 120–132.

E. Perry, Interpretation of acid-base accounting. Chapter 11, in: Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania, PA Department of Environmental Protection, Harrisburg, PA, 1998.

EPA, Acid Mine Drainage Prediction, U.S. Environmental Protection Agency, 1994. Technical Report EPA530-R-94-036

Finkelman, R.B. & Greb, S.F., 2008, 'Environmental and Health Impacts', Applied Coal Petrology: The Role of Petrology in Coal Utilization, 263–287.
Gautama, R.S. & Hartaji, S., 2004, 'Improving the accuracy of geochemical rock modelling for acid rock drainage prevention in coal mine', Mine Water and the Environment, 23(2), 100–104.
H. Shimada, G.J. Kusuma, K. Hiroto, T. Sasaoka, K. Matsui, R.S. Gautama, B. Sulistianto, Development of a new covering strategy in Indonesian coal mines to control acid mine drainage generation: a laboratory-scale result, Int. J. Min. Reclamat. Environ. 26 (1) (2012) 74–89, https://doi.org/10.1080/ 17480930.2011.608505.
International Network for Acid Prevention (INAP). The global acid rock drainage guide, 2009. Available at, http://www.gardguide.com.
J. Skousen, , Simmons, L.M. McDonald, P. Ziemkiewicz, Acid-base accounting to predict post-mining drainage quality on surface mines, J. Environ. Qual. 31 (6) (2002) 2034.
J.E. Pope, P. Weber, A.P. Mackenzie, N. Newman, R. Rait, Correlation of acid base accounting characteristics with the Geology of commonly mined coal measures, West Coast and Southland, New Zealand, N. Z. J. Geol. Geophys. 53 (2–3) (2010) 153–166, https://doi.org/10.1080/00288306.2010.498404.
Johnson, D.B. & Hallberg, K.B., 2005, 'Acid mine drainage remediation options: A review', Science of the Total Environment, 338(1-2 SPEC. ISS.), 3–14.
Kumar, A., Krishna, A.P., 2018. Assessment of groundwater potential zones in coal mining impacted hard-rock terrain of India by integrating geospatial and analytic hierarchy process (AHP) approach. Geocarto International, 33(2), 105-129
M.B.J. Lindsay, M.C. Moncur, J.G. Bain, J.L. Jambor, C.J. Ptacek, D.W. Blowes, Geochemical and mineralogical aspects of sulfide mine tailings, Appl. Geochem. 57 (2015) 157–177, https://doi.org/10.1016/j.apgeochem.2015.01.009.
M.S. Abfertiawan, Y. Palinggi, M. Handajani, K. Pranoto, A. Atmaja, Evaluation of Non-Acid-Forming material layering for the prevention of acid mine drainage of pyrite and jarosite, Heliyon 6 (11) (2020), e05590, https://doi.org/10.1016/j.heliyon.2020.e0559.
Moreno-González, R., Macías, F., Olías, M. & Ruiz Cánovas, C., 2022, 'Temporal evolution of acid mine drainage (AMD) leachates from the abandoned tharsis mine (Iberian Pyrite Belt, Spain)', Environmental Pollution, 295.
Mukhopadhyay, S., Maiti, S.K. & Masto, R.E., 2014, 'Development of mine soil quality index (MSQI) for evaluation of reclamation success: A chrono sequence study', Ecological Engineering, 71, 10–20.
Myers, T., 2016, 'Acid mine drainage risks - A modeling approach to siting mine facilities in Northern Minnesota USA', Journal of Hydrology, 533, 277–290.
Nordstrom, K.D. & Alpers, C.N., 1999, 'The environmental geochemistry of mineral deposits, Part A: processes, techniques, and health issues: Reviews in Economic Geology, 6A', The geochemistry of acid mine drainage, (January 1999), 133–160.
Ochieng, G.M., Seanego, E.S., Nkwonta, O.I., 2017. Impacts of mining on water resources in South Africa: A review. Scientific Research and Essays, 5(22), 3351 3357.
Ojonimi, T.I., Okeme, I.C., Phiri-Chanda, T. & Ameh, E.G., 2021, 'Acid mine drainage (AMD) contamination in coal mines and the need for extensive prediction and remediation: a review', Journal of Degraded and Mining Lands Management, 9(1), 3129–3136.
P.J.C. Favas, S.K. Sarkar, D. Rakshit, P. Venkatachalam, M.N.V. Prasad, Acid mine drainages from abandoned mines, in: Environmental Materials and Waste, Elsevier, 2016, pp. 413–462, https://doi.org/10.1016/b978-0-12-803837-6.00017-2.
Pandey, B., Agrawal, M. & Singh, S., 2014, 'Assessment of air pollution around coal mining area: Emphasizing on spatial distributions, seasonal variations and heavy metals, using cluster and principal component analysis', Atmospheric Pollution Research, 5(1), 79–86.
Qureshi, A., Maurice, C. & Öhlander, B., 2016, 'Potential of coal mine waste rock for generating acid mine drainage', Journal of Geochemical Exploration, 160, 44–54.
R. Ciccu, M. Ghiani, A. Serci, S. Fadda, R. Peretti, A. Zucca, Heavy metal immobilization in the mining-contaminated soils using various industrial wastes, Elsevier BV, Miner. Eng. 16 (3) (2003) 187–192, https://doi.org/10.1016/s0892-6875(03)00003-7.
R.B. Finkelman, D.E. Giffin, Hydrogen peroxide oxidation: an improved method for rapidly assessing acidgenerating potential of sediments and sedimentary rocks, Recreation and Revegetation Research 5 (1986) 521–534.
R.M. Smith, A.A. Sobek, T. Arkle, J.C. Sencindiver, J.R. Freeman, Extensive Overburden Potentials for Soil and Water Quality, Field and Laboratory Methods
R.W. Lawrence, Prediction of the behaviour of mining and processing wastes in the environment, in: F. Doyle (Ed.), Proc. Western Regional Symposium on Mining and Mineral Processing Wastes, Soc. For Mining, Metallurgy, and Exploration, Inc., Littleton, CO, 1990, pp. 115–121
S. Shirin, A. Jamal, C. Emmanouil, A.K. Yadav, Assessment of characteristics of acid mine drainage treated with fly ash, Appl. Sci. 11 (2021) 3910, https://doi. org/10.3390/app11093910.
S.D. Miller, J. Jeffery, T.A. Donohue, Developments in predicting and management of acid forming mine wastes in Australia and southeast asia, Journal of the American Society of Mining and Reclamation, 1994 (1994) 177–184.
S.K. Thisani, D.V.V. Kallon, P. Byrne, Geochemical classification of global mine water drainage, Sustainability 12 (2020), 10244, https://doi.org/10.3390/ su122410244.
Sanliyuksel Yucel, D., 2019, 'Characterization and comparison of mine wastes in Can Coal Basin, northwest Turkey: a case study', Environmental Earth Sciences, 78(5), 1–19.
Sayoga, R.G., Perkins, W., Bird, G., Adije, W., Moore, O., Kusuma, G.J. & Badhurahman, A., 2018, 'Acid Mine Drainage in a Tropical Environment: A Case Study from the Tanjung Enim Coal Mine Site in South Sumatra Indonesia', Proceedings of the International Congress on Acid Rick Drainage (ICARD) 2018, 611–616.