

Acid Mine Drainage Prediction from Sulfide Ores Stockpiled at Kamoia Copper (DRC) : A Combined Static and Kinetic Testing Approach

Patrick Kashala Mpanga^{1*}; Zeka Mujinga²; Yvette Kasongo Kabulo¹;
Guy Nkulu Wa Ngoy²; Jhon Tshomba Kalumbu²

¹Higher Institute of Applied Techniques, Department of Applied Chemistry and Metallurgy,
Kolwezi, Democratic Republic of Congo

²University of Kolwezi, Polytechnic Faculty, Department of Industrial Chemistry,
Kolwezi, Democratic Republic of Congo

Corresponding Author: Patrick Kashala Mpanga*

Publication Date: 2026/06/02

Abstract: As surface oxide ores are depleted, mining operations in the Central African Copperbelt increasingly exploit deeper sulfide deposits. The storage of these sulfide materials under atmospheric conditions raises the risk of acid mine drainage (AMD). This study evaluates the acid-generating potential (AGP) of stockpiled ores at Kamoia Copper (Kamoia, Kakula, Kansoko sites) using a comprehensive methodology including mineralogical characterization (XRD, SEM-EDS), chemical analyses, static tests (ABA, NAG, paste pH), and kinetic humidity cell tests (ASTM D57446-18). A representative composite sample (STC-02) consists of 52.9 % quartz, 22.1 % muscovite, 19.4 % clinocllore, and 1.9 % chalcopyrite. Total S is 1.85 % and total Cu 2.09 % (0.3 % oxide). Static tests yield an Acid Potential (AP) of 47 kg CaCO₃/t, Neutralization Potential (NP) of 16.7 kg CaCO₃/t, Net Neutralization Potential (NNP) of -30.3 kg CaCO₃/t, and Neutralization Potential Ratio (NPR) of 0.36, all below critical thresholds. Paste pH (4.28) and NAG pH (4.13) are <4.5. Kinetic tests confirm acid generation, with leachate pH reaching 4.27, Eh up to 362 mV, and Cu mobilization up to 0.612 mg/L. The sulfide content combined with low carbonate abundance (C total 0.20 %) classifies the material as acid-generating. This study provides a baseline for AMD management in the Central African Copperbelt and highlights the need for proactive strategies (selective stockpiling, covers, and potential blending with neutralising materials).

Keywords: Acid Mine Drainage (AMD), Sulfide Ores, Static Tests, Kinetic Tests, Acid-Generating Potential, Kamoia Copper, Stockpiling.

How to Cite: Patrick Kashala Mpanga; Zeka Mujinga; Yvette Kasongo Kabulo; Guy Nkulu Wa Ngoy; Jhon Tshomba Kalumbu (2026) Acid Mine Drainage Prediction from Sulfide Ores Stockpiled at Kamoia Copper (DRC): A Combined Static and Kinetic Testing Approach. *International Journal of Innovative Science and Research Technology*, 11(5), 2714-2717. <https://doi.org/10.38124/ijisrt/26may1485>

I. INTRODUCTION

The Central African Copperbelt (CAC) hosts one of the world's largest sediment-hosted copper deposits. For decades, mining focused on near-surface oxide ores, but depletion of these resources now forces exploitation of deeper sulfide ores (Ivanhoe Mines Ltd., 2023). Sulfide minerals, especially chalcopyrite (CuFeS₂), bornite (Cu₅FeS₄) and pyrite (FeS₂), are reactive when exposed to oxygen and water, leading to acid mine drainage (AMD). AMD is characterised by low pH and elevated concentrations of sulfate and potentially toxic metals (Johnson & Hallberg, 2005).

Kamoia Copper, one of the largest copper mines in Africa, extracts ore from the Kamoia, Kakula and Kansoko deposits. The ore is stored in large stockpiles before processing. Because of the presence of sulfides and the humid tropical climate, these stockpiles may become sources of AMD if not managed appropriately.

Prediction of AMD relies on a combination of static tests (acid-base accounting, NAG, paste pH) and kinetic tests (humidity cells, columns) (Price, 2009; MEND, 2009). This study applies these methods to characterise the geochemical behaviour of stockpiled ores at Kamoia Copper and to assess the need for preventive measures.

II. MATERIALS AND METHODS

➤ Sampling and Sample Preparation

A composite sample (MK) was collected from the three stockpile areas (Kamoa, Kakula, Kansoko) following a stratified sampling strategy (top, slopes, foot). The sample was air-dried, crushed, homogenised, and split into sub-samples for different analyses.

➤ Characterisation

- Granulometry: dry and wet sieving (38–500 µm).
- Mineralogy: powder X-ray diffraction (XRD) with Rietveld quantification (Bruker D8 Advance) and SEM-EDS (Zeiss EVO) for texture and phase distribution.
- Chemistry: total S and C by combustion (ELTRA), major and trace elements by ICP-OES after acid digestion.

➤ Static Tests

- Paste pH: 1 part solid to 1 part deionised water, pH measured after 10 min.
- Net Acid Generation (NAG): 2.5 g of sample (<75 µm) reacted with 250 mL of 15 % H₂O₂; pH of the solution after complete reaction (pH_{NAG}) was measured, and the solution was titrated with 0.1 N NaOH to pH 4.5 and 7 to determine NAG capacity (Miller et al., 1997).

- Acid-Base Accounting (ABA): Acid Potential (AP) = %S_{sulfide} × 31.25 ; Neutralization Potential (NP) was determined by the modified Sobek method (Sobek et al., 1978) : reaction with 0.1 N HCl, back-titration with 0.1 N NaOH to pH 8.3. Net Neutralization Potential (NNP = NP – AP) and Neutralization Potential Ratio (NPR = NP/AP) were calculated.

➤ Kinetic Tests – Humidity Cells

Humidity cell tests were performed following ASTM D57446-18. Two tests were conducted :

- Test 15 : <6 mm fraction, 200 g, single 24-h leaching.
- Test 16 : <75 µm fraction, 200 g, two successive leaching cycles with aeration in between.

Leachates were collected and analysed for pH, Eh, conductivity, sulfate, and metals (ICP-OES). Acid titratable was measured by titration with 0.1 N NaOH to pH 7.

III. RESULTS

➤ Physical and Mineralogical Characterisation

The particle size distribution shows a dominance of fines: 66.6 % <25 µm (Table 1). This high specific surface area enhances reactivity.

Table 1 Particle Size Distribution of MK

Fraction (µm)	Mass (g)	Proportion (%)
<25	395.4	66.6
25–38	56.3	9.5
38–53	72.8	12.2
>53	69.6	11.7

XRD-Rietveld analysis (Table 2) reveals a silicate-dominated gangue (quartz 52.9 %, muscovite 22.1 %, clinocllore 19.4 %) and 1.9 % chalcopyrite. Carbonate

minerals were not detected (<0.5 % detection limit). Minor gypsum (0.4 %) indicates partial oxidation.

Table 2 Mineralogical Composition of MK (wt. %)

Phase	Formula	Content (%)
Quartz	SiO ₂	52.9
Muscovite	KAl ₂ (Si ₃ Al)O ₁₀ (OH,F) ₂	22.1
Clinocllore	(Mg,Fe) ₅ Al(Si ₃ Al)O ₁₀ (OH) ₈	19.4
Chalcopyrite	CuFeS ₂	1.9
Orthoclase	KAlSi ₃ O ₈	2.1
Biotite	K(Mg,Fe) ₃ AlSi ₃ O ₁₀ (OH,F) ₂	1.0
Gypsum	CaSO ₄ ·2H ₂ O	0.4

➤ Chemical Composition

Total S is 1.85 %, total Cu 2.09 % (0.3 % as oxide), and total C only 0.20 % (Table 3). The low carbon content

confirms the absence of significant carbonate minerals, consistent with XRD.

Table 3 Major Element Composition of MK (wt. %)

Element	Content
SiO ₂	62.30
Al ₂ O ₃	13.80
Fe(total)	5.82
Cu(total)	2.09

S(total)	1.85
C(total)	0.20
CaO	0.44
MgO	3.47
K ₂ O	3.44

➤ Static Tests

- Paste pH : 4.28
- NAG pH : 4.13 ; NAG capacity (pH 7) : 1.66 kg CaCO₃/t
- ABA : AP = 47 kg CaCO₃/t ; NP = 16.7 kg CaCO₃/t ; NNP = -30.3 kg CaCO₃/t ; NPR = 0.36

All indicators classify the material as acid-generating (AGP).

➤ Kinetic Tests

Results are summarised in (Table 4). The fine fraction (<75 µm) exhibited the lowest pH (4.27), highest Eh (362 mV), and highest conductivity (3880 µS/cm). Acid titratable reached 1.66 kg CaCO₃/t after the first leaching.

Table 4 Humidity Cell Test Results

Parameter	Test 15 (<6 mm)	Test 16a (<75 µm)	Test 16b (<75 µm)
Sample mass (g)	100	200	200
Leaching duration (h)	24	7	14
Final pH	4.63	4.27	5.70
Final Eh (mV)	280	362	260
Conductivity (µS/cm)	1819	3880	1301
Acid titratable (kg CaCO ₃ /t)	0.688	1.66	0.298

Dissolved metals (Table 5) show significant Cu release (up to 0.612 mg/L) and Ca release (up to 0.654 mg/L). Iron

and aluminium were below detection limits, likely due to precipitation as secondary phases (e.g., ferrihydrite, jarosite).

Table 5 Dissolved Metals in Leachates (mg/L)

Element	Lixiviat 1 (Test 15)	Lixiviat 2 (Test 16a)	Lixiviat 3 (Test 16b)
Ca	0.222	0.639	0.654
Cu	0.266	0.612	0.107
Mg	0.144	0.145	0.004
Mn	0.038	0.048	0.005

IV. DISCUSSION

The absence of detectable carbonates (C total 0.20 %) and the dominance of quartz and phyllosilicates explain the low neutralisation potential (NP = 16.7 kg CaCO₃/t). The AP of 47 kg CaCO₃/t, derived from total sulfur (1.85 %), reflects the chalcopyrite content (1.9 %). The NPR (0.36) is well below the critical threshold of 1, confirming the material's acid-generating character (Sobek et al., 1978; Price, 2009).

The low paste pH (4.28) indicates that partial oxidation has already occurred during storage, generating soluble acidic salts. The NAG pH (4.13) confirms that, upon complete oxidation, the material will sustain acid conditions.

Kinetic tests reinforce these conclusions. The fine fraction (<75 µm) produced the most acidic leachates and the highest conductivity, consistent with increased specific surface area accelerating sulfide oxidation (Elberling et al., 1994). The relatively high Cu concentrations in leachates (0.612 mg/L) indicate potential for metal release, although Fe and Al are retained in solid phases (Nordstrom & Alpers, 1999; Blowes et al., 2003).

The low carbonate content is typical for the Kakula and Kamoia deposits, where mineralisation occurs in reduced

facies sedimentary rocks with limited carbonate gangue. This contrasts with other parts of the Central African Copperbelt where dolomitic host rocks provide significant neutralisation potential (e.g., Tenke Fungurume). Thus, at Kamoia Copper, the ore itself is inherently prone to AMD when stored under oxidising conditions.

The results highlight the necessity of proactive AMD management. Options include selective stockpiling (separating high-sulfide from low-sulfide materials), covering stockpiles to limit oxygen and water infiltration, and blending with carbonate-rich materials if available from other operations or from waste rock.

V. CONCLUSION

This study provides the first detailed assessment of the acid-generating potential of stockpiled sulfide ores at Kamoia Copper.

➤ Key Findings are :

- The ores contain significant chalcopyrite (1.9 %) and negligible carbonate minerals.

- Static tests (AP = 47, NP = 16.7, NNP = -30.3, NPR = 0.36, paste pH = 4.28, NAG pH = 4.13) classify the material as acid-generating.
- Kinetic tests confirm rapid oxidation and metal release, especially from fine fractions.
- The material poses a significant risk of AMD if left exposed to atmospheric conditions.

➤ *Implications:*

Without mitigation, stockpiles at Kamo Copper could become long-term sources of acidic drainage, contaminating surrounding water and soils. We recommend immediate implementation of preventive measures and further studies to evaluate blending with alkaline materials and the effectiveness of engineered covers.

ACKNOWLEDGEMENTS

The authors thank Kamo Copper for providing samples and laboratory access, and the staff at ISTA and UNILU for their support. This work was conducted within the framework of the doctoral school of ISTA.

REFERENCES

- [1]. Blowes, D. W., Ptacek, C. J., Jambor, J. L., & Weisener, C. G. (2003). The geochemistry of acid mine drainage. In H.
- [2]. D. Holland & K. K. Turekian (Eds.), *Treatise on Geochemistry* (Vol. 9, pp. 149–204). Elsevier.
- [3]. Elberling, B., Nicholson, R. V., & Scharer, J. M. (1994). A combined kinetic and diffusion model for pyrite oxidation in tailings: a change in controls with time. *Journal of Hydrology*, 157(1-4), 47–60.
- [4]. Ivanhoe Mines Ltd. (2023). *Kamo Copper Integrated Development Plan 2023*.
- [5]. Johnson, D. B., & Hallberg, K. B. (2005). Acid mine drainage remediation options: a review. *Science of the Total Environment*, 338(1-2), 3–14.
- [6]. MEND (Mine Environment Neutral Drainage). (2009). *Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials* (Report 1.20.1). CANMET.
- [7]. Miller, S., Robertson, A., & Donahue, T. (1997). Advances in acid drainage prediction using the net acid generating (NAG) test. *Proceedings of the 4th International Conference on Acid Rock Drainage*, 533–547.
- [8]. Nordstrom, D. K., & Alpers, C. N. (1999). Geochemistry of acid mine waters. In G. S. Plumlee & M. J. Logsdon (Eds.), *The Environmental Geochemistry of Mineral Deposits* (Vol. 6A, pp. 133–160). Society of Economic Geologists.
- [9]. Price, W. A. (2009). *Guidelines for the Prediction of Acid Rock Drainage and Metal Leaching for Mines in British Columbia*. Ministry of Energy, Mines and Petroleum Resources.
- [10]. Sobek, A. A., Schuller, W. A., Freeman, J. R., & Smith, R. M. (1978). *Field and Laboratory Methods Applicable to Overburden and Mine Soils* (EPA-600/2-78-054). U.S. Environmental Protection Agency.