XVI International Mineral Processing and Recycling Conference
28-30 May 2025, Belgrade, Serbia

DOI: 10.5937/IMPRC25562S Original research article

KINETIC AMD PREDICTION FOR A MINE TAILINGS DUMP: A SOUTHERN AFRICAN MINE CASE STUDY

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ABSTRACT – Sulfide-containing mine tailings dumps are known to pose the hazard of acid mine drainage (AMD). AMD is a metal-rich and acidic solution that is formed naturally when sulfide minerals react with water and oxygen, and its risks should be considered before, during, and after mining operations. It is critical to accurately predict AMD occurrence over time, so appropriate mitigation and/or treatment processes can be implemented. This study presents the use of a particles-based kinetic AMD predictor for long-term AMD occurrence profile prediction to determine the frequency and amount of AMD leachate produced that would need to be treated and/or processed to mitigate environmental issues. The AMD simulation was performed for a period of 30 years, taking into consideration anticipated monthly weather changes. This study forms the basis of a process to determine the optimal mitigation and/or treatment of the AMD leachates derived from Southern African copper mine tails.

Keywords: Tailings-Dump, AMD, Prediction.

INTRODUCTION

Acid Mine Drainage (AMD) is a global environmental concern that requires urgent attention [1]. Due to extensive mining activities worldwide, an increasing number of mine dumps are being created, leading to greater exposure of sulfide-bearing minerals to oxygen and water. This, in turn, heightens the likelihood of AMD formation [5,11]. As of 2009, approximately 5906 abandoned mine dumps were reported in South Africa, while China had 5800 as of 2018 [14,16,17]. Similarly, Japan recorded 5487 abandoned and/or closed mines in 2000, several of which were observed to be generating AMD [12]. Given the widespread occurrence of these mine dumps globally, conducting a cost-effective analysis to prioritise AMD treatment is crucial, especially for countries with limited resources [3,4,15]. Such an analysis is also essential for appropriately scaling treatment plants. To better mitigate the impact of AMD from mining operations, it has become evident that assessing the AMD generation potential of mine ore should be conducted before, during, and after mining activities [4,11]. Static AMD tests are commonly used to quickly determine whether a given ore will generate acid (i.e., AMD)

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and to assess its acid-neutralizing potential [2,9,13,19]. Recent studies have proposed equations that utilize mineralogical data to estimate the ore's acid-producing or neutralizing potential without requiring extensive laboratory testing [8,10]. However, a key limitation of static AMD tests is that they do not answer the question of *when* AMD will occur. This is a critical factor when prioritising multiple mine dumps for treatment, particularly when only a few can be addressed at a time due to resource constraints. For this reason, kinetic AMD prediction methods—such as experimental kinetic tests and mathematical models—are preferred, as they enable the prediction of AMD occurrence over time [6,15]. In this study, the Mintek Kinetic AMD Predictor is used to forecast AMD occurrence over a 30-year period for a selected copper mine site in Southern Africa. The Mintek Kinetic AMD Predictor is a mineral particles-based predictive tool that requires key input parameters, including mineralogical data (mineral composition, mineral surface liberation, mineral association, etc.), ore or tailings density, particle size distribution, and expected environmental conditions (temperature, rainfall, and wind speed). Compared to literature models such as the one presented by Bernardes de Souza & Mansur [6], the Mintek Kinetic AMD Predictor is more computationally intensive. However, it is expected to provide higher accuracy, as it incorporates detailed particle-based mineralogical data and simulates changes in the system's individual particle properties over time [7,8].

EXPERIMENTAL

Ore tailings characteristics – Mintek Kinetic AMD Predictor input parameters

Copper ore tailings samples from a Southern African copper mine considered in this study were analysed in Mintek's laboratories to determine the necessary input mineralogical data required for the Mintek Kinetic AMD Predictor. The tailings sample bulk modal mineralogical inputs, obtained from automated scanning electron microscopy, are presented in **Figure 1**. Calcite was the predominant mineral phase in the sample, followed by quartz, biotite, orthoclase, plagioclase, bornite, and hornblende. All other mineral phases were present in amounts <1% of the sample mass.

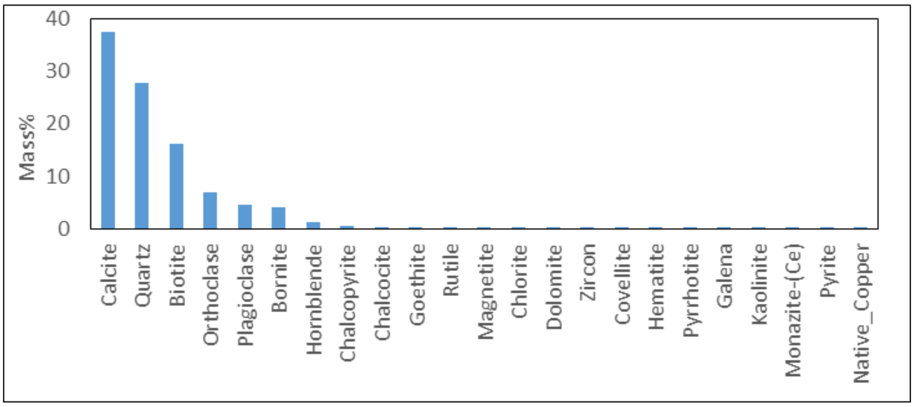

Figure 1 Bulk modal mineralogy for the Cu tailings sample

The base metal sulfides (BMS) minerals identified are summarised in **Figure 2**. They are fine-grained, with over 50% of the sulfides mass reporting to the <38 µm size fraction. The BMS minerals cumulative liberation by the free surface is shown in **Figure 3**. It should be noted that the sulfides are moderately liberated, with 20 to 60% of the mass percentage being more than 80% liberated.

The Mintek Kinetic AMD Predictor uses the bulk modal mineralogical inputs to select the specific chemical reactions associated with the tailings sample particles from its library/database. The grain size and liberation by free surface are used to determine the mineral mass available for that specific chemical reaction at the particle level during the simulation.

The sample chemical element analysis results showed that it had 0.9% S, 4.2% Al, 12.5% C, 2.9% Cu, 2% Fe, and 20% Si. This data was used to reconcile the mineralogical analysis.

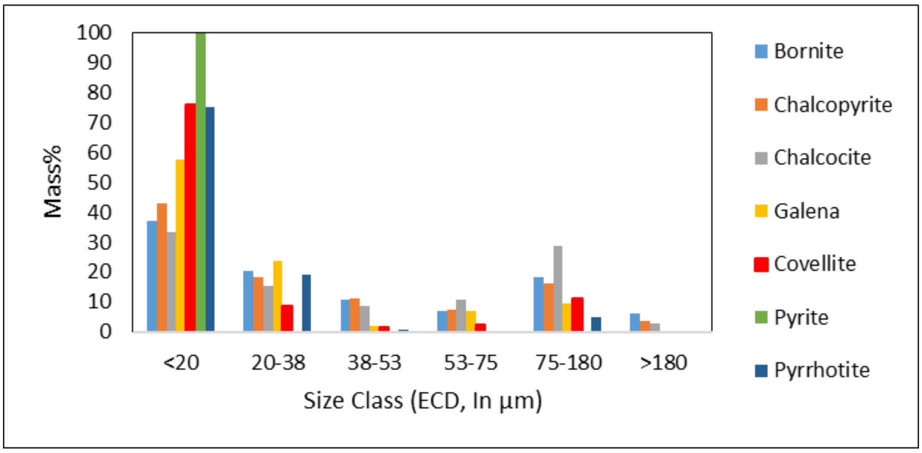

Figure 2 BMS grain size distribution

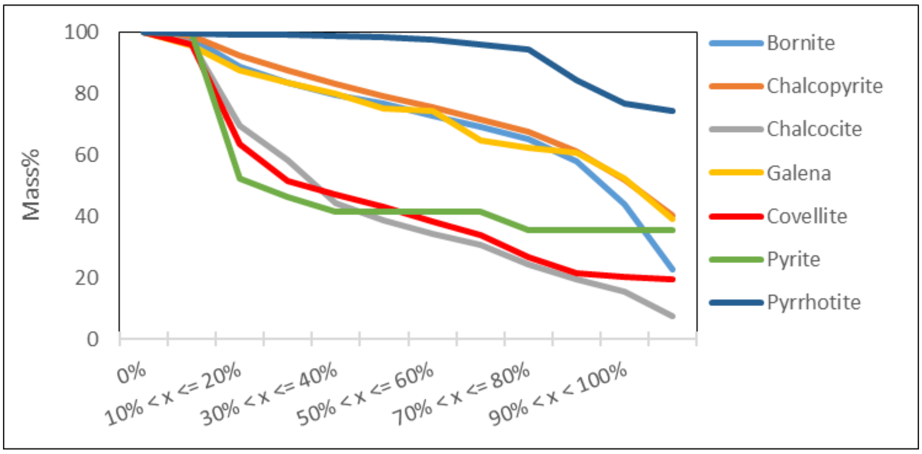

Figure 3 BMS cumulative liberation by free surface

Site Weather Conditions – Mintek Kinetic AMD Predictor input parameters

The 30 years of weather conditions (rainfall, temperature, and wind speed) at the mine site were estimated based on the historical full-year weather conditions data at the mine site obtained from Weatherspark [18]. The Mintek Kinetic AMD Predictor uses the mine site environmental temperature and wind speed to determine the system temperature and oxygen available at each particle level. The amount of rainfall is used by its infiltration model to calculate the fresh water transported to and/or available at each particle level. The seasonal average rainfall, temperature, and wind speed range were 570 mm, 17.0-25.7°C, 3.8-16.1 km/h in Summer, 27.5 mm, 11.9-25.6°C, 9.1-19.3 km/h in Autumn, 0 mm, 12.0-28.7°C, 10.7-24.1 km/h in Winter, and 312.5 mm, 17.8-30.7°C, 7.0-19.8 km/h in Spring.

The other major input to the Mintek Kinetic AMD Predictor was the mine tailings density, which was 2638 kg/m^3. Kinetic humidity cell tests were also done for 3 months to validate the Mintek Kinetic AMD Predictor parameter/results for this tailings site.

RESULTS AND DISCUSSION

The 30-year AMD prediction results for the considered Southern African mine tailings site are shown in **Figure 4**. To avoid a congested graph, the results are presented yearly. A zoomed-in view of the last 3 years is also added to **Figure 4** to show the acid release rate profile per kilogram of tailings per quarter, i.e., to show the impact of seasonal changes.

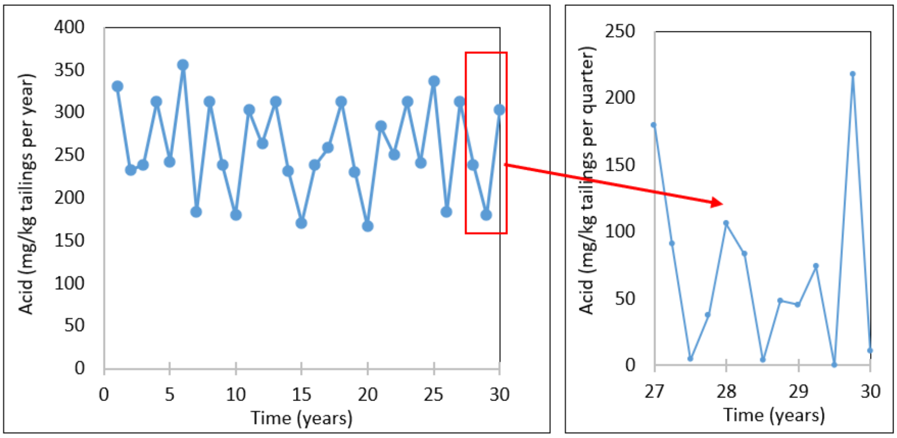

Figure 4 AMD prediction over 30 years

It should be noted from **Figure 4** that the yearly acid release rates vary (with minimum, maximum, and average of 167, 355, and 259 mg/kg tailings per year respectively), and this was expected as the mine tailings site weather conditions also vary significantly as noted from the input weather conditions. In the early years (<10 years), the overall acid production rate was slightly higher, and this could be attributed to the fact that there was still a high percentage of fine sulfide mineral particles (<38 µm) with high free surface area. Further analysis of the change in the cumulative acid release rate showed that the tailings site might reach the peak acid release rate sometime beyond the 30 years used in this study. This information is crucial if a plant is to be designed and built to treat AMD from this mine site.

CONCLUSIONS AND RECOMMENDATION

The Mintek Kinetic AMD Predictor was used in this study to predict the AMD occurrence over 30 years for one of the Southern African copper mine tailings dumps. The results obtained in this study will form part of an ongoing process to determine the optimal AMD leachates mitigation and/or treatment process for this mine site. For improved predictions, it is recommended that the impact of climate change be included in the input weather conditions.

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