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*Technical Communication*

# Improving the Accuracy of Geochemical Rock Modelling for Acid Rock Drainage Prevention in Coal Mine

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**Abstract.** The results of static tests are used to geochemically model the distribution of potentially acid and non-acid forming materials and plan mining excavation and overburden dumping to prevent or minimize the generation of acid rock drainage (ARD). The accuracy of the model depends very much on the amount and validity of the available pre-mine data and how the data is interpreted in both lateral and vertical directions. This results of such modelling was compared with subsequent overburden information provided by analysis of blast hole drill cuttings. We found that the model overestimated the amount of potentially acid forming material, but that it was still useful in ARD prevention.

**Key words:** geochemical rock model, ARD prevention

## Introduction

Acid rock drainage (ARD), also known as acid mine drainage (AMD), develops when sulphide-containing rocks are exposed to air and water. ARD is one of the important potential impacts of mining on the environment, and is commonly associated with ore mines where sulphide minerals are dominant. However, ARD also forms at coal mines, although the percentage of sulphide minerals is relatively small. Preventing the generation of ARD is considered more economical and safer in the long run than perpetual water treatment by the addition of lime. In general, the generation of ARD can be forestalled by minimizing the extent of sulphide mineral oxidation. This is typically accomplished by depositing the excavated overburden in such a way as to prevent the potentially acid forming materials (PAF) from being exposed to air and/or coming into contact with water. To this end, it is crucial that the lithology of the area be sufficiently characterized; the findings are usually plotted using a geochemical rock model that extrapolates the available information laterally and vertically, making certain (usually conservative) assumptions.

The problem most commonly faced in the geochemical modelling of rocks is the limited amount of data available from drilling (Gautama and Tjahyaningtyas 2003). It is important that the geochemical model be validated and updated during the mining operation so that any deviation from the model can be instantly identified and acted on. This paper discusses the use of blast hole cuttings produced during development of Pit AB of the PT Kaltim Prima Coal (KPC) Mine as a case study in how such information can be used to assess the accuracy of a geochemical model.

## ARD Management

### Geochemical Rock Model

Acid-base accounting (ABA) is commonly used to assess whether certain strata has the potential to generate or to neutralize ARD. As it is generally applied, it assumes that all of the sulphur in a rock sample has the potential to generate acid, then calculates a maximum potential acidity (MPA) based on that parameter. It is based on geochemical characteristics of the strata determined before mining takes place, using: % sulphur, acid neutralizing capacity (ANC), net acid generating (NAG) values, and net acid producing potentials (NAPP). These values are all derived from static tests. NAPP is calculated by balancing the MPA and ANC of the sample. If NAPP $\leq 0$, the rock sample is classified as non-acid forming (NAF) material; if NAPP $> 0$, it is classified as PAF material. By using knowledge of the site stratigraphy obtained by pre-mine drilling and interpreting the lateral and vertical distribution of the geochemical characteristics of the rock, a geochemical model of the distribution of PAF and NAF material can be developed for the mine area.

### Overburden Placement Strategy

Overburden dumping or placement strategy plays an important role in preventing ARD generation. Commonly, PAF material is encapsulated with NAF material in such a way as to minimize the infiltration of air and/or water into the PAF material. The success of encapsulation depends very much on the degree of understanding of the geochemical characteristics of each type of material in the overburden, which is why a good geochemical model is sometimes as important as the geological model. Coupling the geochemical model to the excavation or mine planning model allows the mine operator to know in advance whether the material being excavated is NAF or PAF, and therefore how to handle it.

Model Verification during Mining

To ensure the reliability of overburden placement during mining, material type verification is necessary. Since blasting is used to loosen the overburden, it is possible to use blast hole cuttings to characterize the rock being blasted.

**Case Study**

Coal Mining at the Sangatta Area

The Sangatta area is located in East Kalimantan Province, Indonesia (Figure 1). The mines are operated by PT Kaltim Prima Coal (KPC), a contractor working under agreement with the government of Indonesia. With an annual output of 18 million t in 2003, it is one of the largest coal producers in Indonesia.

Geologically, the Sangatta area is located at the northeastern part of the well known Kutai tertiary sedimentary basin, which is one of the most significant hydrocarbon basins in Indonesia. Regionally, this area is characterized by folding structures with northeast-southwest trending axes. In the western part of the mining area, an intrusion has created a dome structure, called the Pinang Dome. The pressure exerted by the intrusion elevated the coal rank.

The important coal seams belong to the Balikpapan Formation, which is dominated by mudstone, siltstone, and sandstone. Nine principal coal seams are mined. Seam thickness varies between 0.5 and 15 m, with most in the 2-6 m range. Dips normally vary between $3^o$ and $20^o$.

The KPC uses shovel and trucks to excavate the coal in open pits. A combination of blasting and ripping is used to loosen the overburden and the coal. The case study takes place in Pit AB (phase 2).

Geochemical Model of Pit AB Phase-2

Rock samples obtained from core drilling were analysed using static testing methods. The results of the static tests led to a grouping of the overburden and intercalating rocks into four types of rocks, namely:

- Type-1 – non-acid forming (NAF) rocks
- Type-2 – low acid forming capacity: NAPP < 2 kg $H_2SO_4$/ton overburden
- Type-3 – medium acid forming capacity: NAPP 2 – 10 kg $H_2SO_4$/ton overburden
- Type-4 – high acid forming capacity: NAPP > 10 kg $H_2SO_4$/ton overburden

For the sake of convenience, the mine operator treated the type-1 and type-2 rocks as NAF materials, and the type-3 and type-4 rocks as PAF materials. The geochemical model at Pit AB Phase-2 was based on samples taken from 93 holes at the site with a distance between the holes of 100 – 200 m. Rock samples were

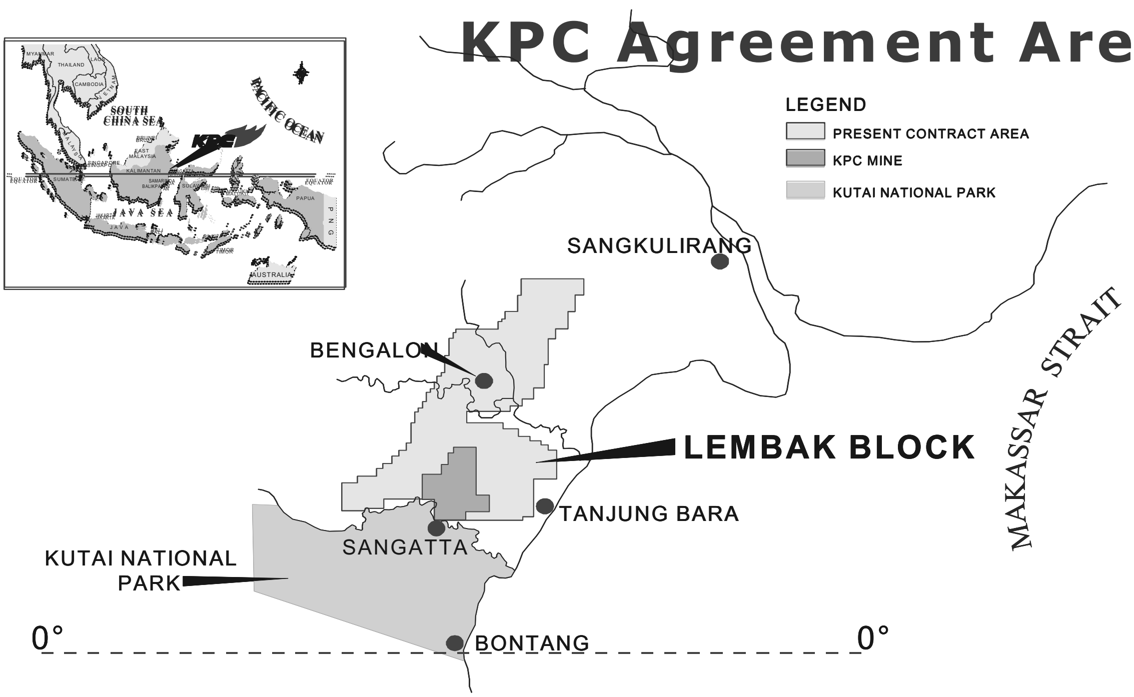


**Figure 1.** Location map of KPC mine

collected every meter from each of the drill holes, and tested to obtain their geochemical characteristics. The data from the drill holes were then correlated based on the coal seam and lithological similarity. The geochemical model was developed based on the correlation between the drill holes, producing a picture of the vertical and horizontal distribution of each rock type. For operational convenience, the geochemical model at Pit AB Phase-2 was made using a total of 37 east-west cross-sections, and colours were added to each cross-section to indicate the type of rock.

With these cross-sections, one can determine the geochemical characteristics of the excavation blocks with a depth or block height of 10 m, which is the height of the mine benches. By convention, the blocks containing more than 5% PAF materials were categorized as PAF (Gautama et al. 2003).

Blast Hole Cuttings Models

For day-to-day operation, the predicted geochemical characteristics of rocks already described in the geochemical models are verified to prevent errors in the depositing or placement of rock types. For this purpose, samples from every 10 m of blast hole cuttings are composited, to match the height of the mine benches, using the following procedure (Hartaji, 2003):

- when coal is present on the surface of the dump, it is removed, since the presence of coal can affect the NAG test results.
- samples are taken from the dump at three points, as shown in Figure 2.
- every sample is taken up-hole, from bottom to top, to ensure that the entire vertical profile of the hole was represented in the sample.
- samples are collected from every fifth hole in every other drilling lines, as shown in Figure 3.

Sampling is carried out in accordance with the short-term plan for the excavation of the overburden. A rapid modified-NAG test allows the operator to have analytical results in less than a day (Miller et al. 1994). Using blast hole sampling, the types of blasted rocks can be identified, influencing the placement strategy at the dump site.

Results of the NAG test for each blast hole are modelled at each excavation block (about 50 x 50 m), to assess the distribution of the PAF and NAF materials within the respective excavation block.

Based on this model, we can design a short-term plan for depositing the overburden. The volume of each material type on the blast hole model is calculated by

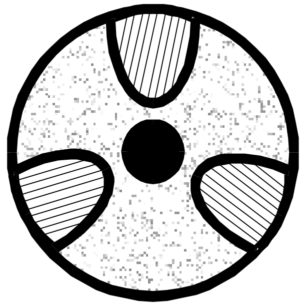

**Figure 2.** Upper view of the blast hole spoil dump showing the three positions for sample taking

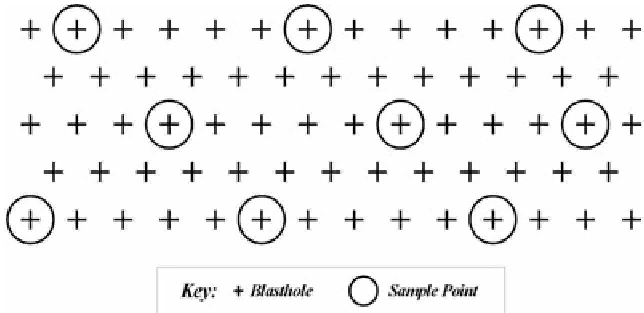


**Figure 3.** Sampling configuration at Pit AB phase-2, namely the fifth hole of every other drilling lines

correlating the NAG test result points on each weekly planned block, so as to obtain material distribution data for each planned mining block.

In assigning the area of each rock type, certain assumptions and extrapolations are necessary. Values from the nearest blast holes are weighted based on the inter-hole distance. If the presence of PAF material is more dominant than NAF in a blasted block, the block is considered as PAF. The opposite is true when NAF materials tend to be more dominant. The objective is to facilitate the mining process. Thus, the boundary between PAF and NAF materials in the respective block should be defined as clearly as possible.

**Comparison of Models**

The geochemical model is validated and verified (or contradicted) by the blast hole cuttings model, allowing the operator to determine the accuracy of the geochemical model. This allows the geochemical model for the not-yet excavated areas to be continuously improved so that over time, the geochemical model becomes more accurate. Comparison of the geochemical model with the model obtained from blast hole cuttings at Pit AB Phase-2 was carried out for the excavation blocks between the 32$^{nd}$ and 43$^{rd}$ week of 2002, which represented a total of 7,503,926 bcm of overburden in 97 excavation blocks. A consistent interpretation between the two models was identified in 62 excavation blocks, with a total volume of 5,612,323 bcm of overburden or 74.79% of the total overburden being excavated.

In general, the volume of PAF material in the blast hole model (3,227,885 bcm or 43% of the total overburden volume), is less than the interpreted volume in the geochemical model (3,889,302 bcm or 51.8% of the total material). The difference (661,417 bcm or 17%) from the interpreted figure in the geochemical model, totalled 8.8% of the total rock volume.

Out of a total of 97 excavation blocks, differences in the volume calculation of the PAF materials were found at 35 blocks, and 28 blocks of them were totally different. This means that materials, which were interpreted as NAF in the geochemical model turned out to be PAF material, or the other way around. Fourteen excavation blocks with a material volume of 615,092 bcm were interpreted as NAF in the geochemical model, and were in reality PAF. Twenty one excavation blocks with a volume of 1,276,511 bcm were first interpreted as PAF but turned out to be NAF in reality. Figure 4 shows the differences at 35 excavation blocks. In term of lithology, the total excavated overburden consists of 9 different types. The volume of each lithological type as well as the differences in geochemical interpretation is shown in Table 1. It can be concluded that as the volume of material increases, so does the likelihood that the characteristics of the rock will differ from the geochemical pre-mine prediction.

**Conclusion**

The study on excavation blocks indicated a 12-week operation, representing 7.5 million bcm of overburden, but the volume of PAF material in the geochemical model (51.8% of the total material) was greater than the real volume shown in the blast hole

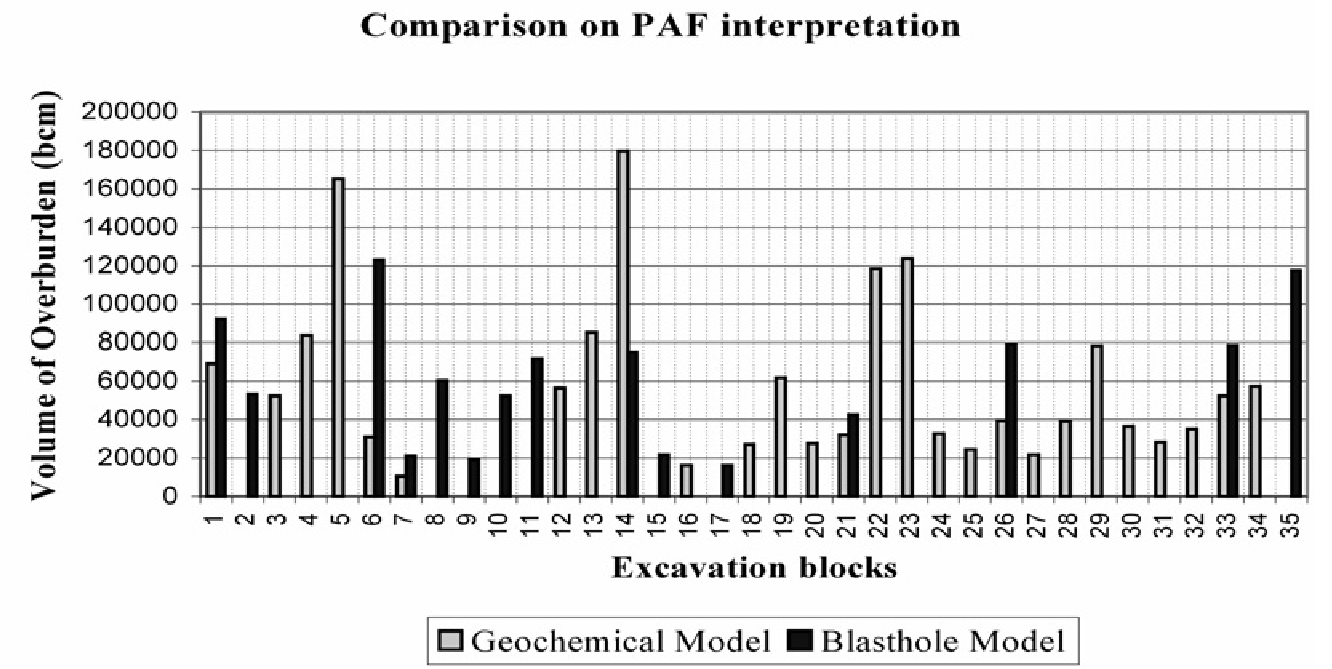


**Figure 4.** Comparison of rock volume in the geochemical and blast hole models

**Table 1.** Comparison between models based on the lithology

| Code | Description | Volume (bcm) | % | NAF-PAF | % | PAF-NAF | % |
|---|---|---|---|---|---|---|---|
| XM1UR | roof seam M1 | 561,578 | 7.48 | | | | |
| XMDUR | interburden M1-MD | 1,122,214 | 14.96 | 156,272 | 13.93 | 27,012 | 2.41 |
| XSNUR | interburden MD-SN | 1,771,393 | 23.61 | 184,829 | 10.43 | 633,742 | 35.78 |
| XSLUR | Interburden SN-SL | 2,232,994 | 29.76 | 181,636 | 8.13 | 485,079 | 21.72 |
| XB2UR | Interburden SL-B2 | 1,571,044 | 20.94 | 81,689 | 5.20 | 130,678 | 8.32 |
| XB1UR | interburden B2-B1 | 132,199 | 1.76 | 10,666 | 8.07 | | |
| XP5UR | interburden B1-P5 | 69,132 | 0.92 | | | | |
| XP4UR | interburden P5-P4 | 36,946 | 0.49 | | | | |
| XP2UR | roof seam P2 | 6,426 | 0.09 | | | | |
| | Total | 7,503,926 | 100.00 | 615,092 | 8.20 | 1,276,511 | 17.01 |
| NAF-PAF | had been classified as NAF, but identified as PAF | | | | | | |
| PAF-NAF | had been classified as PAF, but identified as NAF | | | | | | |

cuttings model (43% of the total material). The difference totalled 8.8% of the total overburden volume or 661,417 bcm. It can be concluded that the geochemical model is more pessimistic in interpreting the PAF material, in large part due to the way the model block is defined in the model: if PAF material found in the model block is more than 5%, the whole block is classified as PAF.

It is suggested that the geochemical model should still be used for overburden excavation and placement planning, but that the results should be modified using the findings from the blast hole cuttings model when such data is available, and that blast hole cuttings analysis is very useful in modifying the on site placement operational strategy.

**Acknowledgement**

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## International Mine Water Association – Executive Council Meeting

On September 20th 2004, 5—7 pm, IMWA's Executive Council will hold its annual meeting in Newcastle upon Tyne, UK (Nicholas Wood Library, Mining Institute). All members of the EC are encouraged to take part. If an EC member has any contribution he wishes to make and cannot attend the meeting, then please send your comments to President Andrzej WITKOWSKI or the Secretary General Christian WOLKERSDORFER so that it can be read out at the meeting. Comments must arrive by September 1st 2004.

***Agenda***

1. Present
2. Apologies
3. Previous Minutes
4. President's report (Andrzej Witkowski)
5. Secretary's report (Christian Wolkersdorfer)
6. Treasurer's report (Adrian Brown)
7. Editor-in-Chief's report (Bob Kleinmann)
8. PADRE Report (Paul Younger, Rob Bowell)
9. 2003 Congress Report (Peet Nel)
10. 2004 Symposium Report (Paul Younger)
11. Symposium 2005, Congress 2006, Symposium 2007
12. Guidelines for future IMWA meetings
13. Electronic votes for IMWA EC and General Assembly
14. Any other Competent Business

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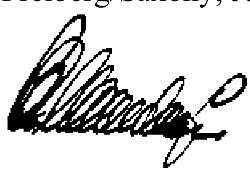

Christian Wolkersdorfer
Secretary General