AMD-TIME: A SIMPLE SPREADSHEET FOR PREDICTING ACID MINE DRAINAGE[1]

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Abstract: Regulatory agencies and industry need a method for predicting the duration and extent of acid mine drainage (AMD) from specific rock masses. The most widely accepted method for predicting AMD is acid base accounting (ABA). ABA only estimates whether there will or will not be a problem. It does not estimate ultimate acid loading, treatment costs nor duration of liability. Nonetheless, the principle behind acid base accounting is reasonable: that there is a relationship between the acid generation and neutralization potentials of a given rock mass. This paper presents a spreadsheet which uses ABA data in a dynamic fashion to predict acid generation, loading, concentration and duration. The spreadsheet uses conventional variables plus three new ones: percent sulfur flux (%Sf), net deliverable neutralization (NDN) and net deliverable acidity (NDA).

The spreadsheet and preliminary validation are presented though it is recognized that a great deal of work is needed before this becomes a reliable prediction tool.

Introduction

Acid Base Accounting.

Acid Base Accounting (ABA) was developed in the early 1970's by researchers at West Virginia University to identify and classify geologic strata encountered during mining (West Virginia University, 1971). A history of Acid Base Accounting is provided by Skousen et al. (1990).

Since its development, ABA has been used extensively in the United States and other countries for premining overburden analysis. Its popularity largely stems from its simplicity. It uses two key parameters: Maximum potential acidity (MPA) and neutralization potential (NP). MPA is estimated by multiplying per cent pyrite sulfur by 3.125 yielding the total acid produced. NP is the acid consumed by the rock in a titration procedure. Both MPA and NP age given in calcium carbonate equivalents.

Acid neutralization in spoil dumps-a paradigm. ABA operates on the assumption that acid producing and acid neutralizing rocks are thoroughly mixed. Violation of this assumption can remove large portions of the alkaline rock mass from the equation.

Most coal spoils consist of mixtures of acid producing and acid neutralizing rocks. AMD can form despite a dominance of alkaline rock in the spoil. AMD may form in localized pockets within the backfill. And, while finding the path of least resistance to the downstream side of the dump, its acidity is influenced only the alkalinity directly in its path. Once this is overcome, AMD flows freely to the nearest stream while the remaining alkalinity persists as a spectator to the process. Dissolution of calcite is controlled by pH and the partial pressure of carbon dioxide. Where pore water gas is confined, and exposed to mineral acidity, its pH will remain around 6.2 the-buffering point of bicarbonate and carbonic acid. In the absence of mineral acidity, its pH will reflect bicarbonate saturation ~ 8.3. In either case, additional calcite will dissolve only upon addition of acidity and outgassing of carbon dioxide. So, unless contacted directly by acidity, most of the spoil calcite will simply remain in solid form. So, the presence of alkalinity in the dump does not ensure that it will be a factor in neutralizing acidity. To be an efficient process, the acid-forming and alkaline rock must be thoroughly mixed.

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[1] Paper presented at the International Land Reclamation and Mine Drainage Conference and the Third International Conference on the Abatement of Acidic Drainage, Pitttsburgh, PA, April 24-29, 1994.

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Proceedings America Society of Mining and Reclamation, 1994 pp 395-400
DOI: 10.21000/JASMR94020395

https://doi.org/10.21000/JASMR94020395

This largely becomes a materials handling issue. Where there is insufficient alkalinity available it would be necessary to add it to the rock. Otherwise, if one relies on random spoil dumping the system would need an overwhelming supply of alkaline rock.

The AMD-TIME Spreadsheet

The preceeding cautionary remarks are meant as background for anyone using an AMD prediction process based on ABA, including this spreadsheet. The estimates generated by either ABA or AMD-TIME are only as good as the estimates of MPA, Np and the operator's materials handling practices.

In developing AMD-TIME the following assumptions were made:

1. Within fairly narrow limits pyrite oxidizes at a nearly fixed rate. It is about 7% per year.
2. The pyrite oxidation rate is the rate limiting step.
3. Rock geometry and porosity are simple multipliers. For example the following factors might be multiplied against 7%.

sandstone	100%
shale	50%
refuse with fines	20%

4. The resulting value is called sulfur flux.

AMD-TIME uses conventional variables plus the following:

%Sf/yr	Percentage of remaining pyritic sulfur oxidized and leached per year.
FLOW	Annual rainfall X surface area X net infiltration.
NDN	Net deliverable neutralization potential. This is the proportion of NP that is exposed to acid water and is able to react with it.
NDA	Net deliverable acidity. This is the proportion of MPA that oxidizes.

AMD-TIME operates on the Quatro Pro spreadsheet developed by Borland International, Inc. Quatro Pro is similar to Lotus 1,2,3 and, except for the graphics would probably work equally well. The spreadsheet only uses several hundred KRAM so it will work on nearly all IBM compatible desktop computers. Naturally, machine power and higher order Intel chips will make it work more quickly.

AMD-TIME was developed for simplicity, not elegance. It uses empirical rather than deterministic variables. Table 1 shows the working end of AMD-TIME. The user only needs to enter the following data:

target NP/MPA ratio
years of mining
acid rock production (tons of rock produced in mining)
surface area (acres)
%Sf/yr
%S pyritic (from ABA)
%NP natural (from ABA)
%NP added
%NDN
%NDA
cost of alkaline amendment ($)
amendment NP (%)

cost of water treatment chemical ($/t)
life of mine coal production (t)

AMD-TIME will then estimate acid loads, concentrations and alkalinity for the next several hundred years. AMD-TIME automatically estimates the chemical cost of water treatment for the life of AMD production. It also automatically estimates the required amount of alkaline amendment needed to reach a target NP/MPA ratio. If you enter that amount at the "%NP added" block the spreadsheet will estimate the cumulative cost of amendment. Costs in current dollars are given in absolute amounts and in dollars per raw tonne of coal.

Comparison of Estimates to Small Scale Field Data:

As configured AMD-TIME is an acidity model. It can also be rün as a sulfate model. This was used to compare various variable combinations to data from 11 year old 400 ton test piles at Island Creek's Upshur Complex (Table 2. Two net infiltration values and three Sf and NDA rates were tested in a factorial arrangement. Sf was calculated for each sampling interval (for a discussion of this experiment see Ziemkiewicz and Meek, 1994). For each pile, Sf was slow during the first six months, then accelerated to a maximum within about 10 months. Three estimates of Sf were evaluated in this study: 1) low-Sf integrated over one year, 2) medium-Sf integrated over the last 7 months and 3) high-Sf integrated over the last 5 months.

The column on the left of the table indicates observed sulfate concentrations at the end of year one and at the end of year 11. The best fit for each pile and variable combination was chosen and is indicated by the shading.

The best fits occurred with either of the two variable combinations:

PILES:	1,3	2,4,5,10
NET INFILTRATION %	50	75
Sf	low	high
NDA(%)	100	50

It was surprising that only two scenarios captured the best fits for all of the test piles. Piles 1 and 3 were primarily sandstone while the other piles were mainly shale. It is logical that high NDA fits better with the sandstones given its greater porosity. Why net infiltration appeared higher on the shale than on the sandstone is a mystery unless this actually estimates residence time of water. These analyses are only the early stages of what will be a rigorous

AMD-TIME was run on the SH and LS1 piles using three sulfur flux rates (high, medium and low). The results were compared observed sulfate concentrations from the same piles. Results indicated that the mid range Sf gave the best fits to observed values when NDA was held at 100% (figures 1 and 2).

Conclusions

Like all predictive tools, AMD-TIME is only as good as the variables which make it run. Values for its controlling variables are generated independently of AMD-TIME. AMD-TIME is not a crystal ball. It simply translates acid base accounting data into acid loads and treatment costs per time. Since it uses empirical variables it is useful to compare predictions within set boundary conditions to field observations. Users will be able to fine tune the imput variables such as sulfur flux, net infiltration, NDN and NDA for their local conditions. As experience with these variables improves so will the quality of the estimates. The Spreadsheet is non-proprietary and copies can be obtained by sending a clean diskette to the author with a self-addressed, stamped mailer.

Literature Cited

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TABLE 1. AMD-TIME SPREADSHEET. ESTIMATED LONG-TERM ACID GENERATION AND COST OF TREATMENT

SITE:	ABC MINING
TARGET NP/MPA:	1
YEARS OF MINING:	2

VARIABLE BLOCK

ACID ROCK PRODUCTION ARP (T)	3672108
SURFACE AREA (ACRES)	60
RATE OF S LOSS (%Sf/YR)	2.00
FLOW (L/YR)	138766500
%S	0.338
%NP NATURAL	0.019
%NP ADDED	2.090
%NP TOTAL	2.109
% NET DEL. NEUTRALIZATION (NDN)	25
%NET DELIVERABLE ACIDITY (NDA)	50
REQUIRED NP (%)	2.09
REQ'D ALKALINE AMENDMENT (%)	2.20
COST ALK. AMENDMENT ($/TON)	12.00
AMENDMENT NP (%)	95
COST OF WATER TRT CHEMICAL ($/T)	60
ACID CAPITAL (T)	19393
ALKALINE CAPITAL (T)	19361

RESULTS BLOCK

LIFE OF MINE PRODUCTION	(TONS)	648000
COST OF WATER TREATMENT	($)	517
COST OF ALKALINE AMENDMENT	($)	969437
COST OF WATER TREATMENT	($/RAW T	0.00
COST OF ALKALINE AMENDMENT	($/RAW T	1.50
TOTAL COST-WATER TREATMENT + AMENDMENT	($/RAW T	1.50

Figure 1. Observed and predicted [SO4] shale control pile (SH).

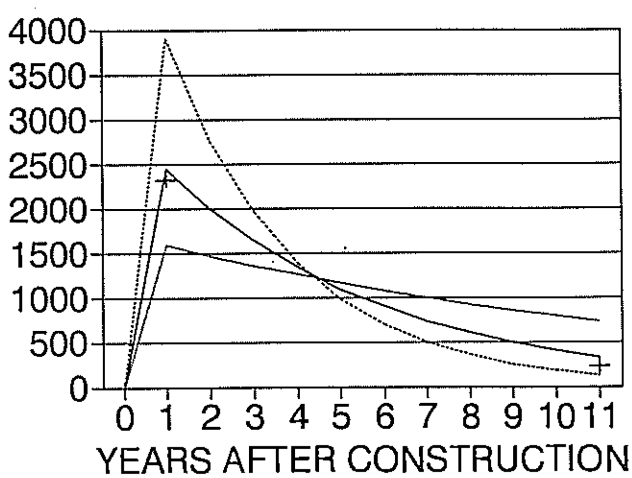
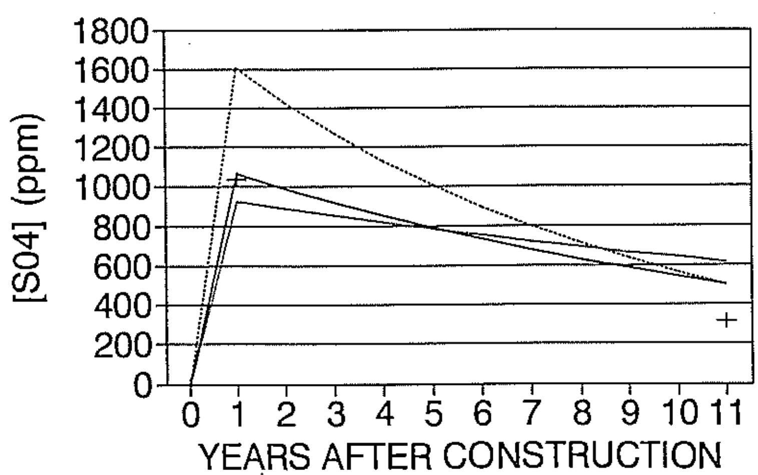


Figure 2. Observed and predicted [S04] 1% limestone amended pile.



+ OBS. [SO4] —— high Sf —— medium Sf —— low Sf

TABLE 2. Use of AMD-TIME spreadsheet to evaluate net deliverable acidity and sulfur flux rates. Sulfur flux rates are derived from observed rates in the field:

Low rate= rate integrated over full first year.

Medium rate= rate integrated over last 6 months.

High rate= rate integrated over the last 3 months.

100% SHALE CONTROL (SH)

ROCK MASS (KG)	365920
AREA (AC.)	0.05
FLOW (L/YR)	200250
%S	0.310
PYRITE S (KG)	1134
NET INF. (%)	75

	%Sf/day	0.0204	0.0204	0.0500	0.0500	0.0800	0.0800
	NDA (%)	100	50	100	50	100	50
Year	Observed [SO4]	Predicted [SO4]					*
0	0	0	0	0	0	0	0
1	2323	1219	610	2835	1417	4303	2152
2		1132	566	2362	1181	3214	1607
3		1051	525	1968	984	2400	1200
4		975	488	1640	820	1792	896
5		905	453	1366	683	1338	669
6		840	420	1138	569	999	500
7		780	390	948	474	746	373
8		724	362	790	395	557	279
9		672	336	658	329	416	208
10		624	312	549	274	311	155
11	220	579	290	457	229	232	116

SANDSTONE/SHALE LAYERED WITH 1% LIMESTONE AMENDMENT (LS2)

ROCK MASS (KG)	376000
AREA (AC.)	0.05
FLOW (L/YR)	200250
%S	0.330
PYRITE S (KG)	1241
NET INF. (%)	75

	%Sf/day	0.0110	0.0110	0.0200	0.0200	0.0300	0.0300
	NDA (%)	100	50	100	50	100	50
Year	Observed [SO4]	Predicted [SO4]					*
0	0	0	0	0	0	0	0
1	1038	732	366	1309	654	1928	964
2		703	351	1217	608	1728	864
3		675	338	1131	565	1549	774
4		649	324	1051	526	1388	694
5		623	312	977	489	1244	622
6		598	299	908	454	1115	558
7		575	287	844	422	999	500
8		552	276	785	393	896	448
9		531	265	730	365	803	401
10		510	255	678	339	720	360
11	312	490	245	631	315	645	322

* = Best prediction curves.