A COMPARISON OF BASIC AND ACIDIC PRODUCTS USING ACID-BASE ACCOUNTING AND SIMULATED WEATHERING STUDIES

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ABSTRACT

Data obtained from pre and post-leach acid-base accounting were compared to the resultants of a simulated weathering study. Certain relationships were analyzed in order to achieve a fundamental understanding of the factors which affect mine drainage under controlled conditions.

Acid-Base Accounting predicted the quality of the leachate obtained from the columns. This study indicated there was a high correlation between pre-leach acid-base accounting and leach water quality.

INTRODUCTION

The quality of mine drainage is a function of the interrelationships of numerous natural and anthropogenic factors. Since many of the interrelationships have not yet been quantified, an understanding of the known relationships and the ability to predict and identify potential problems will minimize the occurrence of acid-mine drainage.

Accurate overburden characterization is necessary in recommending mining reclamation procedures that are both cost effective and simultaneously designed to minimize the potential for acid-mine drainage. Two standard procedures for overburden characterization are acid-base accounting and simulated weathering. In this study which tested the latter process, the simulated weathering columns were based on acid-base accounting data and information supplied by an operator pertaining to his equipment and method of mining. The objectives were to study the effects of various methods of overburden placement on leachate quality using acid-base accounting and simulated weathering studies.

GENERAL BACKGROUND

The mine site used in this study is located in Surface Mining Province II, as originally defined by Arkle (2). The stratigraphic delineation of Surface Mining Province II includes the beds of the uppermost Pottsville, Allegheny and Lower Conemaugh Formations. Surface Mining Province II is broadly defined as having overburdens that are high in total sulfur, low in bases, but have a wide range of rock types. Mining operations in Province II require attention to overburden characteristics and to handling procedures in order to avoid acid-mine drainage. This investigation was based on acid-base accounting data and information supplied by the operator that the proposed operation would mine the Upper Freeport coal by a dragline. It was considered feasible to make a 50 foot, 15.2 m, (approximate) first cut and to segregate any potentially acid-producing materials greater than 1 foot, 30.5 cm, in thickness.

MATERIALS AND METHODS

Acid-Base Accounting and Simulated Weathering

Overburden materials were sampled, described and tested in accordance with EPA Methods (8) for acid-base accounting and sulfur fractionation.

Leaching Study

The columns and simulated weathering cycle in this study are an adaptation of similar studies described by EPA Methods (8) and others (5).

Two-liter polyethylene bottles with tubulation at the bottom were fitted with a "y" connector and two lengths of flexible plastic tubing. One tube was attached to an aeration manifold and the other served as a drain for the leachate. Glass wool was placed in the bottom of each bottle and covered with filter paper to prevent plugging of the drain with fines.

Each column was filled with 1000 grams of sample which had been crushed to pass a 2-mm sieve. Where more than one sample was added to the column, the weight of each material added was determined by the thickness of strata represented. Tables 1 and 2 show the experimental units that illustrated the materials that were added to the columns in layers and for mixtures.

A piece of filter paper was placed on top of the material in each column to provide an even flow of leaching water throughout the fabric. An initial leaching of each column was conducted with 1000 ml of distilled and deionized water to provide background data for that column. Following the background leaching, 10 ml of acid-mine water was added to each column to innoculate the columns with iron and sulfur oxidizing bacteria.

TABLE 1 ACID-BASE ACCOUNT

		---------Tons/1000 Tons of Material-----------						
Sample	Depth feet	Rock type	Fizz	%S	Max. from %S	NP	Max Needed pH7	Excess
1A	2.0-3.0	SS	0	0.010	0.31	0.07	0.24	
01	3.0-7.0	SS	0	<.005	0.16	1.00		0.84
02	7.0-12.0	SS	0	<.005	0.16	1.19		1.03
03	12.0-16.0	SS	0	<.005	0.16	1.41		1.25
04	16.0-20.0	SS	0	<.005	0.16	1.00		0.84
05	20.0-24.7	SS	0	<.005	0.16	1.24		1.08
06	24.7-28.8	SS	3	0.075	2.34	37.57		35.23
07	28.8-32.7	SS	0	0.072	2.25	1.02	1.23	
08	32.7-37.3	SS	0	0.094	2.94	-0.02	2.96	
09	37.3-41.0	SS	0	0.116	3.63	0.34	3.29	
10	41.0-44.0	SS	0	0.159	4.97	14.17		9.20
11	44.0-46.0	SS	0	0.496	15.50	0.75	14.75	
12	46.0-47.3	SS	0	1.05	32.81	-0.78	33.59	
13	47.3-47.8	SS	0	0.268	8.37	7.55	0.82	
14	47.8-48.4	MS	0	1.02	31.88	1.56	30.32	
15	48.4-48.8	Coal	0	6.74	210.63	-0.97	211.60	
16	48.8-49.2	MR	0	2.37	74.06	0.02	74.04	
17	49.2-51.4	Coal	0	3.18	99.37	-0.95	100.32	
18	51.4-51.7	Carb	0	0.822	25.69	2.39	23.30	
19	51.7-52.8	Coal	0	2.03	63.44	-0.85	64.29	
20	52.8-54.0	MS	0	0.525	16.41	1.85	14.56	
21	54.0-55.8	Coal	0	4.21	140.94	-0.75	141.69	
22	0-.2 below	MS	0	0.127	3.97	-1.23	5.20	
23	.2-.7 below	MS	0	0.235	7.34	-0.48	7.82	
24	0-.2 below	MS	0	0.219	6.84	3.11	3.73	
25	.2-.4 below	MS	0	0.253	7.91	2.81	5.10	
26	---	LS	5	0.018	0.58	718.12		717.54

SS - Sandstone
MR - Mudrock
MS - Mudstone
Carb - Carbolith
LS - Limestone sand (10 to 50% passing No. 50 sieve and
2 - 10% passing No. 100 sieve)

TABLE 2 CONTROLLED PLACEMENT LEACHATE STUDY

Leachate Study Sample Number	Description Refer to Table 1
C-1	Composite of 1A-16 inclusive
C-2	Composite of 1A-14 inclusive
C-3	Composite of 1A-10 inclusive
C-4	Composite of 11-16 inclusive
C-5	Composite of 15 and 16
C-6	Sample 18
C-7	Sample 20
C-8	Composite of 22 and 23
C-9	Composite of 24 and 25
C-10	C-1, C-6 + C-7, C-1, C-8
C-11	Same as C-10 with treatment 1
C-12	Same as C-10 with treatment 2
C-13	Same as C-10 with treatment 3
C-14	Same as C-10 with treatment 4
C-16	C-2, C-5 + C-6 + C-7, C-2, C-8
C-17	Same as C-16 with treatment 1
C-18	Same as C-16 with treatment 2
C-19	Same as C-16 with treatment 3
C-15	Same as C-16 with treatment 4
C-20	C-3, C-4 + C-6 + C-7, C-3, C-8
C-21	Same as C-20 with treatment 1
C-22	Same as C-20 with treatment 2
C-23	Same as C-20 with treatment 3
C-24	Same as C-20 with treatment 4

Treatment 1 - 0.1" Limestone sand on pavement
Treatment 2 - 20 tons/Acres AG Lime on pavement
Treatment 3 - same as (2) plus potential acid sandwich between 2 layer of 20 tons/Acre AG Lime
Treatment 4 - same as (2) plus potential acid material mixed with 40 tons/Acre AG Lime

Simulated Weathering Cycle

After innoculation with acid-mine water, moist air was passed through each column for 90 hours. The air was supplied by an air pump and moisture was supplied by first passing the air through water.

At the end of the innoculation period, 1000 ml of distilled deionized water was poured through each column and allowed to drain by gravity. Following the leaching, moist air was passed through the columns for three days, followed by three days of dry air. The sequence of moist air, dry air and leaching was repeated weekly for one year.

Leachate Analysis

Each leachate and blank was analyzed for pH, total hot acidity, mineral acidity, total alkalinity, total iron, dissolved iron, total manganese, sulfates, calcium, magnesium, and specific conductivity (9). All samples were analyzed by acid-base accounting technique prior to placement in the leachate columns and at the completion of the experiment.

RESULTS AND DISCUSSION

General Interpretations

1. Pre-Leach Acid-Base Accounting

Pre-leach acid-base accounting, Table 3, indicated that leachate from C-1, C-10, C-16 and C-20 should be slightly acidic in nature. The materials represented by C-4, C-5, C-6, C-7 and C-8 were defined as being potentially acid-producing while C-9 was considered as being borderline. The materials represented by C-2 and C-3 were identified as having an excess of potential neutralizers, but these excesses were less than 4.0 tons/1000 tons. The treated columns were identified as having excesses of potential neutralizers ranging from 22.0 - 106 tons/1000 tons. Therefore, the leachates from the materials represented by these columns should be basic.

TABLE 3 ACID-BASE ACCOUNT FROM TOTAL SULFUR

(Weighted Averages)

Column	%S	--------$CaCO_3$ Equivalents Tons/1000 Tons of material------ Maximum from %S	Neutralization Potential $CaCO_3$ Equiv.	Maximum Needed pH7	Excess
C-1	0.186	5.81	4.92	0.89	
C-2	0.111	3.47	5.01		1.54
C-3	0.049	1.53	5.41		3.88
C-4	1.30	40.63	0.93	39.70	
C-5	4.56	142.50	-0.48	142.98	
C-6	0.822	25.69	2.39	23.30	
C-7	0.522	16.41	1.85	14.56	
C-8	0.204	6.38	-0.69	7.07	
C-9	0.236	7.38	2.96	4.42	
C-10	0.198	6.19	4.75	1.44	
C-11	0.192	6.00	28.83		22.83
C-12	0.190	5.94	43.57		37.63
C-13	0.175	5.47	111.72		106.25
C-14	0.175	5.47	111.72		106.25
C-15	0.175	5.47	111.73		106.26
C-16	0.199	6.22	4.75	1.47	
C-17	0.193	6.03	28.83		22.80
C-18	0.190	5.94	43.57		37.63
C-19	0.175	5.47	111.73		106.26
C-20	0.199	6.22	4.75	1.47	
C-21	0.193	6.03	28.83		22.80
C-22	0.190	5.94	43.57		37.63
C-23	0.175	5.47	111.73		106.26
C-24	0.175	5.47	111.73		106.26

When pre-leach acid-base accounting using only percent pyritic sulfur was conducted, there were some shifts indicated by the data shown in Table 4. C-1 now possessed a slight excess of potential neutralizers (0.33 tons/1000 tons), but the leachate from the column was still expected to be slightly acidic. C-4, C-5, C-6 and C-7 were still defined as potential acid-producing. However, the leachate from the materials represented by C-8 was expected to be on the borderline between strongly acidic to very moderately acidic. C-9 was not considered to be borderline, but predicted to produce a leachate that would have the characteristics of moderately acidic drainage.

2. Simulated Weathering Studies

The results of the simulated weathering columns agreed with the interpretations made from acid-base accounting. The columns that were identified as potentially acid-producing had leachates characteristic of strongly acid-mine drainage (Table 5). Strongly acidic drainage used in this study is defined as having the following characteristics:

1. pH of 4.0 or less
2. total acidity greater than 10 ppm with mineral acidity
3. dissolved iron content greater than 5 ppm
4. elevated manganese content
5. sulfate content greater than 50 ppm
6. specific conductivity greater than 100 umhos

The columns that were identified as having slight excesses or deficiencies of carbonate equivalents when subjected to the simulated weathering study yielded leachates that were slightly acidic. Slightly acidic drainage used in this paper is defined by the following:

1. pH valves between 6.0 - 7.0
2. very little or no total hot acidity
3. total alkalinity that is greater than total hot acidity but the difference between the two is 15 ppm or less.
4. dissolved iron generally less than 0.5 ppm

TABLE 4 ACID-BASE ACCOUNT FROM PYRITIC SULFUR

(Weighted Averages)

Column	% Pritic S	--------$CaCoO_3$ Equivalents Tons/1000 tons of material------ Maximum from % Pyritic S	Neutralization Potential	Maximum Needed pH7	Excess
C-1	0.147	4.59	4.92		0.33
C-2	0.096	3.00	5.01		2.01
C-3	0.041	1.28	5.41		4.13
C-4	1.00	31.25	0.93	30.32	
C-5	3.15	98.44	-0.48	98.92	
C-6	0.650	20.31	2.39	17.92	
C-7	0.335	10.47	1.85	8.62	
C-8	0.098	3.06	-0.69	3.75	
C-9	0.022	0.69	2.69	2.27	
C-10	0.154	4.81	4.75	0.06	
C-11	0.156	4.88	28.83		23.96
C-12	0.145	4.53	43.57		39.04
C-13	0.129	4.03	111.72		107.69
C-14	0.131	4.09	111.72		107.63
C-15	0.132	4.13	111.73		107.61
C-16	0.155	4.84	4.75	0.09	
C-17	0.156	4.88	28.83		23.96
C-18	0.145	4.53	43.57		39.04
C-19	0.130	4.06	111.73		107.67
C-20	0.154	4.81	4.75	0.06	
C-21	0.155	4.84	28.83		23.99
C-22	0.144	4.50	43.57		39.07
C-23	0.129	4.03	111.73		107.70
C-24	0.131	4.09	111.73		107.64

TABLE 5

Summarized Data of Simulated Weathering Study

Column	Total Acidity	Mineral Acidity	Total Alkalinity	Total Fe	Dissolved Fe	Mn
	ppm					
C-1	7.0	0.0	974	13.36	2.40	6.99
C-2	8.0	0.0	1238	4.66	2.42	7.16
C-3	0.0	0.0	1077	12.41	2.40	4.53
C-4	4211	1976	0.0	700.67	521.47	33.20
C-5	33180	20243	0.0	9796.4	89441.1	18.07
C-6	4250	2173	0.0	303.08	270.58	14.51
C-7	2276	989	0.0	101.31	79.54	9.79
C-8	1660	2.0	0.0	30.41	23.87	1.88
C-9	570	0.0	0.0	19.96	13.70	11.83
C-10	26	0.0	1063	10.40	4.12	19.22
C-11	7.0	0.0	1202	9.02	2.52	3.39
C-12	0.0	0.0	1477	6.35	2.44	4.15
C-13	0.0	0.0	1512	5.69	2.40	1.96
C-14	0.0	0.0	1418	4.49	2.40	2.21
C-15	0.0	0.0	1373	7.21	2.40	2.49
C-16	29	0.0	925	8.40	4.07	15.35
C-17	5.0	0.0	1196	8.77	2.40	2.99
C-18	0.0	0.0	1339	5.04	2.40	3.66
C-19	0.0	0.0	1352	4.42	2.40	1.74
C-20	28	0.0	728	8.10	4.25	12.86
C-21	4.0	0.0	1232	6.90	2.40	3.72
C-22	0.0	0.0	1194	4.84	2.40	4.35
C-23	0.0	0.0	1828	4.06	2.40	1.72
C-24	0.0	0.0	1391	5.06	2.40	1.32

TABLE 5 (cont.)

Summarized Data of Simulated Weathering Study

Column	Specific Conductivity (umhos)	S04	Ca	Mg
		ppm		
C-1	3815	718	424.95	121.78
C-2	4196	502	420.93	86.52
C-3	2946	370	330.39	82.37
C-4	24339	5121	364.65	186.06
C-5	68816	35278	180.64	137.96
C-6	41177	7068	957.04	338.73
C-7	20436	6024	736.93	267.49
C-8	7670	1751	67.72	65.32
C-9	5829	1723	335.47	116.06
C-10	4160	1051	444.00	129.16
C-11	4800	952	589.40	126.16
C-12	5184	897	652.16	133.20
C-13	5131	809	667.46	148.48
C-14	5204	878	686.20	125.24
C-15	4840	866	593.28	119.70
C-16	3914	783	423.65	125.16
C-17	4599	797	548.78	115.01
C-18	4860	825	588.97	120.38
C-19	4954	816	637.14	119.34
C-20	3523	768	369.01	125.99
C-21	4353	724	535.43	110.69
C-22	4703	839	555.51	120.85
C-23	5480	680	745.32	123.31
C-24	4506	695	558.65	99.05

5. sulfates generally less than 15 ppm
6. specific conductivity generally less than 25 umhos.

C-9, which was identified by pre-leach acid-base accounting to have a deficiency of 2.27 ton/1000 tons based on pyritic sulfur, yielded leachates with the following ranges of the parameters tested:

1. pH 3.8-4.5; with 4.5 at conclusion of study
2. total hot acidity 6-23 ppm; with 6 ppm at conclusion of study
3. no mineral acidity
4. total alkalinity of less than 1
5. total iron 0.06-1.66 ppm; with 0.06 ppm at conclusion of study
6. dissolved iron <0.05-1.52 ppm; with <0.05 ppm at conclusion of study
7. total manganese 0.04-1.82 ppm with 0.04 ppm at conclusion of study
8. specific conductivity 40-571 umhos; with 40 umhos at conclusion of study
9. sulfates 8-193 ppm; with 8 ppm at conclusion of study
10. calcium 1.14-52.6 ppm; with 1.14 at conclusion of study
11. magnesium 0.38-17.6; with 0.38 at conclusion of study

These characteristics are typical of moderately acidic drainage. The above confirms the interpretations made from the acid-base accounting data concerning the general quality of the leachate.

All the simulated weathering columns exhibited a similar trend. Following physical redistribution of overburden materials, there was an initial acceleration of chemical weathering. After approximately 20 weeks into the weather cycle, the columns adjusted toward equilibrium or steady state condition.

Amounts of Neutralization Potential and Maximum Acidity Consumed

Table 6 and 7, respectively, show the difference between pre and post-leach neutralization potential; and pre and post-leach maximum acidity. By calculating the difference between pre and post-leach acid-base accounting, the percentage of neutralization potential and maxium acidity leached can be determined.

TABLE 6

PRE-LEACH VERSES POST-LEACH NEUTRALIZATION

Column	Pre-leach NP	Post-leach NP	Difference	%Consumed
	$CaCO_3$ Equivalents Tons/1000 Tons Material			
C-1	4.92	2.35	2.57	52.23
C-2	5.01	2.42	2.59	51.70
C-3	5.41	3.12	2.29	42.33
C-4	0.93	-0.70	1.63	*
C-5	-0.48	-2.80	2.32	*
C-6	2.39	-0.52	2.91	*
C-7	1.83	-0.80	2.63	*
C-8	-0.69	-0.63	-0.06	**
C-9	2.69	1.90	0.72	26.77
C-10	4.75	2.40	2.35	49.47+
C-11	28.83	24.58	4.25	14.74 (1)
C-12	43.57	42.42	1.15	2.64 (2)
C-13	111.72	112.33	-0.61	** (3)
C-14	111.72	109.36	2.36	2.11 (4)
C-15	111.73	91.32	20.41	18.27 (4)
C-16	4.75	2.50	2.25	47.36+
C-17	28.83	23.92	4.91	17.03 (1)
C-18	43.57	36.21	7.36	16.89 (2)
C-19	111.73	81.81	29.92	26.78 (3)
C-20	4.75	2.75	2.00	42.11+
C-21	28.83	16.39	12.44	43.15 (1)
C-22	43.57	26.50	17.07	39.18 (2)
C-23	111.73	100.84	10.89	9.75 (3)
C-24	111.73	93.04	18.69	16.73 (4)

* over 100% consumption
** post exceeded pre
\+ controls

1. limestone sand on pavement
2. 20 tons/acre AG lime on pavement
3. same as (2) plus potential acid sandwich 2 - layers of 20 tons/acre AG lime
4. same as (2) plus 40 tons/acre mixed with potential acid

TABLE /

PRE-LEACH VERSES POST-LEACH MAXIMUM ACIDITY FROM % PYRITIC SULFUR

Columns	----------$CaCO_3$ Equivalents Tons/1000 Tons Material---------------			
	Pre Maximum	Post Maximum	Difference	%Consumed
C-1	4.59	4.00	0.59	12.85
C-2	3.00	2.28	0.72	24.00
C-3	1.29	1.03	0.26	20.16
C-4	31.25	28.69	2.56	7.23
C-5	98.44	48.13	50.31	51.10
C-6	20.31	12.47	7.84	38.60
C-7	10.47	7.50	2.97	28.37
C-8	3.06	1.38	1.68	54.90
C-9	0.69	0.16	0.53	76.81
C-10	4.81	4.09	0.72	14.97+
C-11	4.88	4.41	0.47	9.63 (1)
C-12	4.53	3.63	0.90	19.87 (2)
C-13	4.03	4.03	0	0 (3)
C-14	4.09	3.59	0.5	12.22 (4)
C-15	4.13	4.97	**	--- (4)
C-16	4.84	4.25	0.59	12.19+
C-17	4.88	4.88	0	0 (1)
C-18	4.53	4.38	0.16	3.5 (2)
C-19	4.06	3.97	0.09	2.2 (3)
C-20	4.81	4.53	0.28	5.2+
C-21	4.84	4.91	**	--- (1)
C-22	4.50	4.53	**	--- (2)
C-23	4.03	3.91	0.12	3.0 (3)
C-24	4.09	3.84	0.25	6.1 (4)

post exceeded pre
\+ controls

(1) limestone sand on pavement
(2) 20 tons/acre AG lime on pavement
(3) same as (2) plus potential acid sandwich between 2 - layers of 20 tons/acre AG lime
(4) same as (3) plus 40 tons/acre mixed with potential acid

In the columns identified by pre acid-base accounting to have slight excess or deficiencies (C-1, C-2 and C-3), 12.85 - 24.00% of the maximum acidity and 42.33 - 52.23% of the neutralization potential was depleted from the system. The greatest percentage of neutralization potential and maximum acidity was removed from the materials represented by C-2. On the other hand, in columns C-4, through C-7, which were identified as being potentially acid-producing, more than 100% of their neutralization potential and 7.23 - 54.9 % of maximum acidity were depleted.

Pre and post-leach acid-base accounting was conducted on the control columns and the various treatments. From this, it was determined which handling method would be the most effective in controlling the oxidation of pyritic sulfur, yet utilize the least amount of neutralization potential (Table 6 and 7). The handling procedures represented by C-20 through C-24 were the most effective in controlling the amount of pyritic sulfur oxidized, whereas the handling procedures C-10 through C-14 were the least effective. The procedures represented by C-10 through C-14 utilized the least amount of neutralization potential, and the procedures represented by C-20 through C-24 utilized the most neutralization potential. Overall, the most effective handling procedures are those represented by C-15 through C-19. In the series, C-17 appears to be the most effective under controlled conditions because C-17 minimized pyritic sulfur oxidization and neutralization utilization, simultaneously.

A study was conducted of the effectiveness of the various treatments under controlled conditions, regardless of the handling procedures. This study determined the following in order of effectiveness in minimizing pyritic sulfur oxidization under controlled conditions.

1. Potential acid-producing materials "sandwiched" between 2 layers of 20 tons/acre AG lime, with 20 tons/acre AG lime on pavement.

2. Potential acid-producing materials mixed with 40 tons/acre AG lime, with 20 tons/acre on pavement.
3. 20 ton/acre AG lime on pavement.
4. 0.1" limestone sand on pavement.

Overall, the most cost effective treatment under controlled conditions was 20 tons/acre AG lime on the pavement.

Extreme caution must be taken when extrapolating data derived from laboratory conditions to field conditions. The simulated weathering study was developed with certain factors controlled that are not normally controlled under field conditions. Those are:

1. wetting and drying cycle
2. direction of water movement
3. particle size
4. temperature
5. innoculation with iron and sulfur oxidizing bacteria

This was done in order to study simulated backfill conditions without making unwarranted assumptions. The following statements can be made from the data:

1. Even though rock unit possess little or no free carbonates (low fizz rating), neutralization potential is released.
2. The method of handling material and how the material is selectively placed affects the quantity of pyritic sulfur oxidized.
3. The method of treatment and how the treatment is utilized affects the quantity of pyritic sulfur oxidized.
4. One cannot simply add the quality of the leachates from individual rock units and project the quality of a given backfill situation.

RELATIONSHIPS OF SELECTED PARAMETERS

1. Neutralization Potential of Overburden Material versus Total Alkalinity of the Leachate

Since neutralization potential is the amount of neutralizing bases including carbonates present in overburden materials, and the alkalinity of a liquid is its quantitative capacity to react with a strong acid to a designated pH, the correlation between the total alkalinity leached, in grams, and the change in neutralization potential (ΔNP), in grams, was of

TABLE 8

ΔNEUTRALIZATION POTENTIAL OF OVERBURDEN MATERIAL VERSUS TOTAL ALKALINITY LEACHTED

Column	NP (gms)	Total Alkalinity (gms)
C-1	2.57	0.97
C-2	2.59	1.23
C-3	2.29	1.08
C-4	---	---
C-5	*	*
C-6	---	---
C-7	---	---
C-8	*	*
C-9	0.72	0.57
C-10	2.53	1.04
C-11	4.25	1.20
C-12	1.15	1.48
C-13	**	**
C-14	2.36	1.42
C-15	20.41	1.37
C-16	2.25	0.90
C-17	4.91	1.19
C-18	7.36	1.34
C-19	29.92	1.35
C-20	2.00	0.70
C-21	17.07	1.19
C-22	17.07	1.19
C-23	10.89	1.83
C-24	18.69	1.39

* Negative Pre-leach NP
** No Change
--- Change greater than Pre-leach NP

interest (Table 8). The correlation between the change in neutralization potential and total alkalinity (TAlk) resulted in a R value of 0.43. Its regression equation was:

$$TAlk = 0.015\ (\Delta NP) + 1.07.$$

The comparison was strongly influenced by the various treatments. The ΔNP was greater than that of TAlk, especially in those samples treated with AG lime. The difference can be related to a number of reasons. In a carbonate system, the end point for titration (pHe) should be calculated. Even though it is possible to calculate pHe, the method has not yet been standardized. Another is that it is feasible for carbonates to dissolve without a change in pH or alkalinity until an equilibrium point of that particular system is reached. The difference can also be related to the leaching solution being low in carbonates and encountering material rich in calcium carbonate in the solid form. This may lead to the formation of significant intermediate products before the complete dissolution of the carbonates. It was beyond the scope of this study to determine which factors, or combination of factors, caused the difference.

The comparison between NP and TAlk was repeated, this time the treated columns were excluded. The R value was 0.84, and the regression equation for the comparison was:

$$TAlk = 0.29\ (\Delta NP) + 0.31.$$

2. <u>ΔMaximum Acidity from Pyritic Sulfur versus Total Hot Acidity</u>

The Δmaximum acidity from pyritic sulfur (ΔMac) and total hot acidity (ThAc) leached was compared (Table 9). The correlation showed R of 0.996 and the regression equation was:

$$ThAc = 0.66\ (\Delta Mac) - 0.02.$$

This relationship is only valid under moderately acidic and strongly acidic conditions, since the rate of pyritic sulfur oxidation decreases as systems become less acidic.

TABLE 9

ΔMAXIMUM ACIDITY OF OVERBURDEN MATERIAL VERSUS TOTAL HOT ACIDITY OF THE LEACHATE

Column	ΔMaximum Acidity (gms)	Total Hot Acidity (gms)
C-1	0.59	.007
C-2	0.72	.008
C-3	0.25	0
C-4	2.56	4.211
C-5	50.31	33.18
C-6	7.84	4.25
C-7	2.94	2.28
C-8	1.68	1.67
C-9	0.53	0.57
C-10	0.72	0.026
C-11	0.47	0.007
C-12	0.90	0
C-13	0	0
C-14	0.50	0
C-15	0	0
C-16	0.59	0.029
C-17	0	0.005
C-18	0.15	0
C-19	0.09	0
C-20	0.28	0.028
C-21	0	0.004
C-22	0	0
C-23	0.12	0
C-24	0.25	0

3. Mac - NP Versus ThAc - TAlk

The ΔMac - ΔNP indicates whether there were excess bases or acids leached from the weathering columns. ThAc - TAlk, on the other hand, indicates whether the overall characteristic of the leachates was acidic or basic. Therefore, the two were compared to see how well they correlated to each other (Table 10). The correlation between ΔMac - ΔNP and ThAc - TAlk showed R of -0.86 and the regression equation for the comparison was:

Net Acidity or Alkalinity = -0.48 (ΔMac - ΔNP) -2.23. [Eq.1]

As before, the comparison was strongly influenced by the various treatments. The comparison was repeated; this time the treatments were excluded. This comparison showed R of -0.998 and the regression equation was:

Net Acidity or Alkalinity = -0.69 (ΔMac - ΔNP) -0.42. [Eq.2]

Tables 11 and 12 show the calculated net acidity or alkalinity of leachates, using equation 1 and equation 2, respectively. The calculated basic and acidic ranges based on each equation are quite different. This is related to the treatments which were included in equation 1. The neutral points, using equation 1 and equation 2, are -4.6 gms and -0.6 gms, respectively. Equation 2 appears to have a greater range of adaptability. However, one observation must be stated: as Mac - NP increases, the calculated net acidity using both equations grows nearer and equals each other at 8.5 gms.

SUMMARY AND CONCLUSIONS

The current terminology used to describe drainage from mined lands is vague and in certain circumstances very restrictive. The standard practice of describing existing and/or proposed drainage of mined land is to state that it is either acid or non-acid mine drainage. The criterion being whether drainage is, or will be, above or below a specified pH level. The above criterion tells very little about the characterics of the drainage,

TABLE 10 --ΔMac - ΔNP Versus ThAc - TAlk

Column	Mac - NP (gms)	ThAc - TAlk (gms)
C-1	-1.98	0.97
C-2	-1.87	1.23
C-3	-2.04	1.08
C-4	4.11	-4.21
C-5	47.99	-33.18
C-6	4.93	-4.25
C-7	1.31	-2.28
C-8	2.69	-1.66
C-9	-0.52	+0.57
C-10	-1.63	1.04
C-11	-3.78	1.20
C-12	-0.25	1.48
C-13	*	*
C-14	-1.86	1.42
C-15	*	*
C-16	-1.66	0.90
C-17	-4.91	1.19
C-18	-7.21	1.34
C-19	-29.75	1.35
C-20	-1.75	0.70
C-21	*	*
C-22	*	*
C-23	-10.77	1.83
C-24	-18.44	1.39

TABLE 11 -- CALCULATED NET ACIDITY OR ALKALINITY

Using Equation 1

	Mac - NP (gms)	Net Acidity or Alkalinity
	-10.0	2.6
	-9.0	2.2
	-8.0	1.6
Basic	-7.0	1.1
	-6.0	0.7
	-5.0	0.2
Neutral	-4.6	0
	-4.0	-0.3
	-3.0	-0.8
	-2.0	-1.3
	-1.0	-1.8
	0.5	-2.5
	1.0	-2.7
	1.5	-3.0
	2.0	-3.2
	2.5	-3.4
Acidic	3.0	-3.7
	3.5	-3.9
	4.0	-4.2
	4.5	-4.4
	5.0	-4.6
	5.5	-4.9
	6.0	-5.1
	6.5	-5.4
	7.0	-5.6
	7.5	-5.8
	8.0	-6.1
	8.5	-6.3
	9.0	-6.6

TABLE 12 -- CALCULATED NET ACIDITY OR ALKALINITY

Using Equation 2

	Mac - NP (gms)	Net Acidity or Alkalinity (gms)
	-10.0	6.5
	-9.0	5.8
	-8.0	5.1
	-7.0	4.4
Basic	-6.0	3.7
	-5.0	3.0
	-4.0	2.3
	-3.0	1.7
	-2.0	1.0
	-1.0	0.3
Neutral	-0.6	0
	0.5	-0.8
	1.0	-1.1
	1.5	-1.5
	2.0	-1.8
	2.5	-2.2
Acidic	3.0	-2.5
	3.5	-2.8
	4.0	-3.2
	4.5	-3.5
	5.0	-3.9
	5.5	-4.2
	6.0	-4.6
	6.5	-4.9
	7.0	-5.3
	7.5	-5.6
	8.0	-5.9
	8.5	-6.3
	9.0	-6.6

except under extreme acidic or basic conditions. Current terminology for drainage from mined lands is not very useful in developing mining and reclamation procedures at a particular site. But if the drainage were defined on the basis of its acidic or basic characteristic, then realistic plans could be developed. Both acid-base accounting and this simulated weathering study can predict post-mine drainage, but only if the data is intrepreted by competent personnel.

Extreme caution must be taken when extrapolating laboratory data to field conditions. Simulated weathering studies are developed with certain factors that are controlled in the laboratory but are not normally controlled under field conditions. The following statements can be made from the data derived from the simulated weathering study:

1. Rock units with little or no free carbonates (low fizz ratings) released alkalinity.
2. Pyritic sulfur oxidization is affected by method of the handling and how the material is selectively placed.
3. Pyritic sulfur oxidization is affected by the type of treatment and how the treatment is utilized.
4. Adding together the qualities of leachates from individual rock units cannot project the quality of given backfill situation.

The difference between pre and post-leach acid-base accounting has a strong correlation with the net acidity or alkalinity of the leachate, except in the carbonate influenced system. The data suggest a greater change in neutralization potential in treated columns than net alkalinity leached or the alkalinity calculated from leached Ca or Mg. This phenomemon might be related to:

1. Method of determining total alkalinity.
2. Potential of carbonates to dissolve without change in pH or alkalinity until equilibrium is reached.
3. Formation of significant intermediate products.
4. Interaction with other elements present in the system.

Overall, the data coincide with the thesis of acid-base accounting that potential acidity is related to the percent pyritic sulfur, which can be converted to $CaCO_3$ equivalents and the potential neutralizers in the sample can be expressed in terms of $CaCO_3$ equivalents.

In conclusion, the chemistry of a backfill as presented in this study is a simplified version of a complex chemical system. However, before a backfill can be fully studied under field conditions, each component of the system must be quantified. Therefore, simulated weathering studies can serve as rungs on the ladder to the understanding of the chemistry of a backfill. As with a ladder, one must move one rung at a time.

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