MODIFICATION OF THE NET ACID PRODUCTION (NAP) TEST

Kim Lapakko[1] and Richard W. Lawrence[2]

[1] Division of Minerals Minnesota Department of Natural Resources,
  Box 45, 500 Lafayette Road, St. Paul, MN 55155-4045

[2] Department of Mining and Mineral Process Engineering,
  University of British Columbia, Vancouver, B.C. V6T 1Z4

ABSTRACT

The Net Acid Production Test (NAP) was developed as a hydrogen peroxide-based static test for the prediction of acid rock drainage which could be applied in the field. Previous evaluation indicated the test underestimated the Net Acid Production Potential of mine waste samples. Recognizing that this error might have been the result of incomplete oxidation of iron sulphide minerals in the mine waste, modifications to the test were introduced, primarily to enhance the degree of oxidation. Ten mine waste samples were characterized (particle size, chemistry, mineralogy) and subjected to the modified NAP test, standard Acid Base Accounting, Modified Acid Base Accounting, and the B.C. Research Initial static tests. The results of the NAP test were quantitatively comparable to those of the; other static tests. Comparison of the sulphur content of four samples before and after the NAP Test indicated that 95 to 99 percent of the sulphur initially present was oxidized by the hydrogen peroxide digestion. It was concluded that the modification improved the extent of iron sulphide mineral oxidation and, consequently, the accuracy of the test.

INTRODUCTION

Several static tests have been developed to estimate quickly and inexpensively if a mine waste will produce acidic drainage. The objective of the standard Acid-Base Accounting (ABA, Sobek et al., 1978), Modified Acid-Base Accounting (Lawrence, 1990), and B.C. Research Initial Tests (Duncan and Bruynesteyn, 1979) is to determine the maximum potentials for acid production (acid production potential or APP) and acid neutralization (neutralization potential or NP). The APP is based on sulphur analysis and the NP is determined by the amount of acid neutralized under when the sample is in contact with a solution in the approximate pH range of 1 to 3.5. Whether or not a mine waste will produce acidic drainage is determined by the difference (Net NP) or ratio (NP/APP) of these values.

The Net Acid Production Test (NAP, Coastech Research Inc., 1989) is a static test which was developed due to a perceived need for both an alternative laboratory technique and a simple field procedure to allow rapid on-site waste management/placement decisions. The test has the advantage over other static methods that sulphur analyses, to allow calculation of the theoretical APP of a sample, are not required. This feature makes the test particularly suitable for field use.

The NAP test uses hydrogen peroxide to accelerate the oxidation of sulphide minerals present in a sample of mine waste, and the acid generated then reacts with other host rock minerals. In the referenced method, five grams of mine waste is subjected to oxidation by 100 mL of 15 % hydrogen peroxide. One hour after the reaction is apparently complete, the pH of the mixture of solids and liquid is determined. (It was indicated that the results were comparable when only five minutes were allowed after the apparent completion of the reaction). The solution is then titrated to pH 7.0, yielding a value which allows the Net Acid Producing Potential to be measured directly. In the Coastech Research Inc. (1989) study, this technique correctly identified all nine samples which produced AMD in the field, and two of the three samples which did not produce acid in the field. In general, however, this technique yielded higher equivalent Net NP values than the other static tests for the samples examined.

A test, perhaps based on the NAP test, referred to as the Net Acid Generation test, or NAG, was presented by Miller et al. (1990, 1991), and has been used at mine sites in Australia, New Zealand and the U.S. The authors stated that the NAG typically yielded lower potential acid generation than indicated by the standard ABA method. They correlated the NAG results for one mine site with the Net Acid Production Potential (NAPP) of the samples (NAPP = -Net NP). The NAG values were roughly two-thirds of the standard ABA values. In addition, these workers indicate that simply recording the pulp pH following peroxide digestion could provide a classification of a sample as potentially acid producing or not. It is further suggested that the lag period before acid generation starts in a waste material could be predicted, at least in some qualitative sense, by monitoring rates of temperature and/or pH change during digestion. In any application, however, it is indicated that the methods were site specific. In particular, preliminary testing was required to determine methods of sample preparation, the ratio of mine waste sample to hydrogen peroxide solution, hydrogen peroxide strength, and reaction time.

The NAP is a relatively simple test which could be conducted quickly in the field (Coastech Research Inc., 1989; Miller et al., 1990), a distinct advantage over the three previously mentioned tests. However, both Coastech Research Inc. (1989) and Miller et al. (1990) indicated that the NAP underestimated the capacity to produce acid. One possible explanation for this flaw is that the hydrogen peroxide "digestion" does not completely oxidize the iron sulphides present in the mine waste samples. Consequently, the acid generated in the test is less than the actual acid production potential.

The use of hydrogen peroxide to accelerate the oxidation of sulphide minerals was previously applied to determine the acid potential of soils (Sobek et al. 1978). Mirza et al. (1992) tested this method and reported incomplete oxidation of coal, coal pyrite, and ore pyrite. Finkelman and Griffin (1986) proposed another method, referred to as the Hydrogen Peroxide Test, for determining the pyrite content of coal related wastes. Coastech Research Inc. (1989) applied this technique to hard rock mine samples and concluded the method was "too inaccurate and erratic to be of real use."

O'Shay et al. (1990) subsequently modified the method of Finkelman and Griffin (1986) and achieved pyrite recoveries on pyrite standards of 97 to 102%, as compared to 61 to 171% for the original method. Thus, the modified technique was highly accurate in determining the pyrite content of the standards, which suggests that similar modification may improve the accuracy of the NAP Test. This paper presents results from such a modification, and compares these results to those of other static tests and the Net NP determined by mineralogical analyses. Based on the results, field application of the test is discussed.

METHODS

Materials

Four waste rock samples, identified as RK1 to RK4, and six tailing samples, identified as TL1 to TL6, were collected for testing. The mine waste sample were split into different subsamples for subsequent chemical and mineralogical analysis and static testing. The splitting procedure was tested by analyzing the sulphur and carbon dioxide content of three sample splits, to ensure uniformity of the samples generated.

Sulphur was analyzed by LECO induction furnace and sulphate was analyzed following a sodium carbonate leach. Carbon dioxide was analyzed using a Coolermetrics carbon dioxide analyzer. Silica and major metal components were extracted using borate fusion and analyzed using DC Plasma. X-ray diffraction (XRD), in conjunction with the chemical analyses, was used for mineral identification as well as for determination of the approximate modal composition.

Static Test Procedures

Standard Acid-Base Accounting, Modified Acid-Base Accounting, and the B. C. Research Initial Tests were conducted using the methods of Sobek et al. (1978), Lawrence (1990), and

Duncan and Bruynesteyn (1979), respectively. The Net Acid Production Test (Coastech Research Inc., 1989) was modified to use a stronger peroxide solution and to incorporate recent advancements by O'Shay et al. (1990). To a 1.00 g mine waste sample (80% minus 200 mesh) 100 mL of hydrogen peroxide (at least 30% v/v with distilled) was added incrementally (since the reaction of hydrogen peroxide and sulphide can be violent), and the mixture was heated to near boiling for one hour. If the peroxide was depleted after one hour, 50 mL of peroxide was added and heated for 30 minutes. The flask was cooled for 10 to 15 minutes and 1 mL of 0.0157 M copper solution was added and the mixture was boiled for 10 minutes. The solids were removed by filtration and washed with 1 M $CaCl_2$. A sample of the filtrate was then titrated to pH 7.0. Four samples were analyzed for sulphur before and after the NAP test (RK-4, TL-1, TL-3, TL-6).

RESULTS AND DISCUSSION

Chemical and mineralogical analyses indicated the samples displayed fair degree of compositional diversity. The sulphur content of the ten mine waste samples ranged from 0.46 to 5.81 percent, and from 88 to 99 percent of the sulphur was present as sulphide (Table 1). Pyrite was the predominant iron sulphide in all samples except RK-2, TL-3, and TL-6, in which pyrrhotite dominated. The calcium carbonate and magnesium carbonate mineral content of the samples ranged from trace amounts to a maximum of 4.6 percent. Siderite was also present in measurable amounts in four of the samples (Table 2). Quartz, feldspar, and mica were the major host rock minerals in all samples except TL-6.

The NAP Test was evaluated based on

1)   qualitative comparison of predictions by the NAP Test with those by the standard ABA, Modified ABA, and B. C. Research Initial Tests on whether or not a mine waste sample would produce acidic drainage,

2)   quantitative comparison of Net NP values determined by the NAP Test with those determined by the other three static tests and the Net NP determined based on sample composition, and

3)   qualitative comparison of Net NP values with mineralogical analyses of the samples tested.

Static test prediction of whether or not a mine waste will produce acidic drainage can be based on the Net NP determined by the test. Steffen, Robertson and Kirsten (B.C.) Inc. et al. (1989) indicated that "based on general experience, values of Net NP in the range (between) -20 and +20 tonnes of $CaCO_3/10001$ of sample (-2 to +2% $CaCO_3$) may be considered to have the ability to generate net acidity." It was further noted by Ferguson (1989) that there was poor agreement among static tests on the acid generating character of samples with Net NP values in this range. To simplify data presentation, Net NP values in this range will be referred to as inconclusive. Values below -20 kg $CaCO_3/t$ imply the sample is acid producing, while values

Table 1. Chemical analysis for sulphur, carbonate, and major components in mine waste samples.

	S_{TOT}	SO_4-S	S^{-2}-S	CO_2	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	Na_2O	SiO_2
RK-1	0.46	0.04	0.42	0.11	15.20	0.51	6.27	3.24	3.61	1.19	60.50
RK-2	0.64	0.01	0.63	0.03	17.20	7.79	14.52	0.61	7.90	2.59	45.73
RK-3	1.63	0.03	1.60	1.41	12.80	0.28	4.59	5.84	0.53	0.10	69.30
RK-4	2.91	0.09	2.82	1.42	11.10	1.27	5.67	5.46	1.57	0.06	66.40
TL-1	0.96	0.06	0.90	0.87	11.30	2.05	2.87	5.98	1.47	1.35	69.80
TL-2	1.49	0.04	1.45	0.80	9.91	1.66	4.17	4.53	1.11	0.34	74.98
TL-3	2.19	0.07	2.12	4.06	5.28	1.60	21.94	0.95	4.13	0.19	56.65
TL-4	2.30	0.20	2.10	0.25	14.40	0.35	4.12	4.84	0.67	0.29	68.80
TL-5	5.05	0.20	4.85	0.65	13.60	0.33	7.35	6.70	0.78	1.84	62.40
TL-6	5.81	0.63	5.18	2.01	4.59	14.90	22.30	1.31	4.92	0.27	47.60

Concentrations in Percent

Table 2. Mineral content in weight percent.

	RK-1[1]	RK-2[2]	RK-3	RK-4[3]	TL-1	TL-2[4]	TL-3	TL-4	TL-5	TL-6[5]
Pyrite	0.74	-	2.43	5.16	1.58	2.60	1.08	3.68	8.17	1.93
Marcasite	0.02	-	-	0.16	-	0.08	-	-	0.95	-
Pyrrhotite	0.03	0.64	-	-	-	-	4.30	-	-	10.92
Calcite	?[6]	0.1	0.5	-	1.5	0.7	0.2	0.6	-	4.6
Dolomite	?	-	-	3.0	0.4	0.8	-	-	1.10	-
Ankerite	-	-	-	-	-	-	1.9	-	-	-
Siderite	0.3	-	3.2	-	-	0.2	8.3	-	-	-
Quartz	24	-	41	34	38	53	42	45	21	12
Feldspar	24	54	29	29	39	30	12	13	52	5
Mica	6	4	12	4	14	10	10	30	10	2
Chlorite	14	2	2	2	1	-	14	-	-	-
Kaolinite	2	-	8?	2	-	-	-	6	6?	-

[1] RK-1 also contains 29 % clay (probably montmorillonite) and <1% iron oxides/ilmenite.

[2] RK-2 also contained 4 % amphibole, 18 % pyroxene, 11 % olivine, <1% serpentine, and 4 % iron oxides/ilmenite.

[3] RK-4 also contained 19 % clay (probably montmorillonite).

[4] Trace amounts of copper carbonates were noted in TL-2.

[5] TL-6 contained 3 % amphibole and 55 % pyroxene.

[6] "?" indicates the mineral was probably present but not positively indentified by XRD.

above -20 kg $CaCO_3$/t imply the sample will not produce acidic drainage. These values are not endorsed, but rather used as a tool for data presentation.

For ease of comparison with other tests, the APP determined by the NAP Test was expressed as the equivalent Net NP, using the relationship NAP Net NP = -Net AP. This conversion is not entirely correct. The dissolution of acid-neutralizing minerals may be largely limited by the amount of acid generated as a result of iron sulphide mineral oxidation. If a sample contains an excess of acid-neutralizing minerals, the fraction of these minerals which do not dissolve will not be accounted for. Thus, the NAP is subject to underestimating the amount of acid-neutralizing minerals present in samples in which they are present in excess of the iron sulphide minerals (i.e. samples with a high Net NP). No samples with elevated Net NP values were tested in this study.

For quantitative comparison of NAP results with those from the other static tests, the NAP Net NP was compared with the average values from the standard ABA, Modified ABA and B. C. Initial Tests. This average is not recommended for mine waste evaluation and was used only to simplify data presentation.

The Net NP was also calculated using the mineralogical composition of the samples. The capacity for acid production (mineralogical APP) was calculated based on the sulphur associated with iron sulphide minerals, jarosite, and melanterite. The mineralogical NP was calculated as the sum of calcium carbonate and magnesium carbonate content. It was assumed that the calcium carbonate and magnesium carbonate present in the mine waste samples (Table 2), and only these minerals, would neutralize acid and maintain pH above an environmentally acceptable level of pH 6.0. The mineralogical Net NP was calculated as the difference between the mineralogic NP and mineralogic APP.

QUALITATIVE COMPARISON WITH OTHER STATIC TESTS

The acidic drainage predictions by the NAP Test were generally in good agreement with the other static tests (Table 3). The NAP results agreed with all three of the other static test methods on the acid producing character of eight of the samples (RK-1, RK-2, RK-3, RK-4, TL-1, TL-4, TL-5, TL-6). Three of the samples for which agreement was universal (RK-1, RK-2, TL-1) were classified as "inconclusive", based on Net NP (all tests) values of -14 to +18 kg $CaCO_3$/t. The remaining five samples for which agreement was universal (RK-3, RK-4, TL-4, TL-5, TL-6) were classified as acid producing. The Net NP values (all tests) for these five samples in the range of -147 to -39 kg $CaCO_3$/t, with the exception of one value of -22 kg $CaCO_3$/t (B. C. Initial Net NP for RK-3). The mineralogic Net NP values were in agreement with the classification of all eight samples.

Table 3. Comparison of Net NP values.

Sample	Net NP in kg $CaCO_3$/t				
	NAP[1]	ABA[2]	MOD ABA[3]	B.C.Initial[4]	Mineralogy[5]
RK1	-7.7	-5.7	0.8	-14	-8.8
RK2	5.1	8.5	18	-10	-14
RK3	-39*	-40*	-40*	-22*	-48*
RK4	-103*	-81*	-71*	-57*	-67*
TL1	0.0	-6.2	3.3	-1.8	-5
TL2	-14	-29*	-20	-17	-24*
TL3	-2.6	-26*	-1.7	-20	-44*
TL4	-71*	-66*	-58*	-49*	-55*
TL5	-86*	-147*	-140*	-120*	-131*
TL6	-59*	-84*	-78*	-103*	-136*

[1] Modification described in this paper.
[2] Method of Sobek et al. (1978).
[3] Method of Lawrence (1990).
[4] Method of Duncan and Bruynesteyn (1979).
[5] APP based on sulfide sulfur plus acid generating sulfate mineral content,
     NP based on calcium carbonate plus magnesium carbonate content,
*   values marked with an asterisk classified as acid producing

For the two samples on which agreement was not universal (TL-2, TL-3), all static tests except the standard ABA classified the samples as "inconclusive", based on Net NP values of -20 to -1.7 kg $CaCO_3$/t. The standard ABA predicted samples TL-2 and TL-3 would produce acid based on Net NP values of -29 and -26 kg $CaCO_3$/t, respectively. The standard ABA prediction was consistent with the mineralogic Net NP values for these two samples, which were -24 and -44 kg $CaCO_3$/t, respectively.

QUANTITATIVE COMPARISON WITH OTHER STATIC TEST RESULTS

Although the NAP Net NP was often higher than the other Net NP values, the disparity was not generally large (Table 3 and Figure 1). Indeed, the NAP values more closely approximated those from the standard ABA and Modified ABA than reported by Coastech Research Inc. (1989). Modifications of the previous method, such as the greater dosage of hydrogen peroxide and longer reaction time, may have contributed to this improved agreement. The modified method used sequential doses of 100 mL and 50 mL of hydrogen peroxide (30% strength) per gram waste, and allowed 90 minutes of reaction. The previous method used 100 mL of 15% hydrogen peroxide with a five gram sample of waste, and allowed a reaction time of either five minutes or one hour (Coastech Research Inc., 1989). In addition, the $CaCl_2$ rinse of the solids in the modified method may have released additional acid from the solids and, thereby, improved the accuracy of the technique.
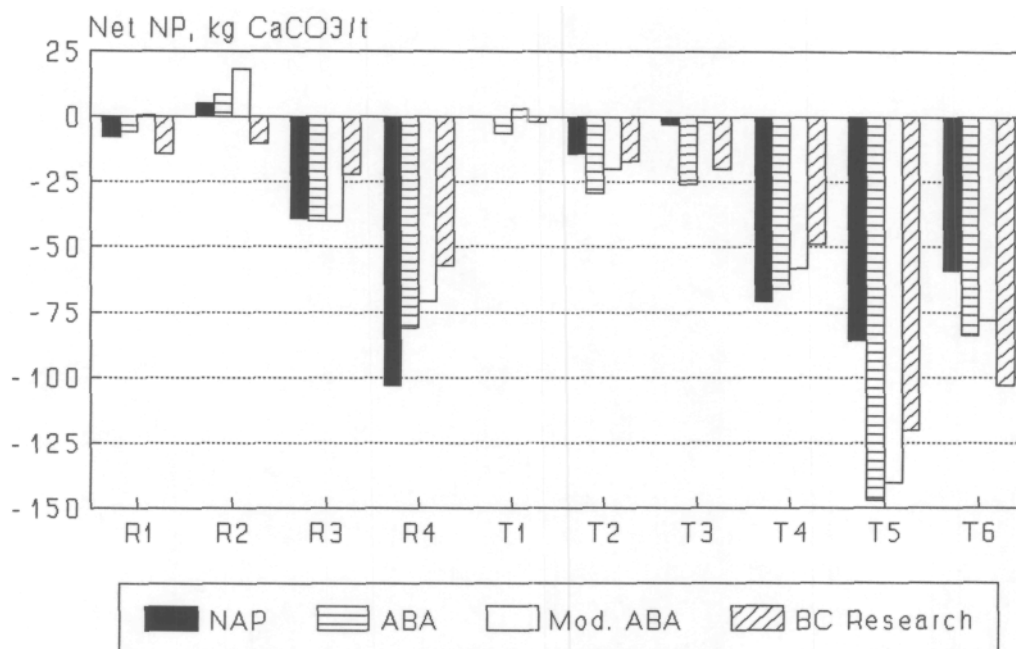
Fig. 1 Comparison of Net NP values from NAP test with other static tests

The average of the standard ABA, Modified ABA, and B. C. Research Initial Net NP values ranged from a high of 5.5 kg CaCO₃/t (RK-2) to a low of -136 kg CaCO₃/t (TL-5). For the three samples with the lowest sulphur content and Net NP values (RK-1, RK-2, TL-1), the Net NP values for the NAP Test were very close to those of the other tests. For these samples the NAP value ranged from 2.5 kg CaCO₃/t below the mean of the other three values to 1.6 kg CaCO₃/t above this mean.

As the average Net NP values (standard ABA, Modified ABA, B. C. Research Initial) decreased from -16 to -136 kg CaCO₃/t, the disparity with the Net NP values generally increased (Figure 1). With the exception of sample RK-4, the most disparate NAP Net NP values (TL-5, TL-6) were higher than the average of the values from the other three tests (Figure 1). Similar trends were observed when the NAP Net NP was compared to Net NP values determined based on sample composition (Figure 2).

The elevated NAP values for samples TL5 and TL6 (and to a lesser degree, RK-2 and TL-3) suggest that for these samples the acid production in the NAP was less than the APP values for the other static tests, or the acid consumption in the NAP test exceeded the NP of the static tests. Incomplete oxidation could lead to underestimation of APP and a resultant NP elevation for samples TL5 and TL6. Samples TL5 and TL6 had the highest sulphur contents, 5.0% and 5.8%, respectively. Sulphur analyses of four samples, before and after the peroxide

oxidation, indicated that the fraction of sulphur oxidized decreased as sulphur content increased (Table 4). Nonetheless, even for TL6 (5.84% S) over 95% of the sulphur present was oxidized.
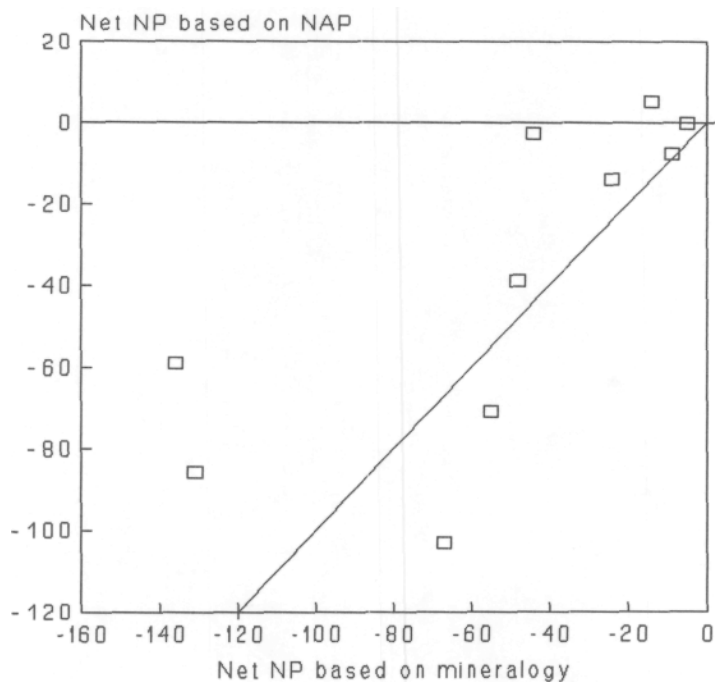

Fig 2. Comparison of NAP and Mineralogic Net NP values

If the residual sulphur occurred as an acid-producing mineral, such as pyrite or pyrrhotite, theactual APP of the sample would be about *5%* less than the true value. This deviation would not account for the discrepancies observed in the Net NP values observed.

Table 4. Extent of sulfide oxidation in the NAP Test

Sample	Head Percent	Residue Percent	Percent Oxidized
RK4	3.48	0.07	98
TL1	1.06	0.01	99
TL3	2.30	0.04	98
TL6	5.84	0.27	95

Incomplete oxidation of the sulphide to a soluble product with an oxidation state less than +4 could have resulted in an underestimation of acid production. Oxidation of sulphide to an oxidation state less than +4 neutralizes acid. For example, oxidation of one mole of sulphide to elemental sulphur neutralizes two moles of acid. However, when sulphide is oxidized to sulphate there is no net acid consumption or production.

Incomplete oxidation of ferrous iron released from iron sulphides would also lead to underestimation of the APP. If ferrous iron were not oxidized during the test and subsequent titration, it would remain in solution and not contribute to the measured acid production. However, over a longer time frame, the ferrous iron would oxidize and ferric hydroxide would precipitate, with a consequent generation of acid. Thus, ferrous iron in solution will produce acid which would not be measured by the NAP Test. This seems more probable than incomplete oxidation of sulphide since the rate of ferrous iron oxidation would be inhibited by the acidic conditions produced in the test.

Excessive dissolution of mine waste components other than calcium carbonate and magnesium carbonate probably neutralized acid during the hydrogen peroxide oxidation of some samples. Such acid neutralization would overestimate the actual NP available to neutralize drainage and, consequently, result in an unrealistically high NAP Net NP. The potential for such dissolution increases as the solution pH decreases and the content of minerals susceptible to such dissolution increases. Solution pH in turn decreases, as the difference between the acid-producing and acid-consuming mineral content (mineralogic Net NP) increases.

Excessive dissolution of silicate minerals most likely contributed to elevated NAP Net NP values for TL5 and TL6. These samples had the highest mineralogic Net NP (difference between acid-producing and acid-consuming minerals content) of the samples examined and, therefore, produced solutions more acidic than other samples during the hydrogen peroxide oxidation. As a result, host rock components were subjected a highly acidic solution, in addition to elevated temperatures, for one to two hours during the NAP Test. Such conditions were conducive to dissolution of minerals other than carbonates and consequent acid neutralization. TL-5 had the highest plagioclase content of the samples and TL-6 had the highest pyroxene content (Table 2). The dissolution of these minerals, and the attendant acid neutralization, was probably accelerated under the test conditions. Excessive feldspar dissolution may have also contributed to the lesser degree of Net NP elevation for sample RK-2, which had a feldspar content similar to that of TL-5 but a sulphur content of only 0.64 percent.

Incomplete oxidation of ferrous iron released from iron carbonate minerals (siderite, ankerite) may have contributed excess acid neutralization by sample TL-3 (mineralogic Net NP = -44 kg $CaCO_3$/t), which had the highest iron carbonate content of the samples examined (8.7 weight percent). It is likely that some iron carbonate dissolved during the test, due in part to the attack by the acid generated, with an attendant neutralization of acid. If the ferrous iron released were not oxidized during the hydrogen peroxide oxidation or the subsequent titration, the iron carbonate dissolution would neutralize acid. Under oxidizing conditions in the environment the ferrous iron released would oxidize to ferric iron which would precipitate as ferric hydroxide. Thus, the dissolution of iron carbonate and subsequent reactions would provide no net acid neutralization.

It is important to note that the NAP Net NP of samples RK-4 and TL-4 was lower than the mineralogic Net NP and for sample RK-3 the NAP Net NP was only slightly higher than the mineralogic Net NP. The mineralogic Net NP values for these three samples ranged from -48 to -67 kg $CaCO_3$/t, suggesting that conditions during the hydrogen peroxide oxidation should have been fairly acidic. Nonetheless, the NAP Net NP values indicated little, if any, excessive acid neutralization by minerals other than those containing calcium carbonate or magnesium carbonate. The combined quartz, mica, and clay (chlorite, kaolinite, montmorillonite) content of these samples ranged from roughly 60 to 80 percent (Table 2). The NAP Net NP values indicate that these minerals did not dissolve extensively, with attendant acid neutralization, despite the aggressive nature of the solution generated during the hydrogen peroxide oxidation.

The extremely low Net NP value determined for sample RK4 is most unusual. The NAP Test determined a Net NP of -103 kg $CaCO_3$/t of this sample. However, the maximum acid production based on the sulphur content of this sample (2.9 percent) is 91 kg $CaCO_3$/t. This discrepancy is difficult to explain other than by error introduced in sample splitting.

APPLICATION OF THE NAP TEST

The NAP Test has been proposed as a static test which could be applied in the field. The results for these ten samples suggest that although predictions by the NAP Test are reasonably consistent with those of other static tests, application of the NAP Test in the field requires several precautions.

First, the NAP Test is subject to the same limitations as other static tests. That is, it does not determine the availability of acid-producing and acid-consuming minerals nor their relative rates of reaction. These limitations are of particular concern in predicting if waste rock will produce acidic drainage. These concerns can be addressed qualitatively by determining the mode of occurrence of iron sulphide, calcium carbonate, and magnesium carbonate mineral in individual rock units contributing to mine waste. Kinetic tests will provide a more quantitative determination of availability and relative reaction rates, and must be conducted on particle sizes which reflect the sulphide and carbonate mineral occurrence in the mine waste.

Second, the NAP Test often overestimates the Net NP by amounts dependent upon the sample composition. The potential for overestimation increases as the mineralogic Net NP decreases below zero. The potential overestimation also increases with the content of minerals which dissolve under conditions of the test, but will not maintain a neutral drainage in the field. This potential error can be reduced by subjecting a series of well-characterized samples from rock units of concern to the NAP Test. The results from this testing will quantify the error in Net NP and provide a means of calibrating subsequent measurements on samples from the rock unit.

Furthermore, sources of error in the NAP Test may be reduced by additional procedural modifications. Results from the present test indicated close to 100 percent oxidation of the iron sulphides present in the samples examined. The excess acid neutralized by silicate mineral dissolution may be reduced by maintaining lower reaction temperatures or higher solution pH

values during the test. The latter objective may be attainable by adding hydrogen peroxide in smaller doses, although the overall extent of iron sulphide oxidation may be affected by such an approach. In addition, potential Net NP elevation due to ferrous iron in solution could be examined. If such interference were verified it could be addressed by titrating to a higher endpoint pH or increasing the time required to determine endpoint stabilization.

SUMMARY

A modification of the Net Acid Production Test compared favourably with the Net NP values determined by the standard ABA, Modified ABA, and B.C. Research Initial Test predictions for ten samples containing an excess of iron sulphide minerals relative to calcium and magnesium carbonate minerals. The NAP prediction of whether or not acid would be produced was generally in good agreement with the aforementioned static tests. Disagreement was observed for two samples which the standard ABA classified as acid producing based on Net NP values of -29 and -26 kg $CaCO_3$/t. The remaining tests classified acid production potential as inconclusive based on values in the range of -20 to +20 kg $CaCO_3$/t. Thus, the NAP predictions were not noticeably different from those by the other static tests.

Solids analyses indicated 95 to 99 percent of the sulphur initially present was oxidized during the test. Nonetheless, the Net NP values determined by the NAP Tests were typically higher than those determined by the other static tests and by solid phase analyses. Apparently the elevated Net NP values were the result of excessive attack of host rock minerals during the hydrogen peroxide digestion. Samples with high mineralogic Net NP were more prone to such dissolution since more acidic conditions would be produced during the hydrogen peroxide digestion of these solids. Feldspars and pyroxenes were apparently susceptible to such dissolution. Incomplete oxidation of ferrous iron released from iron carbonate minerals may have further contributed to elevated Net NP values.

The study described herein reports results from a small set of samples and examination of a wider set of samples is required to establish greater confidence in the NAP Test . However, suitability of the test for laboratory and field use is indicated and has the significant advantage over other static tests in not requiring analysis of total sulphur or sulphur species. The test does not apparently allow identification of samples with an excess of NP relative to APP. This, however does not preclude using the test qualitatively in the field for decisions on waste placement. Caution should be exercised in using the results of the NAP test quantitatively as results tend to indicate higher Net NP values than values based on mineralogy. The discrepancy of equivalent Net NP values from those of standard ABA or other static tests increases with increasing sulphur content. Again, however, as a qualitative field test, the margin of error is likely to be acceptable.

Further work is in progress on a larger sample group to define further the NAP Test conditions and limitations to allow greater confidence, accuracy and reproducibility in its use.

ACKNOWLEDGEMENTS

REFERENCES

Coastech Research Inc. 1989. Investigation of prediction techniques for acid mine drainage. MEND Project 1.16.1 a. Canada Centre for Mineral and Energy Technology, Energy, Mines and Resources Canada. 61 pp. plus appendices.

Duncan, D.W., Bruynesteyn, A. 1979. Determination of acid production potential of waste materials. Met. Soc AIME, paper A-79-29. 10 pp.

Ferguson, K. 1989. Personal communication, Keith Ferguson, Vancouver, British Columbia.

Finkelman, R.B. and Giffin, D.E. 1986. Hydrogen peroxide oxidation: an improved method for rapidly assessing acid-generating potential of sediments and sedimentary rocks. Reclamation and Revegetation Research, 5. p. 521-34.

Lawrence, R.W. 1990. Prediction of the behaviour of mining and processing wastes in the environment. In Proc. Western Regional Symposium on Mining and Mineral Processing Wastes, F. Doyle (ed.), Soc. for Mining, Metallurgy, and Exploration, Inc., Littleton, CO. P. 115-121.

Miller, S.D., Jeffery, J.J., Murray, G.S.C. 1990. Identification and management of acid generating mine wastes - Procedures and practices in South-east Asia and the Pacific Regions. In Acid Mine Drainage Designing for Closure, J.W. Gadsby, J.A. Malick, SJ. Day eds. BiTech Publishers Ltd., Vancouver, British Columbia, p. 1-11.

Miller, S.D., Jeffrey, J.J., Wong, J.W.C. 1991. In-pit identification and management of acid forming waste rock at the Golden Cross Mine, New Zealand. Proc. 2nd International Conference on the Abatement of Acidic Drainage, Montreal, Sept 16-18, 137-151, MEND, Canada.

Mirza, A.H., Herrera, M.N., Doyle, P.M. 1992. Characterization of pyrite-bearing minerals by chemical oxidation. In Emerging Process Technologies. Proc. 121st SME Annual Meeting and Exhibit. S. Chandar, P.E. Richardson, eds. Soc. for Mining, Metallurgy, and Exploration, Inc., Littleton, CO. p. 121-129.

O'Shay, T.O., Hossner, L.R., Dixon, J.B. 1990. A modified hydrogen peroxide oxidation method for determination of potential acidity in pyritic overburden. J. Environ. Qual. 19. p. 778-782.

Sobek, A.A., Schuller, W.A., Freeman, J.R., Smith, R.M. 1978. Field and laboratory methods applicable to overburden and minesoils. EPA 600/2-78-054. 203 pp.

Steffen, Robertson and Kirsten (B.C.) Inc., Norecol Environmental Consultants, Gormely Process Engineering. 1989. Draft Acid Rock Drainage Technical Guide. British Columbia Acid Mine Drainage Task Force, Vancouver, B. C.