Internet Case Study #10:

Comparison of NAG Results to ABA Results for the Prediction of Acidic Drainage

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Introduction

The "Wheel" (Figure 1) represents the current state-of-the-art approach for predictions of drainage chemistry, including pH and metal concentrations, that is being used at many minesites around the world (Morin and Hutt, 1997a). The intent behind the Wheel is that each test is conducted and compared to the results from the others. Any significant discrepancy between predictions from two tests indicates some critical information is still missing. Thus these redundancies among the tests in the Wheel minimize the errors in prediction. Nevertheless, there is still opportunity for significant error when one test, like laboratory humidity cells, provide unique information that cannot be confirmed by another test (Morin and Hutt, 1998). In this case, special care is required in testing and interpretation. Human misinterpretation remains the major cause of predictive errors (Morin and Hutt, 1997b and 1998).

As explained on pages 178 and 179 of Morin and Hutt (1997a), there is a popular static test often called the "NAG" (Net Acid Generation) Test (e.g., Miller et al., 1994 and 1997; Miller, 1996 and 1998). This NAG Test uses hydrogen peroxide to enormously accelerate sulphide oxidation with the assumption that neutralization-potential (NP) dissolution remains proportional. The procedure was developed more than 20 years ago as a method for measuring sulphide content (Sobek et al., 1978), but its interpretation changed over the last decade to estimating net acid generation. The NAG test is popular in Australasia and in some countries in South America. In Australia, 20% of responding coal, base-metal, precious-metal, mineral-sands, and iron minesites indicated they had conducted both NAG and acid-base accounting

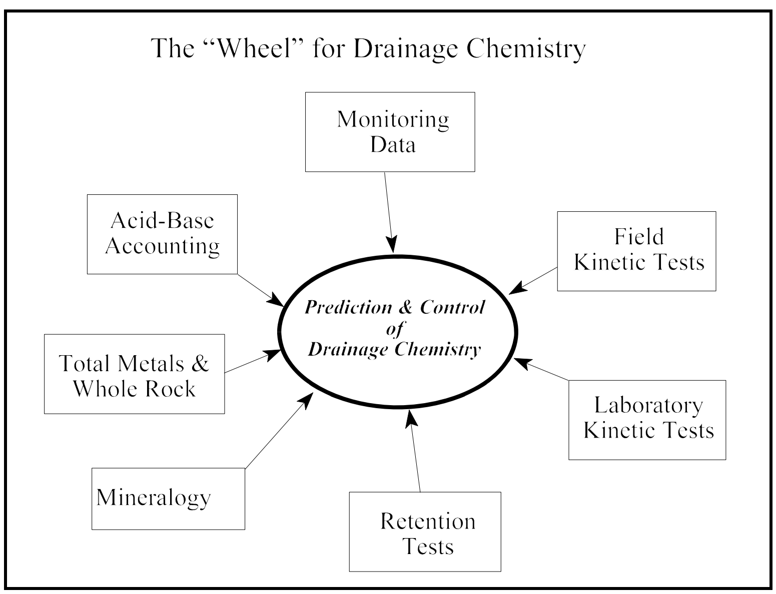

FIGURE 1. The "Wheel" Approach for Predicting Minesite-Drainage Chemistry.

(ABA), 20% had conducted ABA without NAG, and less than 1% had conducted NAG only (based on total responses in Harries, 1997).

The NAG Test can be valuable as an quantitative indicator of (1) the amount of measured sulphide that can oxidize and (2) one-half of the net-acid-generation prediction. In other words, the NAG Test provides numerical estimates of net acid generation, but just a “no” answer if a sample is non-net-acid-generating (net-acid-neutralizing). Thus there is no estimate of NP or Net Neutralization Potential (NNP), as acid-base accounting provides.

In general, the weaknesses of the NAG Test are not critical if it is integrated into the Wheel approach (Figure 2), because the redundancies minimize its inherent errors. Also, it brings additional redundancies, such as checks on negative values of NNP. However, the NAG Test has not been fully integrated into the Wheel in the past. There are some minesites which have conducted extensive NAG testing, along with some ABA and kinetic tests, and then failed to reconcile the discrepancies among these tests. There are also a few minesites that have used NAG Tests almost exclusively, which has led to serious problems. For example, at one minesite, some net-acid-generating material was mistakenly buried in non-net-acid-generating material, and a small acidic seep appeared. The critical question was whether the acidic seep would consume the NP around it, becoming larger and in effect create more net-acid-generating material. This could not be answered, because NP had never been measured.

Because of these issues, it is important that the NAG Test is fully integrated into the Wheel (Figure 2). Although this requires additional time and costs, several minesites are now doing it. As a result, within a few years, the strengths and weaknesses of the NAG test will be better understood and it will make valuable contributions to predictions of drainage chemistry under the Wheel.

This month’s MDAG Internet Case Study presents some initial results in this effort to integrate the NAG Test with the Wheel. Specifically, we discuss the internal consistency of NAG results and we compare NAG results to ABA results. This provides some initial understanding of NAG’s strengths and weaknesses.

There are two basic forms of NAG testing: (1) the unmonitored (or static) NAG Test which yields a final pH and a NAG value in some units of H_2SO_4 per weight of sample and (2) the monitored (or kinetic) NAG Test which measures these values as well as temperature

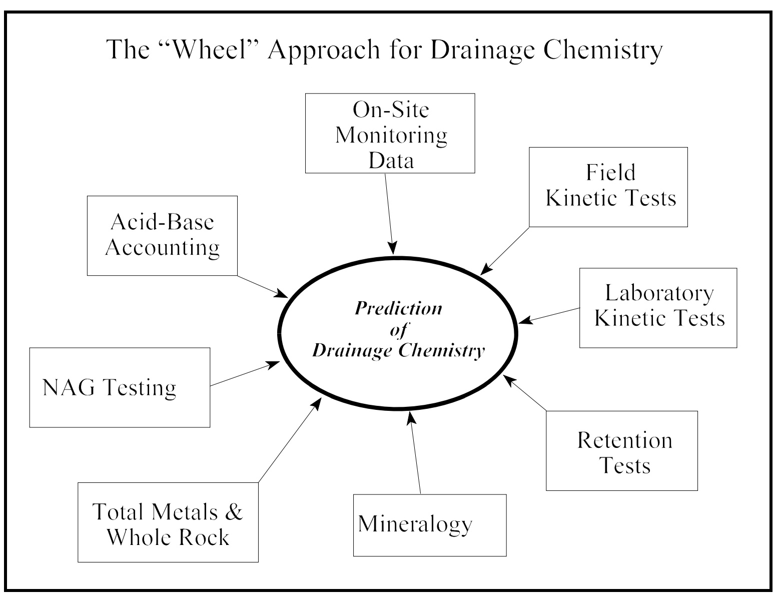

FIGURE 2. The Revised “Wheel” Approach for Predicting Minesite-Drainage Chemistry, Including NAG Testing.

throughout the test period. The monitored NAG Test can provide an estimate of on-site lag time to net acidity, but the critical information is the final pH and NAG value as in the unmonitored test. Again, these tests do not provide an estimate of net-acid-neutralizing capacity.

Predictive criteria have been developed for the final NAG pH and NAG value (Table 1). Interestingly, in the absence of other Wheel tests (Figure 2), ABA is typically given an "uncertain" range due to site-specific factors, whereas the NAG Test has no inherent "uncertain" range (Table 1). Uncertainty in NAG Tests can reportedly only arise through a comparison with one other test, ABA, although such uncertainty is rarely resolved and the NAG results often prevail without question.

Also, the NAG Criteria of Miller (1998) in Table 1 do not recognize the concept of analytical detection limit, which means that a less-than NAG value is still greater than zero and thus still potentially net acid generating. Many laboratories prefer to report less-than values instead of zero, and this leads to interpretive problems as shown below. Finally, the NAG Criteria of Table 1 employ a pH of 4.5, which implicitly means that the pH of the starting hydrogen-peroxide solution must also be very close to 4.5 or the criteria are inappropriate.

TABLE 1
Predictive Criteria for NAG Testing (based on Miller, 1998)

NAG Prediction	Detailed Prediction	Final NAG pH	NAG Value (t H_2SO_4/1000 t)
Potentially net acid generating	High Capacity	< 4.5	> 5[1]
	Low Capacity	< 4.5	0-5[1]
Potentially non net acid generating and potentially net acid neutralizing		≥ 4.5	0
Uncertain		any disagreement between the above NAG predictions and the ABA prediction	

[1] The value of 5 can range up to 10 depending on site-specific factors

Internal Consistency of NAG Testing

One objective of this case study is to examine the internal consistency of NAG results. This is based on the comparison of NAG pH to the NAG value. As indicated in Table 1, any NAG value greater than zero must have a NAG pH less than or equal to 4.5, because no disagreement is allowed for. Figure 3 shows these comparisons for three minesites.

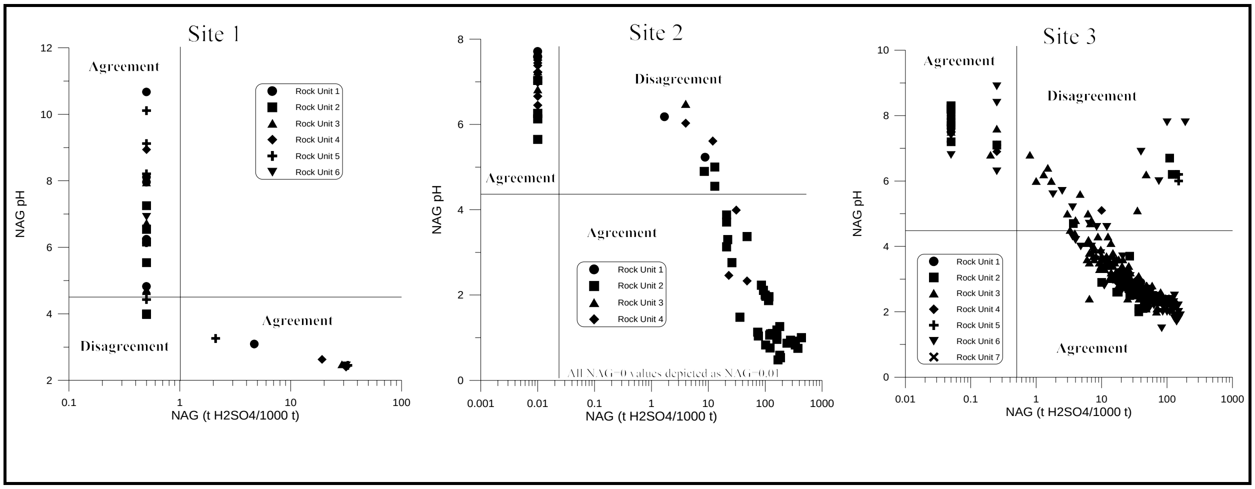

FIGURE 3. Comparison of NAG pH and NAG Value at Three Sites as a Check on the Internal Consistency of NAG Testing.

The laboratories for Sites 1 and 3 did not report any zero values for NAG values, only less than their detection limits. This creates problems under Table 1 because all samples for Sites 1 and 3 have positive NAG values and are thus potentially net acid generating, while in reality the less-than values are probably zero. To reconcile this and to minimize errors in internal consistency, the zero criteria in Table 1 are adjusted here to less than detection limit. For Sites 1 and 3, less-than-detection values are plotted in Figure 3 as one-half the detection limit.

Based on the adjustment of zero to the detection limit, the internal discrepancies are minimized, but there are still discrepancies for all three sites. The error for Site 1 is that NAG pH (<4.5) predicts net acid generation for some samples, whereas the NAG value (<1 t H_2SO_4/1000 t) predicts non net acid generation. The error is reversed for Sites 2 and 3, with the NAG value predicting net acid generation in contrast to NAG pH. Overall, the errors for the three sites are 10%, 13%, and 8% of all samples, for an average of 10% of samples having internal inconsistency under NAG testing. The causes of these errors could be related to factors like mineralogy, but they have not yet been identified and resolved under the Wheel (Figure 2).

Another approach for examining consistency is duplicate analyses for NAG pH and NAG, which is apparently rare. Nevertheless, when such duplicates exist (Figure 4), they show that NAG pH can be in error up to 0.5 pH units, which affects the strict pH 4.5 criteria of Table 1, and that NAG values can frequently be in error by at least 25% and up to a factor of two. Thus it would be prudent to develop an “uncertain” range within NAG criteria (Table 1) that at least reflects analytical uncertainty and variability.

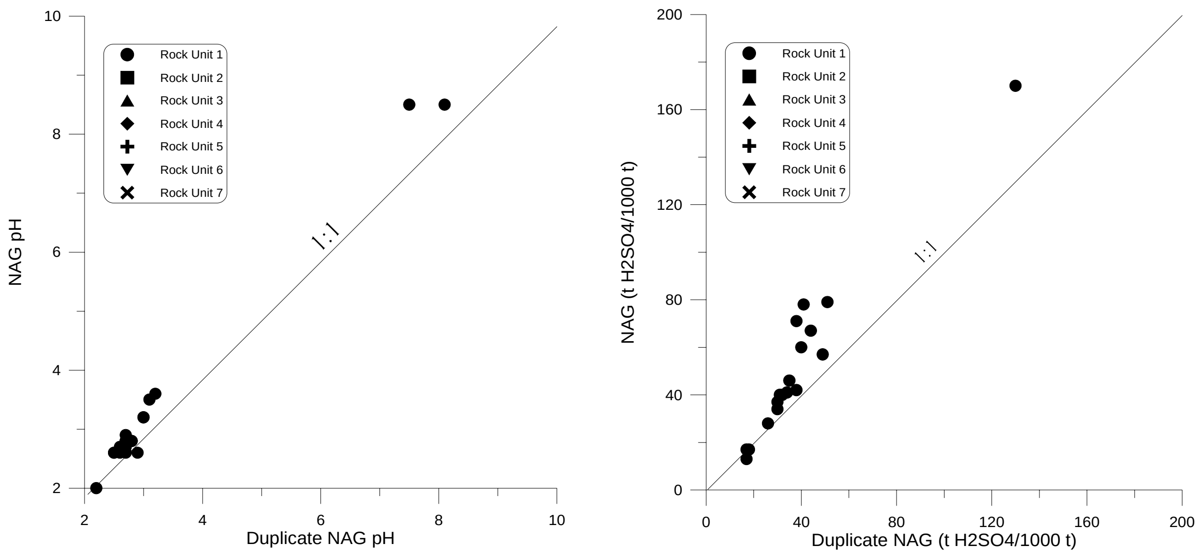

FIGURE 4. Quality-Control Comparison of NAG-Test Results to Duplicate Results for Site 2.

Comparisons of NAG Predictions with ABA Predictions

The NAG Tests from three minesites discussed in the previous subsection also corresponding acid-base accounting (ABA) analyses, allowing the comparison of NAG predictions to ABA predictions. Site 1 had 30 such samples; Site 2 had 63; and Site 3 had 249. Only Site 3 is discussed below, and a summary for all three minesites follows.

Site 3

Site 3 has 249 samples with both ABA and NAG results. A comparison of SNNP (=NP-SAP) from ABA to NAG results (Figure 5) shows that 3% (NAG value) to 8% (NAG pH) of samples have contradictory predictions, with SNNP providing more net-acid-generating predictions. The uncertain range of 0 to +20 t/1000 t in SNNP has little effect on these percentages.

With SNPR (=NP/SAP) from ABA, again 3% (NAG value) to 8% (NAG pH) of samples have contradictory predictions, with SNPR providing more net-acid-generating predictions (Figure 6). The uncertain range in SNPR has only a small effect on these percentages, in agreement with SNNP above.

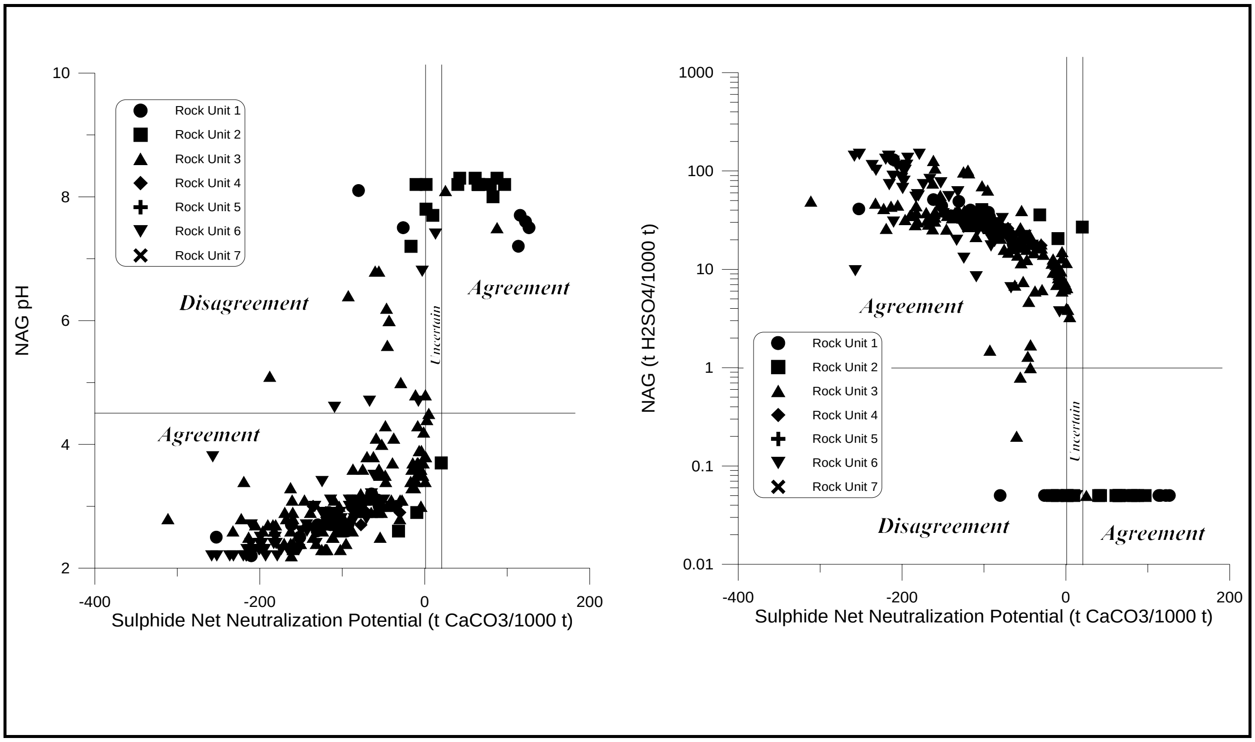

FIGURE 5. Comparison of SNNP (=NP-SAP) from ABA to NAG-Test Results for Site 3.

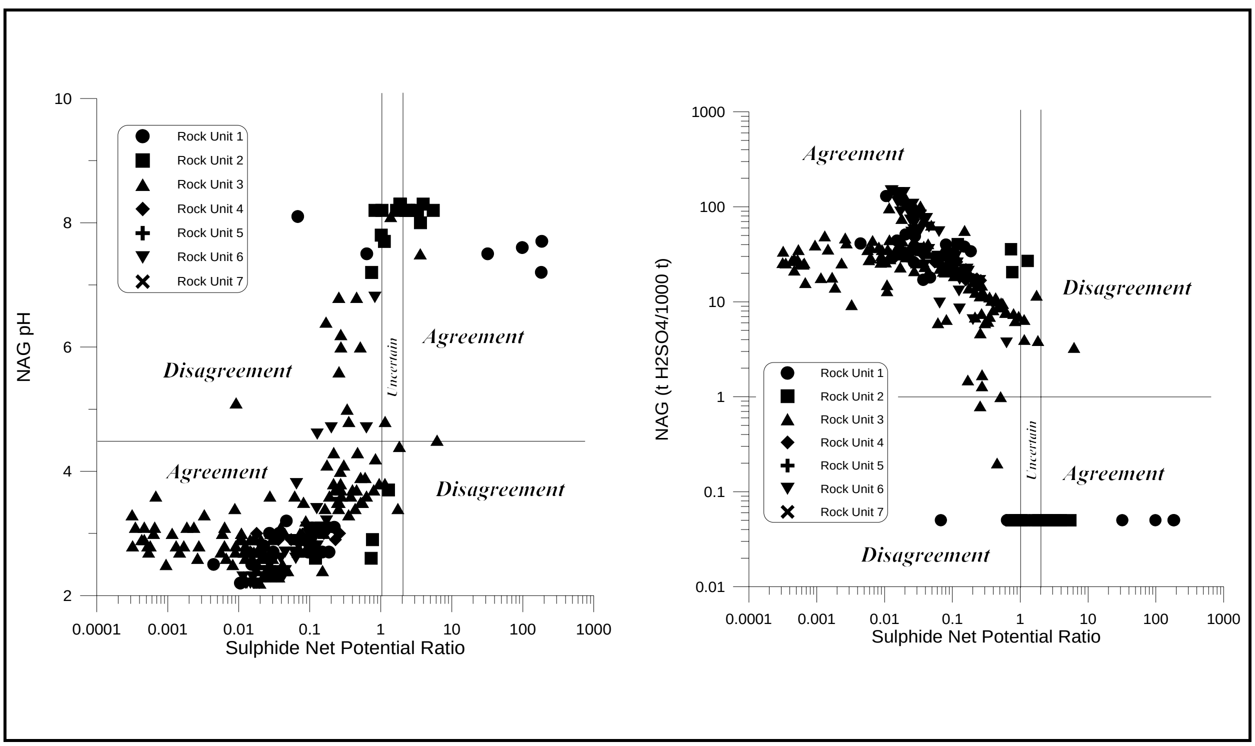

FIGURE 6. Comparison of SNPR (=NP/SAP) from ABA to NAG-Test Results for Site 3.

Summary

As an initial step in integrating the NAG Test into the Wheel approach for drainage-chemistry predictions (Figure 2), the results of NAG tests at three minesites were checked for internal consistency and were also compared to corresponding ABA analyses. The number of samples from each minesite ranged from 30 to 249.

To check internal consistency, predictions based on NAG pH were compared to those based on the corresponding NAG value, showing that on average 10% of samples at the three minesites had contradictory predictions. Also, duplicate analyses of NAG pH indicated that pH values could vary up to 0.5 pH units. Duplicate NAG values frequently differed by at least 25% and up to a factor of two. These observations indicate an "uncertain" range should be incorporated into standard NAG criteria, as is typical of universal ABA criteria.

The comparison of NAG results to ABA results for the three minesites typically showed contradictory predictions for 3% to 14% of samples, depending on the NAG parameter (NAG pH or NAG value) and the ABA parameter (TNNP/SNNP or TNPR/SNPR). Contradictory predictions were particularly high for Site 1 (25% of samples), even after adjustment for low-sulphur, low-NP samples. The number of samples with contradictory predictions for Site 2 were sensitive to the TNPR criterion due to the number of samples in this range. Kinetic testing under the Wheel (Figure 2) indicated the criterion for Site 2 was approximately 1.5, leading to the delineation of contradictory predictions from NAG Tests.

This work has shown that discrepancies within NAG Tests and compared to ABA will often be around 5-15% of the samples, highlighting the general uncertainty in NAG predictions. The causes of these discrepancies are not known, but should be identified so that the NAG Test becomes an integral part of the Wheel approach for drainage-chemistry predictions.

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