THE INTERNATIONAL STATIC DATABASE (ISD)

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Abstract

The International Static Database (ISD) has grown from the recognition that valuable lessons can be learned from compiling geochemical static-test data from many minesites around the world. At this time, the ISD contains more than 20,800 static-test analyses, primarily acid-base accounting, from 126 minesites.

Some of the most valuable observations and conclusions in the ISD come from simple comparisons of one parameter against another. For example, the assumption that low sulphur samples cannot produce net acidity has been found to be incorrect. Samples with very low sulphur contents (< 0.05%) were found which produced an acidic paste pH # 5.0. Also, sulphur content can span over 4 orders of magnitude for almost any value of paste pH.

Criteria for sulphide-based Net Neutralization Potential and Net Potential Ratio, above which material would not be predicted as net acid generating (SNNP = +20 t $CaCO_3$ equivalent/1000 t and SNPR = 2.0), were found to be generally reliable ($99.5% and $98.0%, respectively, of samples correctly classified). One explanation for the occasional failure of criteria is unavailable neutralization potential (UNP), which is commonly 10 t $CaCO_3$ /1000 t or less. However, UNP can reach almost 100 t/1000 t in rare circumstances, highlighting the error in assuming that all measured NP is available for neutralization.

Key Words: International Static Database, acid rock drainage, ARD, acid-mine drainage, acid-base accounting, ABA

Introduction

The prediction of environmental problems such as acid rock drainage (ARD) at mining operations requires a variety of techniques and analytical procedures. Within the mining industry it has been generally accepted that an integrated or "wheel" approach[1,2,3,4] should be taken to reliably predict ARD and metal leaching. This "wheel" includes various static tests, including acid-base accounting (ABA) which is the focus of this paper.

An expanded ABA test typically includes analysis for total sulphur, sulphide sulphur, acid-leachable sulphate sulphur, neutralization potential (NP), total carbon, carbonate carbon, paste pH and, depending on the sample type, rinse pH. The analyses for the sulphur species generally follow a procedure outlined in an EPA document developed by Sobek et al. in 1978[5]. On the other hand, NP analysis has been the focus of many papers over the past 15 years[6,7,8], with several researchers discussing different methods. Additionally, ABA also consists of a series of calculated parameters such as carbonate neutralization potential (CaNP), net neutralization potential (NNP) and net potential ratio (NPR). This paper does not address the pros and cons of these parameters and methods but examines the results as a whole.

Since ABA testing has been so widely used for such a long period of time, assumptions have been made and accepted as to what information ABA results can provide. For example, criteria have been established for various ABA parameters which define whether there is potential for ARD at a minesite. These criteria have then been applied to other minesites and assumed correct without additional testing (such as analyses from the "wheel" including kinetic testing, mineralogy, NAG, and soluble constituent testing) to verify their accuracy.

This paper looks at some of the commonly accepted criteria, or myths, applied to ABA data. A massive compilation of ABA data known as the International Static Database (ISD)[9] containing more than 20,800 samples from 126 minesites around the world (Table 1) is used to test their general validity.

Table 1. Data currently available in the International Static Database (ISD)

Parameter	Type	No. of Values
Total Number of Samples	-	20806
Number of Minesites	-	126
Paste pH	Measured	12885
Total Sulphur (%)	Measured	19833
Sulphide Sulphur (%)	Measured	6801
Sulphate Sulphur (%)	Measured	6500
Total Acid Potential (t $CaCO_3$/1000 t)	Calculated	19833
Sulphide Acid Potential (t $CaCO_3$/1000 t)	Calculated	6801
Neutralization Potential (NP) (t $CaCO_3$/1000 t)	Measured	19095
Total Carbon (%)	Measured	3972
Carbonate Carbon (%)	Measured	982
Carbonate Neutralization Potential (CaNP) (t $CaCO_3$/1000 t)[1]	Calculated	4941
Total Net Neutralization Potential (TNNP) (t $CaCO_3$/1000 t)	Calculated	18851
Sulphide Net Neutralization Potential (SNNP) (t $CaCO_3$/1000 t)	Calculated	6797
Carbonate Net Neutralization Potential (CNNP) (t $CaCO_3$/1000 t)	Calculated	4920
Refined Net Neutralization Potential (RNNP) (t $CaCO_3$/1000 t)	Calculated	3332
Total Net Potential Ratio	Calculated	18851
Sulphide Net Potential Ratio	Calculated	6797
Carbonate Net Potential Ratio	Calculated	4920
Refined Net Potential Ratio	Calculated	3332

[1] CaNP calculated using carbonate carbon, but total carbon was used if carbonate was not available.

It is recognized by the authors that many factors can affect whether minesite materials are considered potentially acid generating. For example, rock and material types, sampling site (which minesite component the sample was taken from), age of the sample, site location and regulatory criteria can all play key roles in an ARD assessment. The authors also realize that there are differences in the quality of the data depending on the laboratory doing the analyses and methods they use. These and others factors are not addressed in this paper, so the data contained in the ISD is simply being used here to generally test certain well established criteria.

Generally Accepted Criteria

Several criteria based on ABA analyses have been applied industry-wide to determine ARD potential at minesites around the world (Table 2).

Table 2. ABA criteria for predicting ARD potential.

Criterion No.	ABA Parameter	Criteria	Prediction
1	Paste pH	# 6.0	Acid generating
		# 5.0	Acid generating
2	% S (Sulphide) or % S (Total)	# 0.3	Not potentially acid generating
		# 0.05	Not potentially acid generating
3	NNP[1]	< -20[1]	Potentially acid generating
		> +20[1]	Not potentially acid generating
		Between -20[1] and +20[1]	Uncertain range
4	NPR[2]	< 1.0	Potentially acid generating
		> 2.0	Not potentially acid generating
		Between 1.0 and 2.0	Uncertain range

[1] Net Neutralization Potential = Neutralization Potential (NP) - Acid Potential (AP); units of t $CaCO_3$ equivalent per 1000 t of material.

[2] Net Potential Ratio = NP / AP; dimensionless

Criterion 1: Paste pH

The first step in predicting whether minesite materials have the potential to generate net acidity is to determine exactly what defines acidic material. This criterion is generally set by regulatory agencies governing the minesite's activities. The decision to use a pH of 6.0 may be based on downstream aquatic impacts, whereas using a pH of 5.0 may be based on aqueous chemistry. For example, a regulatory agency may choose a pH criterion of 6.0, even though rain water generally has a pH below 6.0 and thus any unimpacted rain water running off the minesite at pH 5.3 would be labelled ARD. For this reason, in most cases, a criterion of 5.0 may often be more appropriate.

At some minesites, the difference of one pH unit in the assigned criterion can significantly change the volume of material that is declared net acid generating, in turn affecting waste management or remedial actions. Within the ISD there are 12885 paste pH measurements, and 7% have values # 5.0 while 14% have values # 6.0. Although these percentages are relatively low, twice as many samples are considered acidic at pH 6.0 than at pH 5.0. Doubling the percentage of acidic rock at larger minesites could mean special management for hundreds of millions of tonnes of additional rock.

Criterion 2: Sulphur Content

There is sometimes an assumption that only high sulphur samples will produce net acidity. The ISD provides 12685 samples with both total sulphur and paste pH data and indicates that acidic pHs can be obtained at total sulphur contents spanning 4 orders of magnitude (Fig. 1). A similar observation is made for sulphide sulphur (Fig. 2).

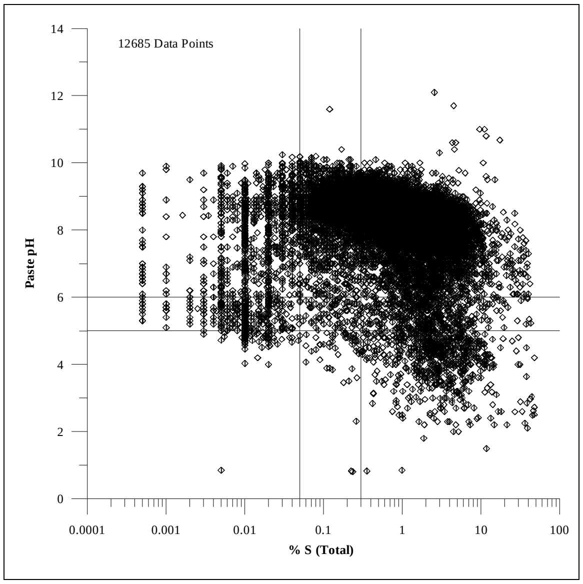

Fig. 1. Total Sulphur vs Paste pH.

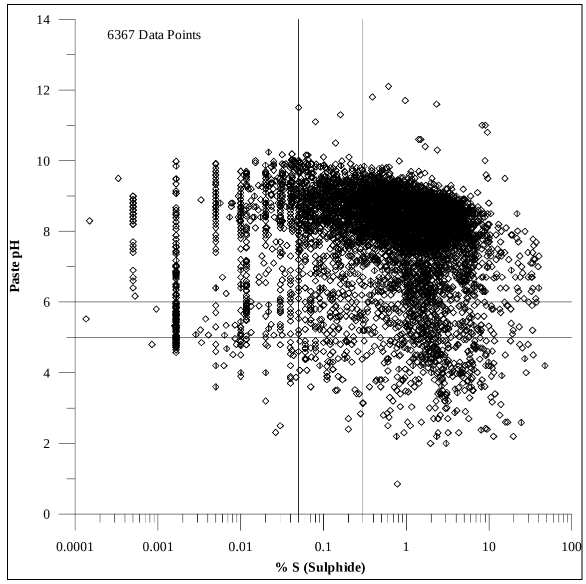

Fig. 2. Sulphide Sulphur vs Paste pH.

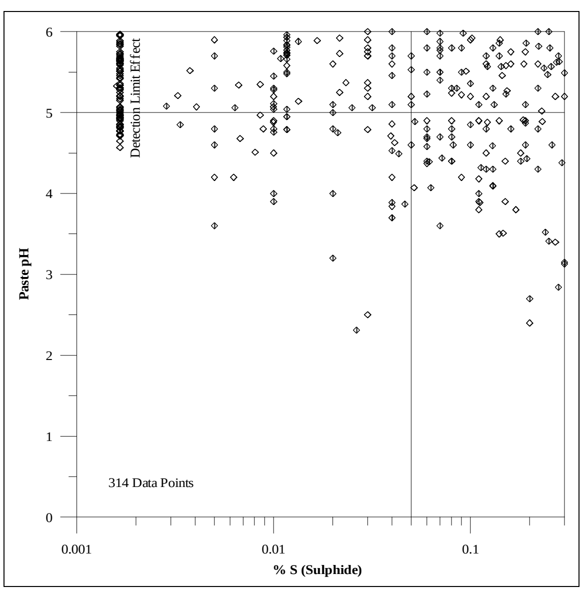

Fig. 3. Sulphide Sulphur vs Paste pH (Close-up).

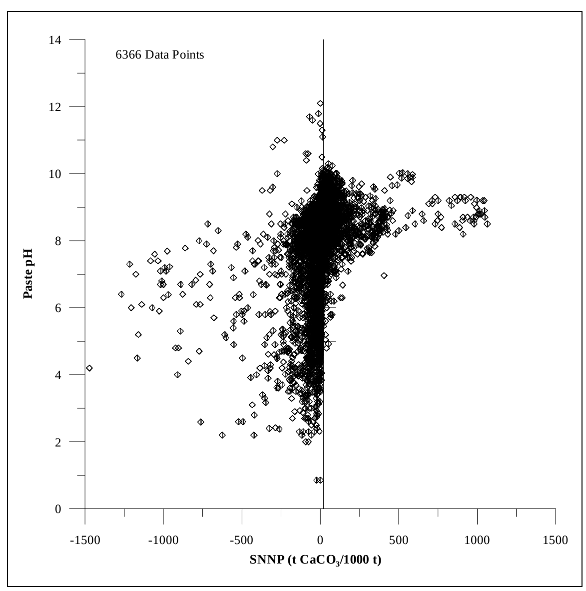

Fig. 4. SNNP vs Paste pH.

It has often been assumed that material with low sulphide sulphur contents, such as below 0.3% or 0.05% (Table 2), can not produce acidic paste pHs. In the past, the justification for using 0.3% seemed to be that no samples with < 0.3% sulphide sulphur were found with acidic paste pHs. The justification for using 0.05% was that the resulting acid potential of 1.5 t $CaCO_3$/1000 t was negligible and would not significantly affect pH.

Plots of sulphide sulphur against paste pH from the ISD (Figs. 2 and 3) show that for some samples neither cut-off criterion is correct. For a total of 6367 of samples with paste pH and sulphide sulphur measurements, 1% of the samples had a sulphide sulphur content # 0.05% with an acidic paste pH # 5.0, while 2% of samples had a sulphide sulphur content # 0.3% with an acidic paste pH # 5.0. For the paste pH # 6.0 criterion, 5% of the samples had a sulphide sulphur content # 0.3%, and 3% had a sulphide sulphur content # 0.05%. Based on this, there appears to be no minimum sulphide value above detection that is consistently associated with paste pH > 5 or > 6, and a sulphide criterion of 0.05%S would be generally reliable for $97% of samples at pH 6 and $99% of samples at pH 5.

Criterion 3: NNP Value

The calculated parameter of NNP (Table 2) has been used for a many years. In the ISD, 6366 samples had both paste pH and SNNP (sulphide-based net neutralization potential) values and they show that SNNP can span a wide range for most pH values (Fig. 4).

The criteria (Table 2) state that a sample with a NNP $ +20 t $CaCO_3$ eq./1000t should not produce net acidity. Based on the ISD, there are only 2 anomalous samples (0.1 % of samples in this range) with SNNP values greater +20 and paste pH # 5.0, whereas there are 10 anomalous samples (0.5 % of samples in this range) with paste pH # 6.0. Therefore, with $99.5% of samples currently showing no net acidity at SNNP $ +20 t $CaCO_3$ eq./1000t, this criterion is frequently reliable, but there are rare exceptions or errors and only an integrated study will identify such exceptions or errors at a minesite. Also, because fresh samples do not show net acidity during testing, some may turn acidic with time, so more exceptions may appear with increasing oxidation times.

In past studies, some have assumed that any NNP greater than 0 (zero), rather than +20, t $CaCO_3$ eq./1000t is not potentially net acid generating. So it is worthwhile to examine this older approach. In the ISD there are 3334 samples (52% of total SNNP data) with SNNP greater than 0. Of these, 17 samples (0.5 % of samples in this range) have a pH # 5.0, while 116 samples (3.5 % of samples in this range) have a pH # 6.0. This indicates that the criterion of 0 t $CaCO_3$ eq./1000t is not as reliable ($96.5% of samples correctly classified) as the criterion of +20 t $CaCO_3$ eq./1000t ($99.5%).

The ISD provides 2264 samples with SNNP values between -20 and +20 t $CaCO_3$ eq./1000t (Fig. 5), in the “uncertain” range (Table 2). There are 175 uncertain samples (7.7% of samples in this range) with paste pH # 5.0, and 437 samples (19 % of samples in this range) with paste pH # 6.0. Thus, 7.7-19% of uncertain samples turn out to be acidic, and these percentages would likely increase as fresh samples oxidized. If a narrower uncertain range of 0 to +20 is used, then only 1.2-8.5% of uncertain samples are acidic.

Some of the uncertainty in SNNP criteria may be related to the amount of unavailable NP[1] (UNP) that is measured but provides no significant neutralization of pH. A scatterplot of paste pH against NP highlights how a value of 10 t $CaCO_3$ eq./1000 t or less is common for UNP (Fig. 6). It also shows that UNP values can reach almost 100 t/1000 t in rare circumstances[10], demonstrating the error in assuming that all measured NP will be available for neutralization.

Criterion 4: NPR Value

The calculated parameter of NPR (Table 2) has come into more frequent use in the past 5-10 years. In the ISD, 6366 samples have both paste pH and SNPR (sulphide-based net potential ratio) data, with the SNPR spanning at least 4 orders of magnitude at any paste pH (Fig. 7).

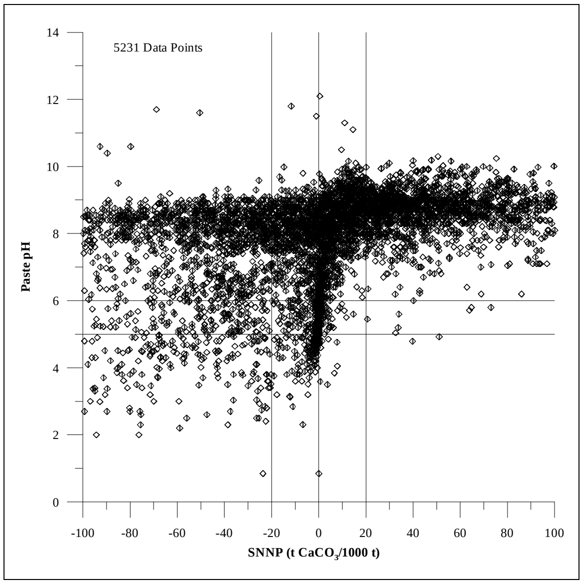

Fig 5. SNNP vs Paste pH (Close-up).

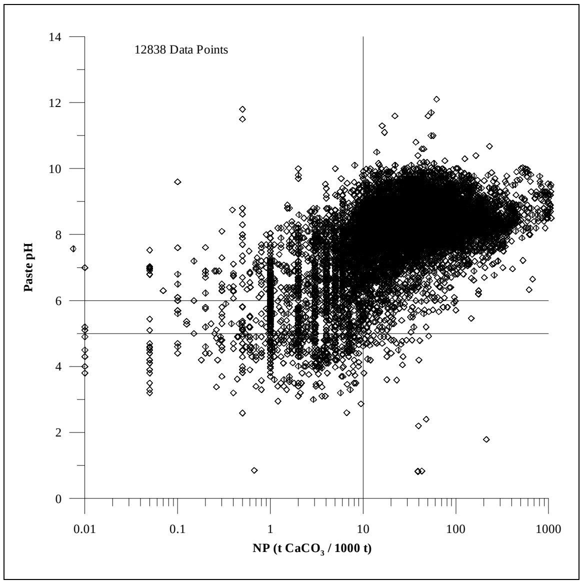

Fig. 6. NP vs Paste pH.

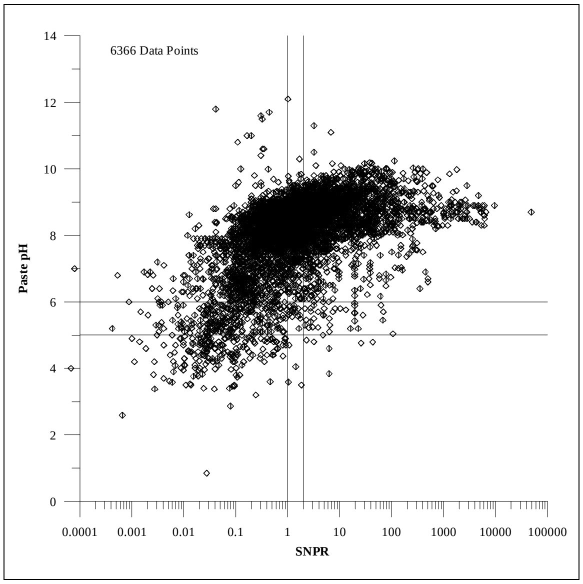

Fig. 7. SNPR vs Paste pH.

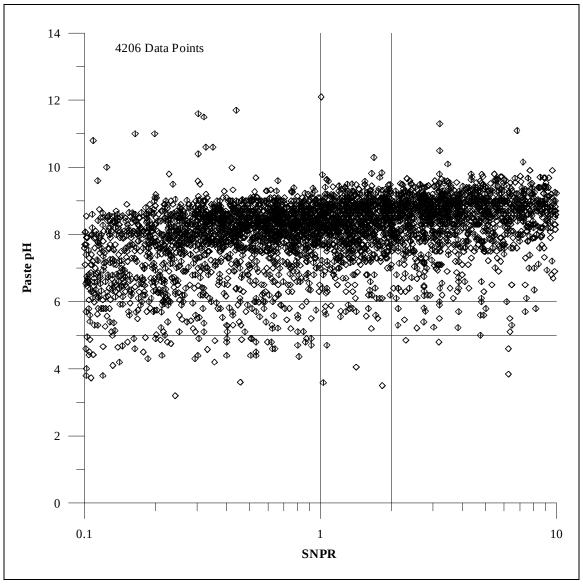

Fig. 8. SNPR vs Paste pH (Close-up).

A value of 2.0 has often been chosen as the criterion above which materials are considered not net acid generating (Table 2). One rationale for this comes from the observation that it requires up to two moles of $CaCO_3$ to fully neutralize one mole of acidity. Within the ISD, there are 7 samples (0.3 % of samples with SNPR $ 2.0) that produced net acidity at pH # 5.0, and 45 samples (2 % of samples with SNPR $ 2.0) that were acidic at pH # 6.0. Thus it is clear that there are several exceptions to the criterion.

Like NNP, there is an uncertain range for the NPR criteria, which is between 1.0 and 2.0 (Table 2). In the ISD, 836 samples are within this range (Fig. 8) and most of these samples were not (yet) acidic. However, 4 samples (0.5 % of uncertain samples) had pH # 5.0, while 20 samples (2.4 % of uncertain samples) had pH # 6.0. These percentages of 0.5-2.4% are generally lower than SNNP-based percentages of 1.2-19%, indicating the uncertain range for SNPR contains relatively fewer acidic samples, although percentages could increase after additional weathering time.

Conclusion

By using the large amount of data within the International Static Database (ISD), it was possible to generally assess the reliability of some criteria which have be established over the years to determine the ARD potential of minesite materials. After plotting total sulphur, sulphide sulphur, NP, SNNP, and SNPR data each against paste pH, the following conclusions can be drawn:

1) There are some exceptions to each criterion indicating that no one ABA parameter alone can reliably define a material's ARD potential. Although the reliability of some criteria are roughly 99%, their failure at one out of 100 minesites can represent many millions of dollars in environmental liabilities.

2) Although ABA provides valuable information regarding the ARD potential of minesite materials it is only one part of a complete integrated assessment and should not be used as a stand-alone test.

3) The assumption that low sulphur samples will not produce net acidity is incorrect. From the data contained within the ISD, samples with very low (# 0.05%) sulphur contents can still be acidic.

4) From data available in the ISD, a SNNP of +20 t $CaCO_3$/1000 t is generally reliable ($ 99.5%) as a criterion for non-net-acid generating materials. Within the "uncertain" range, up to 19% of samples were acidic. However, it should be noted that a sample that was not acidic at the time of testing may become so later, and thus site-specific verification of this criterion including kinetic testing is required.

5) From data available in the ISD, a SNPR of 2.0 seems to be generally reliable ($98.0%) as a criterion for non-net-acid generating materials. Within the "uncertain" range, up to 2.4% of samples were acidic. As with SNNP, it should be noted that a sample that was not acidic at the time of testing may become so later, and thus site-specific verification of this criterion including kinetic testing is required.

6) One reason why the criteria are not 100% reliable is unavailable NP (UNP), which is measured but does not actively neutralize acidity. UNP values # 10 t $CaCO_3$/1000 t are common in the ISD, but values up to nearly 100 are occasionally encountered.

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