

FROM THEORY TO PRACTICE Defining Effective Neutralization Potential for Acid Rock Drainage Characterization Studies

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Why this topic? NP is pretty straightforward, something that as geochemists we likely think about all day. Starting a few years ago, I started seeing comments come back from external reviewers about "effective" neutralization potential. I did a quick search when putting together this talk – was it just me? Scanned comments posted online for various provincial, territorial and federal reviews of geochemical characterization for mining projects... a few common threads where these turned up – some projects had low carbonate minerals, some projects had low sulphide mineral content... in general were all characterized by long predicted lag times to onset of acidity, and in many cases factors related to local environmental conditions were raised.

I have spent a lot of time untangling specifics of what makes NP effective on projects and how it related to mine waste management in operation and at closure. And I asked some friends – hence the acknowledgements – what their experience was, and again, there were some common threads. These are summarized in this talk.



And to that end, now I will also ask you – a little task to keep you awake and interested after last night's festivities... feel free during this talk or after to use this poll to provide your insights, references and methods. One of the supplementals that will be provided to this talk is the reference list that we have gathered over the years related to this topic.



Let's start at the beginning – a quick review of the basics related to neutralization potential. Both these methods I think are safe to say the most commonly used approaches in north America, well documented, and referenced by both the GARD Guide and MEND document 1.20.1

But the inherent challenge is that the interpretation of these results is effectively operationally defined – Sobek NPs contain the sum of all reactive NP and may result in an overestimation of the effective NP, whereas carbonate NP may in fact not include some silicate NP that becomes relevant in either low carbonate systems or systems with low sulphide oxidation rates



And this brings us to the inherent challenge of NP estimation – we tend to err on the side of overestimation of the effectiveness of NP to account for the risk of variability of NP between idealized lab conditions and in the field. However, at projects where carbonate is low and every gram of NP counts, eyebrows get raised when we start looking at these sources of NP that are small (in terms of quantity), but can still be significant in terms of buffering ability.



So, we were presented with a question – tell us about effective NP. And we began with the good book - MEND 1.20.1 offers the following definition of effective NP...

"acid neutralization that can neutralize internal and external acidity inputs sufficiently to maintain a near-neutral drainage pH"

i.e., alkalinity that is used before the onset of acidic conditions

Situations where your Lab NP might not be fully effective? Let's say that you have carbonate minerals that are for some reason occluded from reaction... you have sources of silicate mineral NP that are not reactive... or you have an abundance of a non-net neutralizing carbonate mineral like siderite.

But what about that case where you actually have more buffering potential than would be predicted by laboratory analyses?

Let's talk about one of those scenarios.



This is a case example from an unnamed site, thank you Client X.

The sample is an intrusive lithology which has undergone some level of propylitic alteration. There isn't a lot of carbonate in this sample. But there is sulphide. Any geochemist would look at this NPR and say the material will likely generate acidity.

But the question is how much and for how long. And in this case, we waited a long time for the sample to go acid – in fact, about 7.5 years in the lab.

Why did this sample take so long to react?



Mineralogy.

John Jambor and others wrote a series of papers in the early to late aughts that focused on defining the neutralization potential of individual minerals against standard references. While the sample in question doesn't contain an abundance of carbonates, it does in fact contain some of these minerals that contribute low levels of buffering capacity.

But what does this buffering capacity matter if it is non reactive and not available?



This plot is another helpful source that can be used to contextualize mineral reactivity, and again, I've included the references. The presence of some of these alteration phases that are known to be present in this sample are slow weathering, but can still contribute to effective NP.



How does the composition of Sample X measure up in terms of mineralogical neutralization potential? Well, as it turns out, the math maths... the estimated NP according to mineralogical content is pretty close to the estimated value from the Sobek measurements. Carbonate is a bit off, but this could be because of variability in the sample. Furthermore, what it tells us that our main mineral phases fall into that slow to very slow weathering category. Not a lot of surprises here. If we use the reactivity "correction factors" proposed by Lawrence and shesky and Karlsson, we are down to about half of the measured NP.



So, what's next? Let's take a look at sulphide reaction rates to estimate how much of that NP is effective. Again, looking to the definition in MEND 1.20.1, we took the opportunity to use the acid neutralization potential consumed in the sample before the onset of acidity.



From this we see that of the laboratory measured NP, only about 1/3 is effective. These values line up not unreasonably with the predicted NP using the reactive mineralogical method.

So – what's the story here? We have confirmed the sample has low NP, and this value makes sense. Why is it that it took almost 8 years to go acidic in the lab?



The real story here is that although the sample has low NP, and it appears to be slow reacting, the rate of sulphide mineral reaction is low. In fact, the sulphide reaction rates were low enough for the first 300-ish years of the test that the NP generated by the available NP was sufficient to buffer the sample. After about 7 years, the rate of sulphide reaction started to exceed the rate of NP depletion and we saw the onset of acidic conditions in the HCT.



Where does this take us? The elephant in the room is that we assume that all sulphide minerals are highly reactive and equally reactive, and that is not the case. One cannot consider effective NP in isolation – the effectiveness of the sulphide mineral reactions also needs to be considered in the quantification of effective NP.

This is a sample, not from the same site, but from a legacy waste rock pile. The mine wastes are likely about 40 years old. You can see that there a multiple generations of sulphide mineralization in this sample – fine grained, which has oxidized in the light red spots... but check out those cubes of pyrite – virtually unoxidized.



Let's be practical – not all projects can withstand 5 year plus waiting period for a sample to go acidic. In my information poll, the acid base characteristics curve test was mentioned as an effective tool to quantify effective neutralization potential.

This and the following figure are extracted from the referenced paper from Warwick Stewart and others... An example of an ABCC curve. This is a batch titration test Effective acid neutralisation, producing a gradual decrease in pH with acid added pH dropping rapidly below pH 4 once the equivalent total measured ANC capacity is consumed.

The curve closely corresponds to that of the dolomite standard, indicating that the carbonate in the sample is dolomitic, and readily available.



What this curve tells us -

curve drops sharply after ANC is consumed - some portion of the ANC appears to be of calcitic origin, resulting in the strong buffering in the early part of the test, but remainder of NP is from an alternate source

Slow rate of buffering - slow flushing rates and long residence time in the waste material would be required for the entire ANC to be effective.



Let's do a quick recap:

 Mineralogy is important and we know that there are some factors that can be quantified to come up with mineralogical correction factors for effective NP. Let's look at this idealized situation – every sample is going to comprise a mélange of NP, some is available, some is not net neutralizing, some may react slowly or not at all. This involves a hefty amount of quantification and best professional judgement.

Effective NP

•Measured NP: Bulk NP

LSNP (Long-term, slowly reacting NP): NP that is slow weathering BUT is able to sufficiently neutralize acidity in field conditions

Ineffective NP

nnNP = contained in non-net neutralizing minerals (e.g., siderite) **UNP (Unavailable NP): NP minerals that are physically** occluded minerals in field-scale, site conditions

IRNP (Insufficiently reactive NP): NP minerals that are unable to neutralize acidity at field rates



But what about the environmental effects, that are an additional layer of judgement. One needs to rely on lab tests that can take a considerable amount of time – again, can be years to decades – particularly if one is evaluating low temperature conditions.

In addition, there are issues related to particle size effects, how sorting can influence oxygen and water infiltration, local climate... vegetation.



Is there a magic approach? Is there a right approach?

Conceptualization of the site and the associated risks is critical to defining the approach. If acidification is a key decision point, then the most conservative path forward is likely to use carbonate NP. If lag time to onset of acidification is relevant, other forms of NP may be relevant – these can be assessed with a coupled mineralogical and kinetic testing approach. If site specific factors are of concern, you will need to go outside the box to look at custom designed tests to account for either mechanisms of source control or catalysts to buffering reactions. And lastly, and as becoming more relevant in the context of investigations related to long term stability of mining landforms, that combination of mineralogical assessment and targeted testing is necessary to evaluate stability in the range of proposed conditions.



