

# **Title (Times New Roman 13, Bold, Center at the Top of Page, Title Case, Style Title)**

William A. Price<sup>1</sup>, Ken Smith<sup>2</sup>, and John Doe<sup>3</sup> (Times New Roman 11, Normal, Center; Style Authors)

<sup>1</sup>Affiliation, city, province/state (2-letter abbreviation), country, and e-mail address

<sup>2</sup>Natural Resources Canada, Smithers, BC, Canada, e-mail address (Times New Roman 9, Normal, Center; Style Affiliations)

<sup>3</sup>University of Science, Syracuse, NY, USA, e-mail address

Note: Authors should be listed in order of contribution to the paper.

## **Abstract (Times New Roman 11, Bold, Left, Style Level 1 Heading)**

Please see p. 4 of this document for a mock paper formatted according to this template. The abstract (Times New Roman 11, Normal, Left, Style Text) should outline the information to be presented. It should not exceed 300 words.

Key Words: Up to six key words (Times New Roman 10, Normal, Left, Style Key Words) should follow the abstract after one blank line. Do not repeat words in the title: the title is already searchable.

## **Level 1 Heading (Times New Roman 11, Bold, Left, Title Case, Style Level 1 Heading)**

Title Case Capitalizes the First Letter of Major Words.

## **Level 2 heading (Times New Roman 11, Bold, Left, Sentence case, Style Level 2 Heading)**

Sentence case capitalizes only the first letter of first word.

## *Level 3 heading (Times New Roman 11, Italics, Left, Sentence case, Style Level 3 Heading)*

### **Body of Manuscript**

Text for the body of the manuscript should be in Times New Roman 11, Normal, Left (Style Text).

Paper orientation for all pages: portrait.

Margins for all pages: top/bottom/left/right: 2.5 cm (0.98 in)

A proper paragraph should have at least two sentences.

Use only italics or bold to highlight portions of text. Avoid underlining, because this crosses through the lower parts of letters, such as q, p, and g.

### **Spacing**

Line spacing: single throughout. No spaces before or after in paragraph spacing menu!

Leave one blank line (Style Text) after each paragraph. Do not indent paragraphs.

Leave one blank line (Style Title) after title, affiliations (Style Affiliations), abstract (Style Text), key words (Style Key Words), a figure caption (Style Text), and a table (Style Text).

Do not leave a blank line between authors or between affiliations.

Do not leave a blank line between a figure and its caption or between a table and its title.

### **Bullets**

In the paragraph before starting a bullet list, insert a colon at the end:

- Use level 1 (full circle) and level 2 (dash) bullets only.
- Bullet Level 1: Left indent 0.63 cm/0.25 in, hanging indent 0.63 cm/0.25 in (Style Bullet – Level 1)
  - Bullet Level 2: Left indent 1.27 cm/0.50 in, hanging indent 0.63 cm/0.25 in (Style Bullet – Level 2)

### **Numbered Bullet**

In the paragraph before starting a bullet list, insert a colon at the end:

1. Numbered bullet item 1: Left indent 0.63 cm/0.25 in, hanging indent 0.63 cm/0.25 in (Style Numbered Bullet)

2. Numbered bullet item 2
3. Numbered bullet item 3

**Figures (includes Illustrations, Graphs, and Photographs) and Tables**

Figures and tables should be centered (**Style Centered**) and positioned “in line with text.” To do this, select figure, format > position > In Line with Text.

Crop off excess white space around all sides of figures.

To fit within the margins of 2.5 cm (0.98 in), the maximum figure or table width is 6.69 in.

Number figures and tables sequentially from the beginning of the paper (Figure 1, Figure 2, Table 1, Table 2, etc.), and have a descriptive caption/title.

Place captions below figures (no blank line above caption) and titles above tables (no blank line below title). The caption title begins with “Figure 1.” and the table title begins with “Table 1.” The caption/title should be in Times New Roman 11, Normal, Centered (**Style Figure Caption/Table Title**). Captions/titles do not end with a period unless they are a sentence.

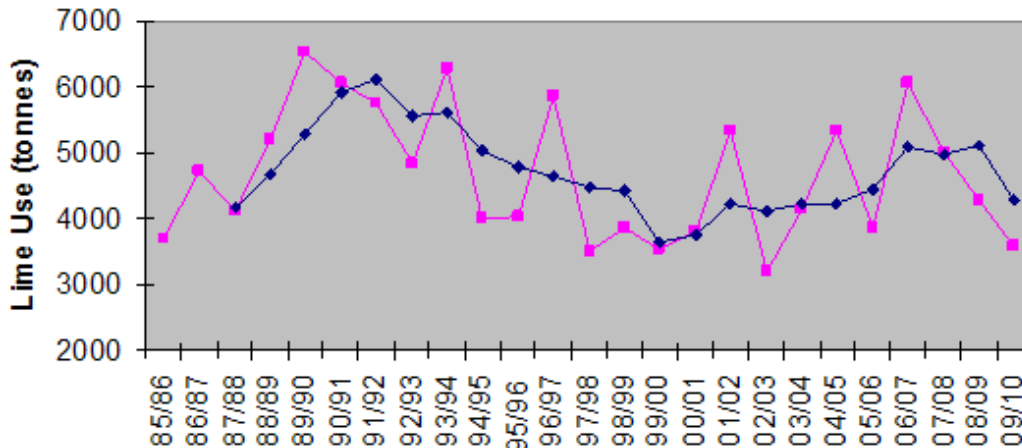


Figure 1. Annual and three-year rolling average July/June lime use

All figures and tables must be referenced in the text and be placed soon after they are first mentioned, preferably as the next paragraph, or at the top of the next page. It may be necessary to use a smaller font to get all data in a table to fit on a page, but do not use a font less than 10 pt. Consider dividing large tables into multiple tables.

Figures and tables may appear side-by-side on the page. The simplest way to do this is to insert the figures and tables in a two-column table with no borders. In this case, they should be the same height.

Figures and tables and their respective captions and titles must fit on a single page.

Figures can be in colour or black-and-white, but only figures of high quality will be accepted. Photographs should be given in the size of publication (1:1 ratio).

Tables must be created in Word, not pasted from another application (ie, they need to be editable). Use 10 or 11 pt Times New Roman font.

Remove frame lines from figures and legends when using figures from spreadsheet programs.

## Chemical Reactions and Mathematical Equations

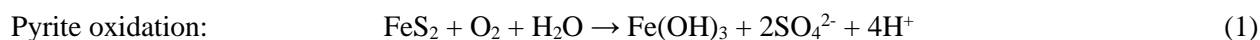
Chemical reactions and mathematical equations should be centered and numbered sequentially from the beginning of the paper.

Leave one blank line before and after a chemical reaction or an equation (Style Text).

Chemical reactions and mathematical equations should be numbered separately, with mathematical equations identified as such.

Reaction and equation numbers should be placed in parentheses at the right margin of the column:

$$bA^2 = cx \quad (\text{Equation 1})$$



## Acknowledgements Heading (Times New Roman 11, Bold, Left, Style Level 1 Heading)

Acknowledgement text should be in Times New Roman 10, Normal, Left. All acknowledgements, including those for funding sources, must be included at the end of the paper, immediately before the References section.

## References Heading (Times New Roman 11, Bold, Title Case, Style Level 1 Heading)

### In-text citations (this is an example of a level 2 heading)

Literature should be cited in text as Francis (1978) or (Francis 1978). Two-author citations should be cited as HacsKaylo and Gerdemann (1971) or (HacsKaylo and Gerdemann 1971). For more than two authors, use Vance et al. (1992) or (Vance et al. 1992).

List references alphabetically if multiple citations support a statement. Separate them with a semi-colon.

Do not number references in the text.

### Reference list (this is an example of a level 3 heading)

Do not number references in the reference list.

List references alphabetically by author surname, which is listed first, followed by author initials.

Individual references should be in Times New Roman 10, Normal, Left, 1.27 cm (0.5 in) hanging indent (Style References).

All references to publications cited in the text, figures, and tables must be listed in the reference list and vice-versa.

Check your text against the References section to ensure that all references are cited properly.

Paste your reference list into the free tool at <https://apps.crossref.org/simpleTextQuery> to obtain Digital Object Identifiers (DOIs) to insert at the end of each reference.

Below are some reference list formats.

### **Journal paper**

Authors (Year) Paper title. Journal Name (in full), volume number, page numbers (inclusive). DOI  
Antonovics, J., Bradshaw, A.D. and Turner, R.G. (1971) Heavy metal tolerance in plants. *Advances in Ecological Research*, Vol. 7, pp. 1-85. [https://doi.org/10.1016/S0065-2504\(08\)60202-0](https://doi.org/10.1016/S0065-2504(08)60202-0)

### **Chapter in Book**

Author(s) (Year) Chapter title. Book Title. Editor(s), publisher, city of publication, page numbers (inclusive)

### **Book**

Authors (Year) Book Title, Publisher, City of publication.  
Baker, R.W. (2004) *Membrane Technology and Applications*, 2nd edn, John Wiley & Sons Ltd., Chichester.

### **Proceedings paper**

Authors (year) Paper title. In, Proceedings Full Title, Editors (if noted), event date, city, and country.  
Kempton, H., Bloomfield, T.A., Limerick, P. and Hanson, J. (2009) Policy review for permitting and closure of new hardrock mines predicted to require perpetual environmental management. In, *Proceedings of the Securing the Future and Eighth International Conference on Acid Rock Drainage*, June 23-26, 2009, Skellefteå, Sweden.

### **Government report or paper**

Authors or Government Department (Year) Title of Document. Report number, Government Department, page(s).  
Sobek, A.A., Schuller, W.A., Freeman, J.R. and Smith, R.M. (1978) *Field and Laboratory Methods Applicable to Overburdens and Minesoils*. Report PB-280 495, U.S. National Technical Information Bureau, 403 p.

### **Document in a website**

Authors (Year document published or last revised) Title of document. Viewed date dd mm yyyy, <https://www.sitename.direct> link to the file  
Cowan, W.R., Mackasey, W.O. and Robertson, J.G.A. (2010) The policy framework in Canada for mine closure and management of long-term liabilities: A guidance document. Viewed 27 07 2011, <https://www.abandoned-mines.org/publications-e.html>

### **Acronyms**

List the acronyms used in your paper, except for those in Appendix 2, at the end of the paper in Times New Roman 10, Normal, Left (**Style Acronyms**).

# Acid Base Accounting Criteria Used in Prediction of Drainage Chemistry

William A. Price<sup>1</sup> and John Doe<sup>2</sup>

<sup>1</sup>Natural Resources Canada, Smithers, BC, CANADA, Bill.Price@nrcan.gc.ca

<sup>2</sup>University of Science, Syracuse, NY, USA, [JDoe@syracuse.edu](mailto:JDoe@syracuse.edu)

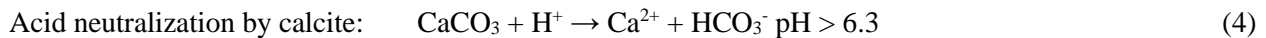
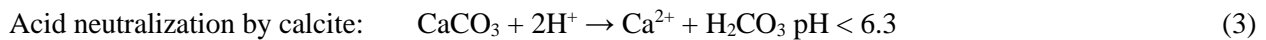
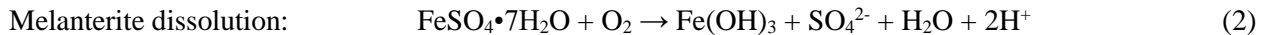
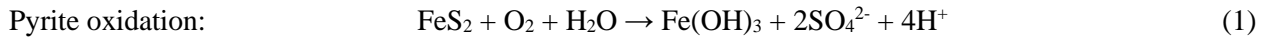
## Abstract

Acid Base Accounting (ABA) consists of a series of compositional analyses and calculations. ABA is used to guide decisions regarding the potential for acidic drainage and is a key component of sound environmental and fiscal management. Challenges include limitations of the analyses and calculations and the many parameters and processes potentially contributing to drainage pH. ABA analyses and criteria may enable cost effective prediction but users need to consider whether ABA results and predictions are compatible with the mineralogy, elemental concentrations, weathering rates, weathering and leaching conditions, and other inputs of acidity and alkalinity.

Key Words: acidic drainage, acid potential, prediction, neutralization potential ratio

## Introduction

The future potential for neutral or alkaline sulphidic geologic materials to produce acid rock drainage (ARD) if exposed to oxygen and water depends on the relative concentration and reaction rates of acid generating sulphur minerals or acid potential (AP) and neutralizing minerals or neutralization potential (NP). The relative magnitude of the NP and AP is indicated by the NP/AP or Neutralization Potential Ratio (NPR).



As illustrated in Figure 1, assuming the correct AP and NP, the future drainage pH is (Price 2009):

- potentially net acid generating (PAG) if NP/AP < 1
- not potentially net acid generating (non-PAG) if NP/AP > 2
- uncertain if NP/AP is between 1 and 2

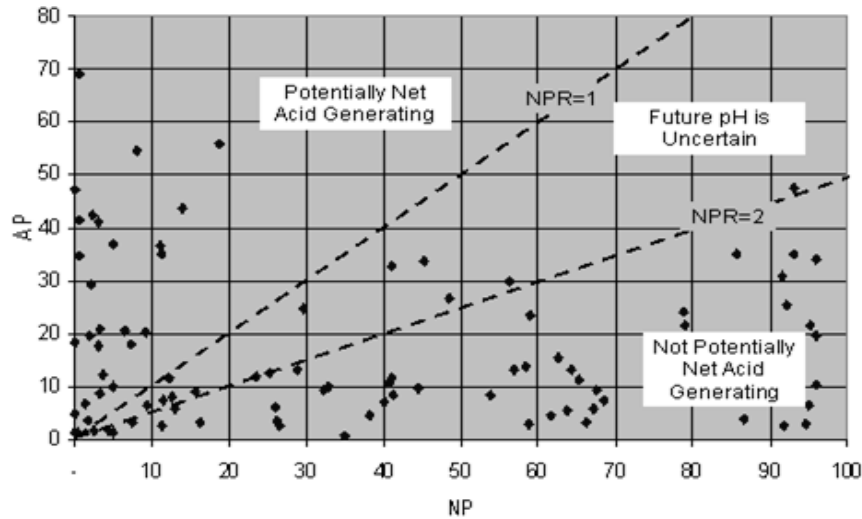


Figure 1. An example of AP versus NP data

Safety factors may need to be added to these criteria to address limitations in the precision or accuracy in sampling, material handling or prediction of the magnitude of the NP and AP. There are many possibilities for over or under estimating the AP and NP.

Preferential deposition of heavier sulphide minerals may result in a tailings beach with a higher AP than predicted from the analysis of tailings leaving a processing plant. The exposed AP of waste rock may be higher than predicted by analysis of pre-mine drill core or pre-blast hole chips, if sulphides preferentially report to waste rock fines (< 2 mm) (Table 1).

Table 1. AP and NP of > 2 mm and < 2 mm waste rock particle size fractions from a Cu mine

	> 2 mm	< 2 mm	< 2 / > 2 mm
AP (kg/t)	86	257	3.0
NP-Sobek (kg/t)	32	44	1.4

### Other Considerations

- Prediction of the ARD potential typically assumes oxidized, conditions.
- The question is not whether a sample generates acid (AP); most rock generates some acid, but whether it will become net acid because there is insufficient NP to neutralize the acid.
- The ARD potential between NPR 1 and 2 will depend on the fate of alkalinity ( $\text{HCO}_3^-$ ) produced by the  $\text{pH} > 6.3$  neutralization reaction (Reaction 4).
- Net Neutralization Potential (NNP) = NP-AP is additive rather than a ratio and cannot distinguish between materials with an NPR > 2 and an NPR 1 to 2 and is not recommended for characterizing the future potential for acidic drainage (Figure 2).
- Drainage chemistry prediction should be conducted if the NPR > 2 because contaminant concentrations at near-neutral or alkaline pH may still be above environmental guidelines (Stantec 2004).

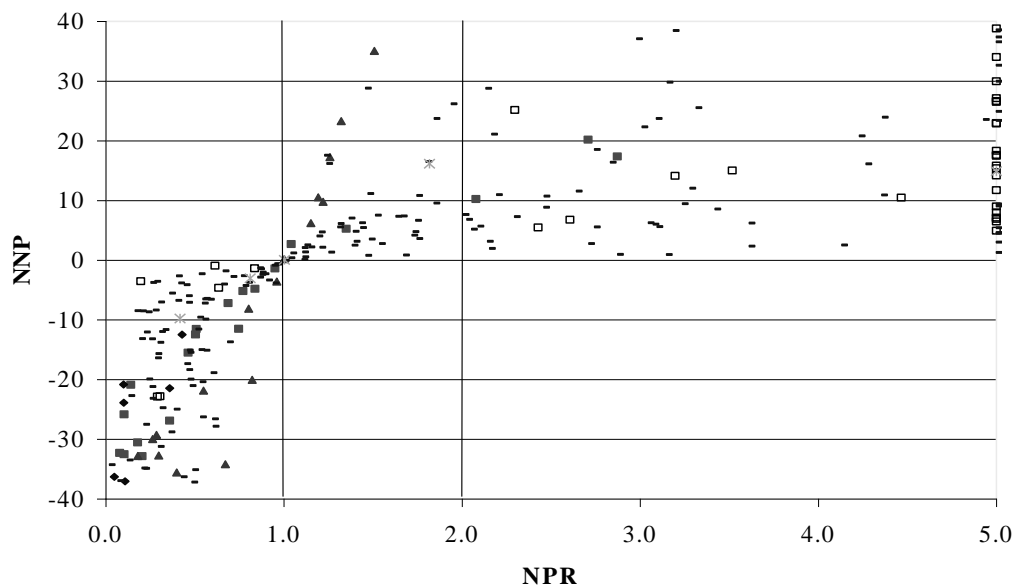


Figure 2. NNP versus NPR data from a proposed Cu-Au deposit

## Interpretation of Geochemical Results

### General considerations

A common concern is how much information to provide. Unfortunately, the devil is often in the details and therefore a comprehensive explanation of details is generally required (e.g., how samples were collected and whether analyzed samples are representative of the overall population). Only a small portion of the material may be sufficient to produce significant ARD or metal leaching. Consequently, variability and distribution of parameters such as NPR (NP/AP) and metal concentrations are typically more important than central tendency or average composition. Depending on the situation, descriptive statistics such as the 10th and 90th percentile and median are a useful way to describe the variability, but are no substitutes for plots showing the distribution of data. Sensitivity analysis can be used to determine whether additional information is required. Spatial variability is important in determining when geochemically different materials are mined and whether segregation is possible.

Plan views and cross sections of the site are typically used to show the spatial relationship of variability in ML/ARD properties and their correlation with rock units and different forms of mineral alteration. Diagrams should show sampling locations, the outline of the underground workings and/or pit, and the location of the ore versus waste materials.

### Identifying potentially ARD generating materials

It is important to recognize that the primary source of toxicity is metals and that unacceptably high metal leaching may occur with neutral pH drainage. At other sites, water quality is only a concern if the wastes generate ARD. However, even where neutral pH drainage is a concern, the occurrence of ARD typically results in much higher metal solubility and weathering rates, and therefore the identification of ARD generating materials is important.

In ML/ARD test work, commonly the first step in assessing whether the neutralizing minerals in a sample are sufficiently plentiful and reactive to neutralize the acidity generated from the oxidation of sulphide minerals is to calculate the acid potential (AP) and neutralizing potential (NP). The ARD potential is then predicted from the NP:AP ratio (NPR). Assuming the AP and NP are accurate and there is exposure to air and leaching, ARD is judged likely if the NPR is < 1, uncertain if the NPR is 1 to 2 and of low probability if the NPR is > 2.

## References

- Antonovics, J., Bradshaw, A.D. and Turner, R.G. (1971) Heavy metal tolerance in plants. *Advances in Ecological Research*, Vol. 7, pp. 1-85. [https://doi.org/10.1016/S0065-2504\(08\)60202-0](https://doi.org/10.1016/S0065-2504(08)60202-0)
- Baker, R.W. (2004) *Membrane Technology and Applications*, 2nd edn, John Wiley & Sons Ltd., Chichester.
- Cowan, W.R., Mackasey, W.O. and Robertson, J.G.A. (2010) The policy framework in Canada for mine closure and management of long-term liabilities: A guidance document. Viewed 27 07 2011, <https://www.abandoned-mines.org/publications-e.html>
- Sobek, A.A., Schuller, W.A., Freeman, J.R. and Smith, R.M. (1978) *Field and Laboratory Methods Applicable to Overburdens and Minesoils*. Report PB-280 495, U.S. National Technical Information Bureau, 403 p.

## Acronyms

NPR      Neutralization Potential Ratio