Nitrate Dynamics at Mine Sites – Broader Context, Source and Management Considerations

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Abstract

Nitrate is considered to present the most widespread groundwater contaminant globally and levels of nitrate related contamination are increasing (Spalding & Exner 1993; Abascal *et al.* 2022). While the main anthropogenic sources of nitrate include fertilisers, animal and human waste, discharge of inadequately treated industrial wastewaters and leachate from landfill sites; mining specific sources, such as the use of nitrogen-based explosives, are getting increasing attention when assessing potential water quality impacts associated with mining (Brochu 2010; Bosman 2014; Nilson 2016; Hendry *et al.* 2018).

To assess the potential influence of nitrogen sources at mine sites, a meta-analysis was undertaken of several studies available in the public literature. Based on the meta-analysis of 10 sites, a description of nitrate concentrations attributed to background conditions and nitrate concentrations attributed to mining related activities is provided. This study further outlines recommended management considerations, including methods to identify background contributions to nitrate concentrations, a framework for assessing the potential risk associated with mine influenced nitrate concentrations in groundwater, as well as remedial technologies that can be applied where required.

Keywords: Nitrate, Ammonium, Nitrogen, Water Quality, ANFO

Introduction

Nitrate is considered to present the most widespread groundwater contaminant globally and levels of nitrate related contamination are increasing through human activity (Spalding & Exner 1993; Abascal *et al.* 2022). Potential water quality effects of elevated nitrate concentrations include health effects (specifically through the development of methemoglobinemia – to which infants are most suspectable [WHO 2016]), as well as environmental effects through eutrophication of water bodies which is typically detrimental to species diversity and which can lead to toxic blue-algae blooms (Clarke *et al.* 2017). The main anthropogenic sources of nitrate include fertilisers, animal and human waste, discharge of inadequately treated industrial wastewaters and leachate from landfill sites (Gutiérrez *et al.* 2018; Abascal *et al.* 2022).

Mining specific sources include the release of nitrogen previously contained within undisturbed lithologies and the use of nitrogen-based explosives (Brochu 2010; Bosman 2014; Nilson 2016; Hendry *et al.* 2018). Metasedimetary and metavolcanic lithologies can be naturally elevated in elemental nitrogen (Bosman 2014), and disturbance of these rock units along with exposure to the atmosphere can lead to seepage with elevated nitrogen concentrations being released to the environment (similar to the release of sulfates following sulfide oxidation in disturbed rock units). The dominant mine related source of nitrate at mine sites constitutes nitrogen-based explosives, of which Ammonium Nitrate Fuel Oil (ANFO) is the most widely used globally (Brochu 2010; Hendry *et al.* 2018). The nitrogen contained in ANFO is highly water soluble, and the decomposition of undetonated ANFO can result in elevated nitrate concentrations in seepage emanating from mineral waste storage areas. While a number of potential mine related sources are considered, potential nitrate contributions associated with the use of ANFO forms the main focus of the studies evaluated as part of the meta-analysis.

Methods

A meta-analysis was undertaken of several studies available in the public literature. These studies present the results of site-specific assessments evaluating potential contributions of mining related activities to nitrate concentrations in groundwater, and concentrations attributed to background conditions. Studies considering background contributions included assessments utilising the stable isotopic composition of nitrate ($\delta^{15}N$- and $\delta^{18}O$-NO_3). Where available, concentration data for other nitrogen species (such as ammonium) were included in the meta-analysis summary to provide potential insights into relative nitrogen loads and nitrogen cycling at the study sites. Geographical locations of case studies varied from Africa, Asia to Australia, and North America.

Results

Nitrate concentrations (as NO_3-N) attributed to background conditions were generally < 1 mg/L at the 10 mine sites. While background concentrations were generally < 1 mg/L, $NO_{3\text{-}}$N concentrations as high as 54 mg/L has been attributed to background conditions in undeveloped (non-mining areas) of Central Australia (Salvestrin & Hagare, 2009). Nitrate concentrations attributed to mining influence, along with upper levels of background concentrations derived at the respective mine sites (where available), are shown in Figure 1. The concentrations attributed to mine influence, for the studies forming part of the meta-analysis, ranged between 1.5 and 60 mg/L $NO_{3\text{-}}$N.

Summary and Implications

This study presents a discussion of potential nitrogen sources at mine sites within the context of the nitrogen cycle as well as the results of a meta-analysis of nitrate concentrations at 10 mine sites. The results include a description of nitrate concentrations attributed to background conditions and nitrate concentrations attributed to mining related activities.

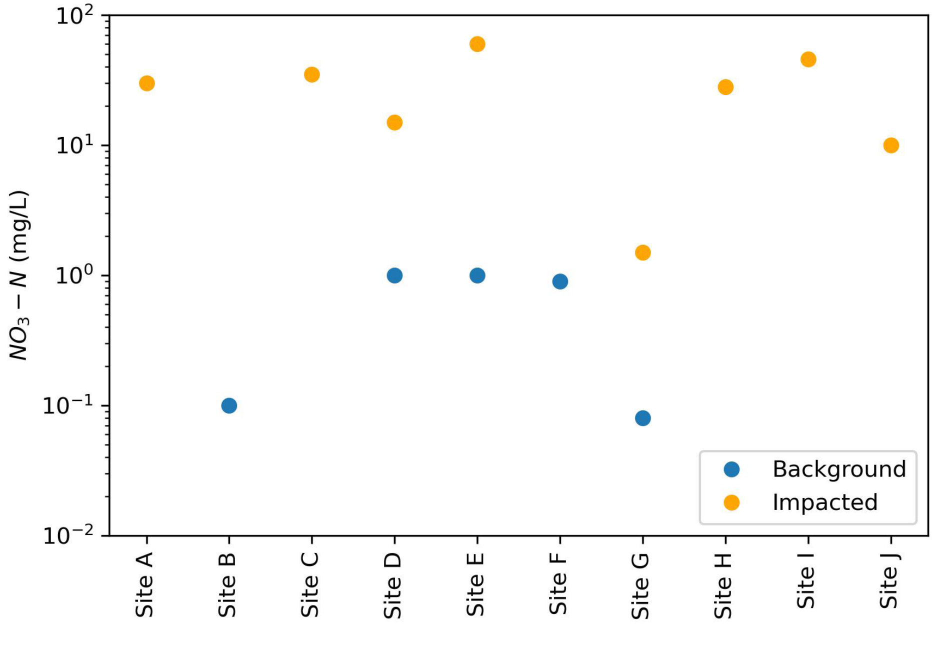

Figure 1 Nitrate Concentrations Attributed to Background and Mine Influence

Management considerations for nitrate at mine sites include:

- methods to identify background contributions to nitrate-concentrations;
- a framework for assessing the potential risk associated with mine influenced nitrate concentrations in groundwater; and
- assessment of remedial technologies including passive and active remediation approaches.

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