An Overview of Challenges Associated with Defining and Applying Water Quality Standards in the Absence of Applicable Regulatory Limits

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Abstract

Water quality protection is a key guiding principle for responsible mining companies. This paper reviews challenges with identifying appropriate water quality standards for mining projects in various jurisdictions that lack comprehensive standards.

Baseline conditions and criteria for 'compliance' need to be defined before a risk assessment can be completed. However, the development of site-specific criteria can require extensive effort. Various internationally recognised standards are available, but these vary with respect to parameters and values. Stakeholder engagement is essential to develop a shared understanding with regulators and communities of the water quality objectives (what receptors need protecting and what are the risks) and how to achieve that compliance.

Keywords: Water Quality, Regulations, Environmental Protection, Mining

Introduction

Mining activities have the potential to impact water quality through modification of receiving water physciochemical conditions as well as concentrations of metal(loid)s (Nordstrom, 2011). Water quality impacts are a potential risk wherever geochemically reactive minerals are disturbed and subject to oxidation and leaching processes. Such impacts could cause harm to human health and/or environmental ecosystems and can occur at any stage during a mining project life cycle from exploration through to post-closure.

Mining companies are typically striving towards responsible mining and usually have a significant focus on environmental and social governance (ESG) and water stewardship. Water quality protection is therefore a key priority for many mining companies and is an important part of the social license to operate. As such, there is a drive to understand risks associated with the potential deterioration of water quality so that effective water management measures can be implemented to prevent, minimise or mitigate those risks.

This paper highlights some of the risks and challenges associated with establishing and applying water quality standards to mine site data. When a mine is located within a greenfield site, establishing and applying water quality standards can be particularly challenging if there is limited or no regional baseline monitoring, and if there are no pre-existing mines within the surrounding area and in regions where there is not a history of modern industrial scale mining.

Challenges and Considerations for Existing Water Quality Standards

There are a number of steps that should be considered when undertaking risk assessments for mine sites, and these often focus on the characterisation of the rock materials and the associated potential oxidation and weathering behaviour. However, it is key to identify early on whether there are applicable environmental standards, and if not, to develop a defensible approach to assigning water quality standards for the protection of the environment and all relevant stakeholders. These steps are outlined as follows.

Do water quality standards exist?

There are significant differences between the level of information available for the protection of surface waters and groundwaters across different jurisdictions. In some cases, well-established thresholds and clear guidance exist. Conversely, there are a significant number of countries often with rich resources yet to be developed, where water quality standards have not been developed. Where standards are available, those standards may not be suitably protective of key receptors or may not meet the levels of protection that the mining company are required to meet by their own corporate standards. There are several considerations which should be made even where localised or national standards exist. These are discussed further below.

Who, what and where are the potential receptors?

Water quality standards typically include thresholds for industrial effluent discharges, thresholds for the protection of aquatic organisms within freshwaters or marine waters, drinking water standards for the protection of human health and agricultural limits for irrigation and livestock purposes. When reviewing any existing water quality standards in the context of a particular site, it is important to consider whether the standards are relevant to all potential receptors. It is possible that the standards are tailored towards a particular receptor, for example, there may be drinking water standards but no environmental quality standards for the protection of sensitive ecosystems, or generic industrial effluent discharge standards may not be relevant or adequately stringent to be protective of the receiving watercourses for domestic consumption or in remote pristine environments.

Identifying potential receptors is a critical task but may not be straightforward. It will likely require consultation with specialists responsible for undertaking baseline studies such as biodiversity or social baselines to obtain a clear understanding of who or what may be impacted by potential changes to water quality in the vicinity of the proposed mining project.

Are the existing standards suitable for use?

When existing standards are available it is important to interrogate the available information to ensure that the standards offer a suitable level of protection. The parameter suite should be reviewed to ensure that there are no missing key parameters which could pose a risk of impact to the receptors identified, particularly for parameters that may be affected by the planned activities. The threshold limits should be reviewed to ensure that they offer an appropriate level of protection to potential receptors. When reviewing threshold limits it is also necessary to consider if these are reasonable based upon existing water quality baseline data and what is realistically achievable by a suitable laboratory. Care should be given as to whether the guideline relates to total or dissolved concentrations. Comparison of in-country standards with common internationally recognised standards (such as WHO drinking water guideline values (WHO, 2022), Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000), US EPA Aquatic Life Criteria (US EPA, 2022), or similar) can provide a useful comparison, although it should also be recognised that the values assigned within the various standards can vary over orders of magnitude for some parameters (discussed in Section 3).

Having an adequate water quality baseline is essential to assess any potential future impacts which might arise from mine development, operations or closure. Baseline monitoring data should ideally be representative of pre-mining conditions to accurately allow assessment of impacts from mining. Baseline solute concentrations may be naturally elevated in arid, highly mineralised areas and lower where precipitation is high, or bedrock has a high neutralising capacity for example. It may be necessary to distinguish the natural baseline from water quality data impacted by anthropogenic activities when deciding which standards to apply. For example, at Questa Project, New Mexico, US, it was proven that pre-mining baseline conditions were already elevated relative to standards which enabled site-specific standards to be negotiated with regulators (Nordstrom, 2008).

Surface water and groundwater quality baseline data should be spatially and temporally representative of the mining project area. Sampling frequency should be sufficient to assess seasonal trends (ideally a minimum of monthly sampling for greater than one year).

Baseline sampling should include field measurements, laboratory analyses and appropriate quality assurance quality control (QA/QC) such as blanks, standards and duplicates. Laboratory detection limits must be sufficiently low to enable assessment against potential water quality standards. QAQC review should incorporate checks on trends that might indicate a bias or systematic analytical error to identify errors or anomalies. In addition to the QAQC review, the data should be suitably interrogated as part of the data interpretation to identify any trends or correlations which could assist in the application of water quality standards.

Consideration should be given to any localised physio-chemical changes, which might affect specific parameters such as changes to pH or water hardness and in turn may have implications for constituent toxicity. Baseline water quality data are also important for understanding whether certain parameters are naturally elevated in a particular area prior to mining, for example because of natural weathering of mineralised rock.

Where and how should compliance be assessed?

If suitable water quality standards exist, the next stage should be identifying where and how compliance should be assessed. The actual point of compliance should be specified and agreed upon with regulators. Will the standards be at the point of discharge ('end-of-pipe'), or should the evaluation be based upon maintaining or achieving a certain quality level within the receiving water? If the latter, dilution within the receiving water needs to be understood and factored in. For example where assessment is 'in-river', the compliance point is usually set at a location downstream of the discharge point to allow for mixing.

The frequency of monitoring should comply with regulatory requirements and consideration should be given to a risk-based monitoring approach where the frequency is adapted to site specific requirements. For example, more frequent monitoring could be undertaken at specific locations such as close to waste rock dumps or tailings storage facilities. It may also be necessary to alter the sampling frequency to accommodate localised weather conditions to account for important seasonal variations, such as first-flush events as dry seasons turn to wet seasons, following storm events or as snowmelt occurs and stream flows increase.

When assessing compliance with standards it is important to understand what represents a trigger where further immediate action should be undertaken. A good understanding of any applicable local regulations and a strong water management plan should inform decisions. It is possible that compliance is based upon an absolute limit but more often, compliance is percentile based. ANZECC (2000) specify that no action is required where 95% of data at a particular compliance point fall below guideline values.

Options in the Absence of Suitable Water Quality Standards

In the absence of existing water quality standards, the mine operator will need to decide how to address this issue and set appropriate standards that are protective of the environment and water users. There are two broad options to achieve this:

1. Using existing internationally recognised standards; or
2. Establishing new site-specific standards

Either option may be applied entirely where there are no existing standards or may be used selectively to target specific parameters that are not included for the in-country standards.

In some instances, even where mining projects decide to apply internationally recognised standards, it may also be necessary to develop site-specific standards where baseline conditions are elevated above the water quality standards.

Applying Internationally Recognised Standards

In the absence of a suitable dataset from which to derive site-specific standards, the most straight-forward option is to apply internationally recognised standards. There are a wide range of internationally recognised standards to select, including International Finance Corporation Effluent Guidelines (IFC, 2007), WHO Drinking Water Guidelines (WHO, 2022), US EPA National Recommended Water Quality Criteria (US EPA, 2022), Canadian Council of Ministers of the Environment, Environmental Quality Standards (CCME, 2023), DWAF Water Quality Guidelines (DWAF 1996a,b), ANZECC Guidelines for Fresh and Marine Water Quality (ANZECC, 2000), EU Directive 2013/39/EU and the Initiative for Responsible Mining Water Quality Criteria (IRMA, 2018).

The standards all vary in the parameters included and the values applied, and where or how they are applied. Some standards are ecologically-based, some are human-health based, some apply as end-of-pipe, some are applicable within the receiving water after mixing has occurred. Figure 1 presents water quality standards for several parameters from multiple international guidelines and jurisdictions. This figure highlights the variability of the standards and emphasises that the challenge for a mining project becomes selecting which is the most appropriate standard to use.

It may not be sufficient to apply standards based upon similar geographical locations alone, particularly if receptors vary. Selecting the lowest internationally recognised standard may be the most conservative approach but could be inappropriate if baseline water quality is already at levels above these thresholds. Selecting the lowest criterion may also be overly conservative and lead to unnecessary requirements to manage, mitigate or treat water. Conversely, selecting the highest, most lenient thresholds may not offer a suitable level of protection.

IRMA (2018) is of particular note, as they have acknowledged the difficulty of the wide range of potential water quality standards that may be used and have aimed to address this by presenting a set of water quality criteria as a standardised approach for international mining. The standards set out in IRMA were compiled from internationally recognised sources, based on scientific evidence or from international agreement across a number of jurisdictions.

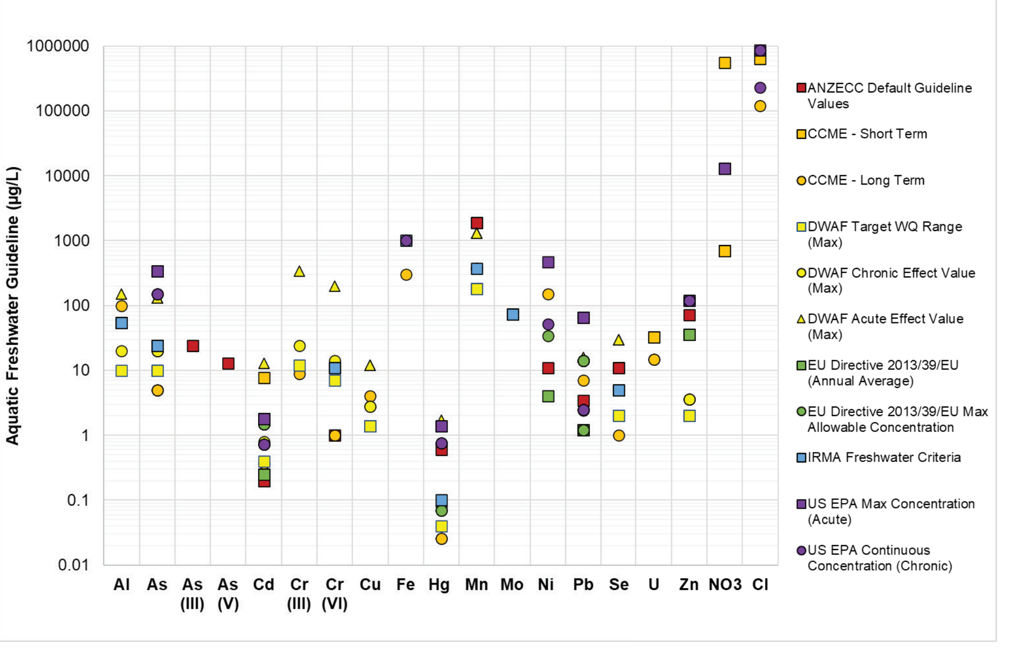

Figure 1 Summary of Internationally Recognised Standards for Key Parameters (Freshwater Aquatic Ecosystems)[1]

Water quality standards are also updated as new information becomes available. For example, WHO (2017) reported an aesthetic drinking water standard for manganese of 0.1 mg/L and a health-based standard of 0.4 mg/L. However, because the health-based standard was greater than the aesthetic standard, the health-based guideline was not presented. In WHO (2022) the health-based standard was subsequently reduced to 0.08 mg/L.

Existing water quality standards applied to a mining project should be periodically reviewed to ensure they are current and up to date. As the above example shows, it is possible that water quality standards could decrease through the course of a mining project life cycle which has the potential to affect compliance. In this instance, regulator liaison would be essential to establish a resolution.

Developing or Adapting Site-Specific Water Quality Standards

The second option available is to develop site-specific standards. These can be developed where appropriate standards are absent, or at sites where the standards may not be appropriate (for example due to an elevated baseline). In some jurisdictions, developing site-specific thresholds is encouraged. ANZECC (2000) recommends using default guideline values (DGVs) as a generic starting point for assessing water quality only in the absence of more relevant local jurisdiction standards or site-specific standards. The US EPA (2022) has established national water quality standards, but localised standards also exist for several states, for example Idaho, Alaska, Nevada, New Mexico, North and South Carolina. On the other hand, throughout Europe, all EU Member States are required to adopt the Water Framework Directive (WFD) Environmental Quality Standards (EQS) which cover a wide range of parameters, although the WFD also allows member states to set their own standards for some parameters where this can be justified.

Setting and agreeing to site-specific water quality standards is a challenging and highly variable process. As detailed above, existing internationally recognised standards sometimes show significant differences. For example van Dam et al., (2019) states that a lack of clear guidance for developing site-specific standards often leads to under-estimating or over-estimating limits which can result in unintentional environmental impacts or unnecessary costly management measures. Establishing new site-specific standards is also an extremely long and data intensive process which often takes a significant investment of time and money, so isn't necessarily the most practical option – hence another benefit to the use of internationally recognised standards is that they are immediately available. When generating site-specific standards engaging with regulators and relevant stakeholders at the earliest opportunity is key. It is important to ensure that the process followed is transparent and defensible. Any guideline levels established should offer an appropriate level of protection whilst remaining realistic in terms of natural baseline levels and achievable detection limits. ANZECC (2000) provides guidance for developing guideline values using a pressure-stressor-ecosystem receptor (PSER) causal pathway. The ANZECC recommended approach uses local baseline data to determine thresholds around the 80th percentile, or lower if there is a need to apply a more precautionary approach. According to ANZECC (2000) site-specific thresholds should be based on at least two years of monthly monitoring data from suitably representative unimpacted water bodies. Seasonal variations should be included, and it may be appropriate to set limits specifically for wet or dry seasons or high and low flows.

The Department of Water Affairs and Forestry (DWAF), South Africa, also provides options to modify water quality standards in accordance with very specific criteria. DWAF require adequate site-specific data for at least one annual hydrological cycle and site-specific studies including toxicity tests for at least three locally significant species confirming that any modifications offer the same level of protection to aquatic organisms.

Engaging in Discussions with Regulators and Stakeholders

Early engagement with regulators and stakeholders is crucial to the successful implementation of any water management plan. Identification of receptors is key, and this process should involve stakeholders and regulators from the outset. The process of agreeing and establishing water quality standards should include ongoing discussions and workshops with regulators and stakeholders to ensure that there is a defensible and transparent approach. Regulator and stakeholder engagement is particularly important in the event of needing to amend existing water quality standards or generate entirely new site-specific standards. DWAF (1996b) states that modifications to standards should only be considered under expert advice.

It is possible that regulators and/or stakeholders may not have much familiarity or experience with potential impacts associated with mining activities. In this instance, it is even more important to engage with regulators early in the process to identify key competencies and strengths. An open dialogue will ensure that all parties are confident and comfortable with the proposed approach.

Conclusions

Mining has the potential to create changes in baseline water quality and where there is a risk of acidity generation or solute leaching this can lead to an increase in constituent concentrations. Understanding potential risks is a key priority for operators as part of their ESG policy. Early identification of appropriate water quality standards is crucial to understanding and mitigating risks posed to key receptors, but the approach of establishing water quality standards can be complex where suitable standards are not available. Even if standards exist for the jurisdiction where the mine will be located, there can still be challenges which need to be considered, such as whether the standards offer sufficient protection to receptors, how standards compare to existing baseline data and how standards should be implemented, where compliance should be measured and what triggers a failure. The absence of relevant water quality standards presents a bigger challenge. Operators are faced with a decision to implement internationally recognised standards or go through the often long and expensive process of establishing site-specific standards. The large variances seen between international standards highlights the difficulties faced when deciding what to apply.

Regulators and stakeholder inputs will ultimately determine if and when mining permits are approved. Early engagement is therefore crucial especially when the proposed approach involves any deviation from existing water quality standards. A transparent approach of regular ongoing discussions can help ensure the success of the implementation process.

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