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Selection of Passive AMD Treatment Systems – Flow Chart for New Zealand Conditions

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Abstract

Passive systems for the treatment of acid mine drainage (AMD) are typically more economic in the long term than active systems. Various flow charts for treatment selection have been prepared by scientists in the USA, however, they have typically not included a variable important at New Zealand AMD sites on the West Coast: topography and available land area. Very steep topography, dense and often protected vegetation (and animals such as snails), and a high-rainfall climate result in AMD with very high flow rates in locations with very limited space for remediation. Flow charts specific to New Zealand have been prepared which accommodate topography and available land area. Parameters necessary to use the flow charts are iron and aluminium concentrations, pH, ferrous to ferric iron ratio, dissolved oxygen concentration, topography and available land area. Prior to full scale construction, is it recommended that flow rates be quantified, small-scale trials be conducted, and cost, effectiveness, limitations, and risk of failure be reviewed for various options. One full-scale remediation system has been installed in New Zealand based on this methodology and another is planned. The performance of these systems, as well as future systems to be installed, will be used to validate these treatment system flow charts.

Introduction

Acid mine drainage (AMD) is a common issue associated with coal mining in New Zealand. It has been documented at both active and abandoned mines, both opencast and underground in various areas but mostly on the West Coast (Alarcon, 1997; deJoux, 2003; James, 2003; Black, Trumm and Lindsay, 2005; Pope, Newman and Craw, 2006). The severe effects of AMD on the aquatic ecosystem have been extensively studied (Winterbourn, 1998; Harding and Boothryd, 2004; Harding, 2005).

Treatment of AMD can be accomplished by either active or passive treatment systems (Waters at al., 2003). Long term, treatment using passive treatment systems is typically more economic than active treatment systems (Skousen and Ziemkiewicz, 2005). Active systems require continuous dosing with neutralising materials, consume power, and require regular operation and maintenance. Passive systems avoid continuous dosing with neutralising material and the consumption of power by taking advantage of naturally occurring geochemical and biological processes and clever use of topography. However, problems with passive systems, such as short circuiting of flow, armouring of limestone, or plugging with precipitates, can arise unless systems are carefully selected and constructed.

Various flow charts for treatment selection have been prepared over the years by scientists in the USA (Hedin and Nairn, 1992; Skousen et al., 1999; Skousen et al., 2000). These flow charts incorporate the parameters of flow rate and water chemistry, but have typically not included a variable important at New Zealand AMD sites on the West Coast: topography and available land area. This work presents flow charts specific to New Zealand which accommodate topography and available land area.

Passive Remediation Strategies

Remediation of AMD using passive remediation technologies can be placed into two broad categories: oxidising and reducing strategies. AMD is generated through an oxidation process, which results in the dominant contaminant, iron, being present in two states, ferrous (Fe^{2+}) and ferric (Fe^{3+}; Singer and Stumm, 1970). Remediation systems employing the oxidising strategy remove iron from the AMD by continuing the oxidation process such that all ferrous iron is oxidised to ferric iron, and once the pH has been raised sufficiently, precipitated out of the AMD as ferric hydroxide ($Fe(OH)_3$). In remediation systems using the reducing strategy, the AMD oxidation process is reversed, such that iron cations and sulphate are reduced, forming the compounds FeS_2, FeS, and H_2S, effectively removing iron and sulphate from the AMD.

In the oxidising strategy, alkalinity is added by the dissolution of limestone or other alkaline materials, and DO is added by aerating the AMD water. Typical remedial systems that employ the oxidising strategy are open limestone channels (OLCs), limestone leaching beds (LLBs), slag leaching beds, and diversion wells (DWs; Anonymous, 2001). OLCs and DWs typically require a steep topography in order to generate the necessary aeration and to prevent armouring of limestone by metal hydroxides, which can inhibit the dissolution of limestone (Ziemkiewicz, et al., 1997).

For the reducing strategy, DO is stripped from the AMD water using a system that creates an anaerobic environment, and alkalinity is then added by the dissolution of limestone. After the pH is raised, metals not already removed as sulphides precipitate as metal hydroxides. Typical remedial systems that employ this strategy are anaerobic wetlands (Anonymous, 2001), anoxic limestone drains (Hedin and Watzlaf, 1994), sulphate-reducing bioreactors, and successive alkalinity producing systems (SAPS), also known as vertical flow wetlands (VFWs; Zipper and Jage, 2001).

The choice between the two strategies is typically based on the water chemistry (largely DO content and ferrous/ferric (Fe^{2+}/Fe^{3+}) iron ratio). For AMD which is highly oxidised (DO level at saturation and all iron as ferric iron) the oxidising strategy is most appropriate; for AMD with low DO and all iron as ferrous, the reducing strategy is usually recommended. However, site limitations, such as available land area, may limit the use of the most appropriate system.

Flow Charts

Parameters necessary to use the flow charts prepared by Hedin and Nairn (1992), Skousen et al., (1999), and Skousen et al., (2000) include water chemistry (DO content, ferrous/ferric iron ratio, aluminium concentration and pH), and flow rate. Topography and available land area are not included among the parameters, however, on the West Coast in New Zealand, these parameters may limit choice between systems. Very steep topography, dense and often protected vegetation (and animals such as snails), and a high-rainfall climate result in AMD with very high flow rates in locations with very limited space for remediation. Flow charts have been prepared for New Zealand AMD sites incorporating site parameters of AMD chemistry (Fe concentration, Al concentration, ferrous/ferric iron ratio and DO), site topography and available land area (Figure 1). Topography descriptions are restricted to steep and not steep; available land area descriptions are restricted to large flat area and long narrow area. Rather than numerical values for Fe and Al concentration, only high versus low are included on the chart as the flow chart is still under development. One full-scale remediation system has been installed in New Zealand based on this methodology (SAPS unit at the Pike River Adit based on the results of the field trials documented in Trumm, Watts and Gunn, 2006) and another is planned (LLB unit at the Herbert Stream based on the results of the field trials documented in Trumm, Lindsay and Watts, 2007). The results of AMD remediation trials and AMD full-scale treatment systems will be used to help finalise the flow chart.

Once potential treatment solutions have been identified through the use of the flow chart, it is recommended that small-scale trials be constructed on site to test the effectiveness of the various options before investing in full-scale system construction (see Trumm, Watts and Gunn, 2006 for examples of small scale trials). Ecotoxicity experiments should be conducted using treated water to verify treatment will enable restoration of the aquatic ecosystem, and system autopsies should be performed to verify system performance parameters and system longevity. The choice of the full-scale system should be based on the results of the field trials and a review of the cost, effectiveness, limitations and risk of failure for each option.

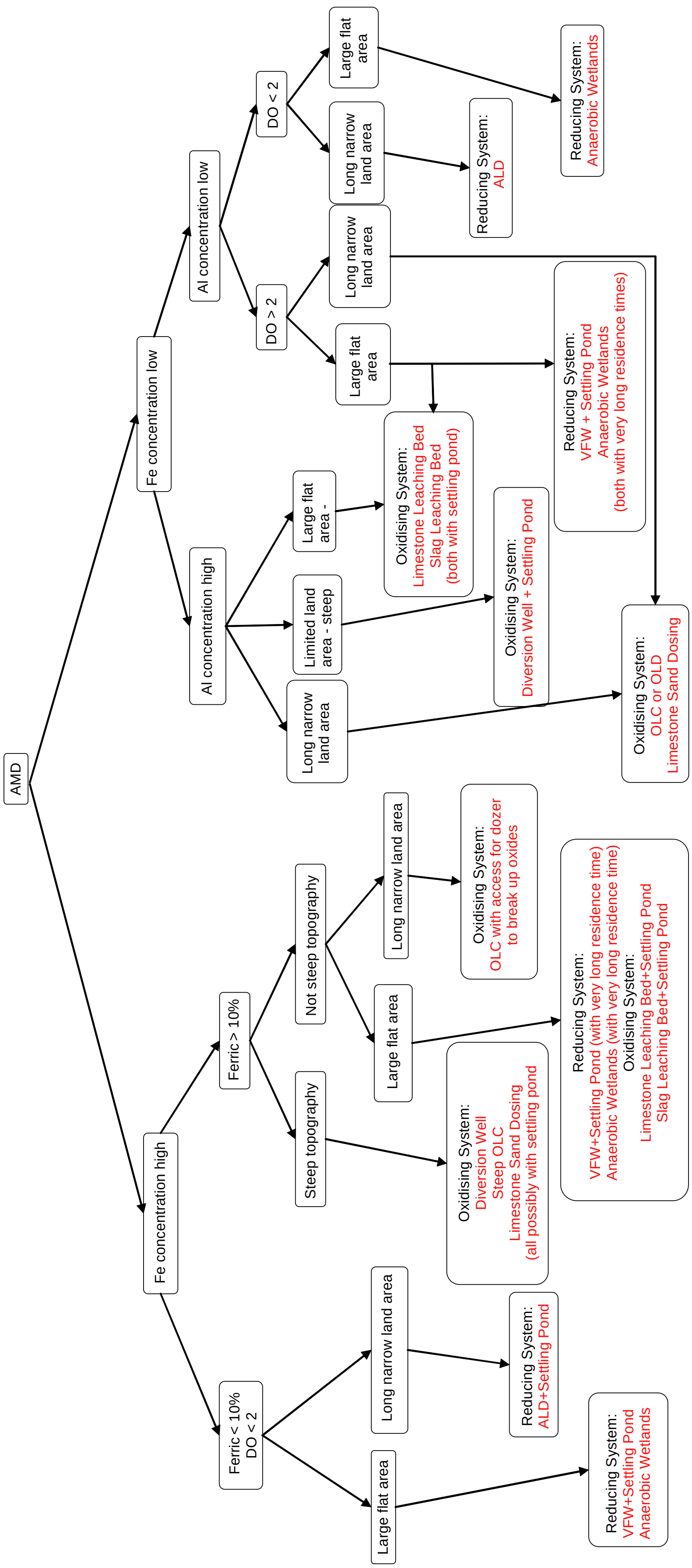

Figure 1: Flow chart to select among AMD passive treatment systems based on water chemistry, topography and available land area.

Conclusions

Researchers in the USA have identified major parameters necessary for site-specific treatment selection. The flow chart presented here uses some of these parameters in conjunction with two important parameters to New Zealand: topography and available land area. Topography at AMD sites in New Zealand is often steep with limited space for remediation systems. Therefore, treatment selection may be restricted by topography and land area as well as AMD chemistry. Prior to construction of full-scale treatment systems, it is recommended that small-scale trials be conducted on site to verify optimal treatment selection.

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