# NZ minerals sector environmental research - tools to make better mines


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## Abstract


Over the last 14 years, CRL and collaborators from Landcare Research, O'Kane Consultants NZ and Universities of Canterbury, Otago and Auckland have completed government funded research on minerals sector environmental issues. Our focus has been diverse including, rock geochemistry, aquatic chemistry, aquatic ecology, terrestrial ecology, and within these disciplines we have identified mechanisms for impact, methods for management and treatment, options for rehabilitation and timelines to recovery.

Our objective is to complete underpinning science for the New Zealand minerals sector that builds on international expertise and experience to ensure that New Zealand operates mines with world class environmental performance. We have completed this research through important collaborations with New Zealand mining companies, regulators, DOC and minerals sector associations and without these contributions much of the research by this team could not have been completed.

We present a snapshot of current minerals sector environmental research in New Zealand.



***Keywords:*** geochemistry, aquatic toxicology, mine rehabilitation, economics, life-cycle. CMER – Centre for Minerals Environmental Research.


## Introduction

The New Zealand minerals sector has mining operations that occur in diverse local conditions. These include native beach or podocarp forests, dairy farm land, arid grazing country, coastal dune-land, coastal highlands and urban areas. Each of these environments come with different regulatory requirements and rehabilitation challenges associated with diverse underlying geological and geochemical conditions that dictate the types of environmental issues that must be managed. However, each of these environments have something in common, they are all in some-ones back yard and high standards of environmental performance are demanded by local communities that are adjacent to New Zealands mines.

Throughout the last 14 years CRL Energy and collaborators, Landcare Research, University of Otago, University or Canterbury, and O'Kane Consultants have competed multidisciplinary research to provide underpinning environmental science that supports the New Zealand minerals sector to achieve or exceed the expectations of the adjacent communities. The New Zealand minerals sector has supported this research programme with access to sites and data, collaboration on field work, installation of field trials and in-kind support for analysis where appropriate. Other minerals sector stakeholders including Minerals West Coast, Straterra, DOC, Iwi, Coal Association and Regional Councils have also supported our research programmes with site access and governance of our research programmes. These organisations also supported the research team to deliver many science outputs including peer reviewed papers, conference papers, presentations, workshops, journal special editions and overarching guideline documents.

Over the last 4 years the research team have self-branded as the Centre for Minerals Environmental Research and have set up a website to house research outputs www.cmer.nz. This website hosts over 190 conference papers and peer reviewed journal articles that have been written by this research team as well as the other key research outputs. We present some highlights and current work from this large and long term research programme and encourage delegates to the 2018 AusIMM conference to dig deeper into the diverse outputs from this programme and make use of them.

The research programme covers several scientific disciplines including, geochemistry, aquatic ecology, terrestrial ecology, as well as environmental management, water treatment, waste management, rehabilitation practise.

## Geochemical Research and Tools

Prediction of high wall runoff geochemistry and duration has been completed to enable planning for acidity loads throughout and after mining (Figure 1).

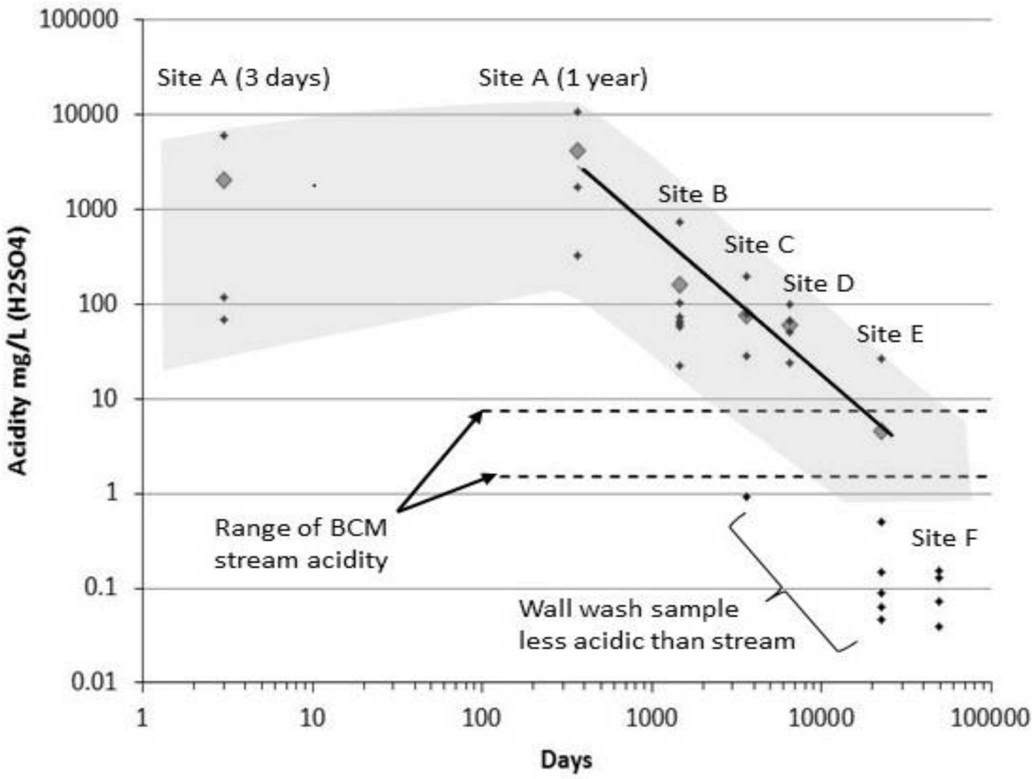


**Figure 1.** Acidity in run off from different aged exposures of coal measure rocks (after Pope et al., 2018).

Tools for selection of optimal geochemical test regimes have been developed that improve the completeness and accuracy of waste rock classification as well as reducing the testing cost (Figure 2).

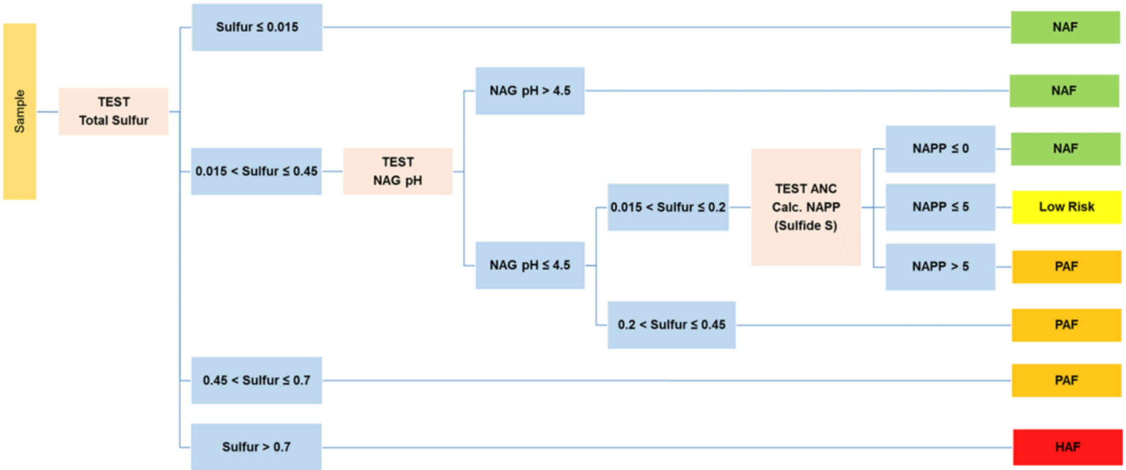


**Figure 2.** Process flow approach to waste rock classification (Olds et al., 2015).

Geochemical modelling can be a powerful tool for prediction of trace element mobility in aquatic environments, however, the reliability of modelling for real word applications especially where concentrations, acidity or salinity are high can be difficult to assess. The CMER research team have completed several studies that identify the application and limitations of geochemical modelling for mine drainage environments Figure 3 & 4).

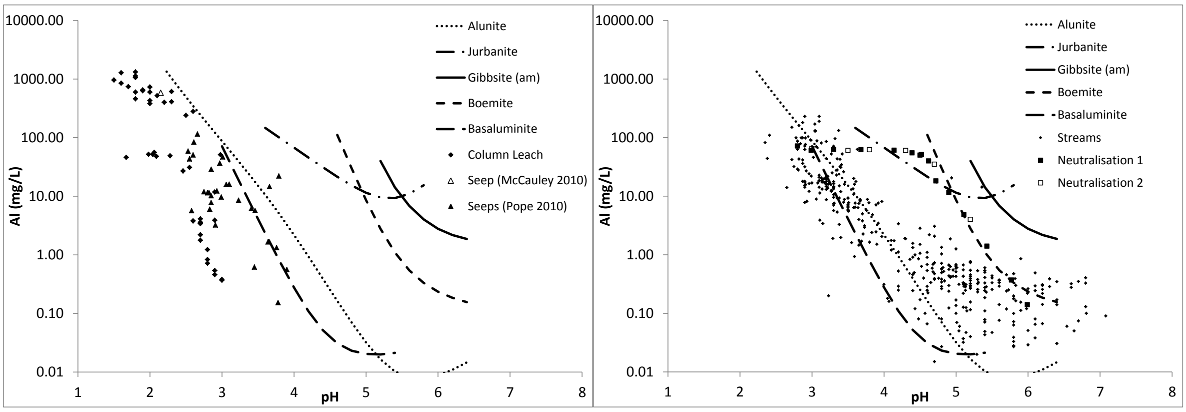


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**Figure 3.** Mineralogical control of Al in water from mine drainage seeps, impacted streams and experiments for neutralisation of mine drainages (Pope and Trumm, 2014).

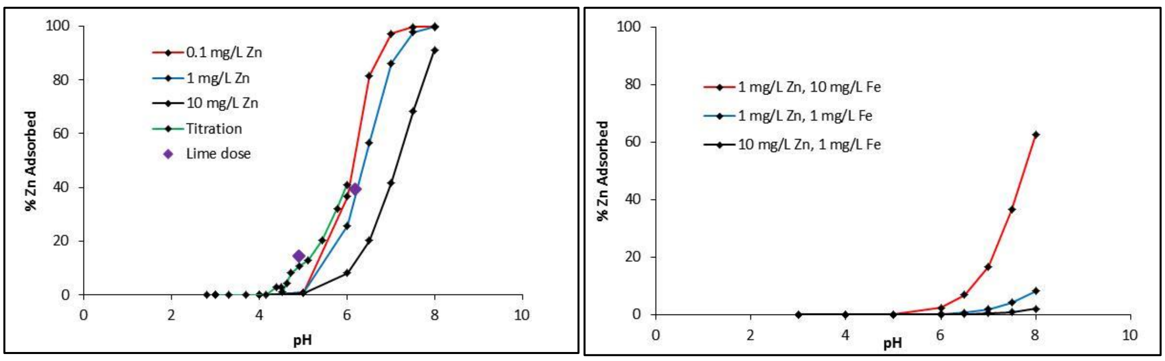


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**Figure 4a&b.** Modelling and field data for the prediction of Zn adsorption to amorphous Fe minerals in gold and coal mine drainages (Pope and Trumm, 2015).

Often geochemical challenges that occur on mine sites require multidisciplinary understanding of hydrogeology, bio-geochemistry, vadose zone capillary processes, diffusion, advection as well as aqueous precipitation and dissolution processes. The CMER research team have provided some of the only published field trials on that provide information on these multidisciplinary challenges (Figure 5).

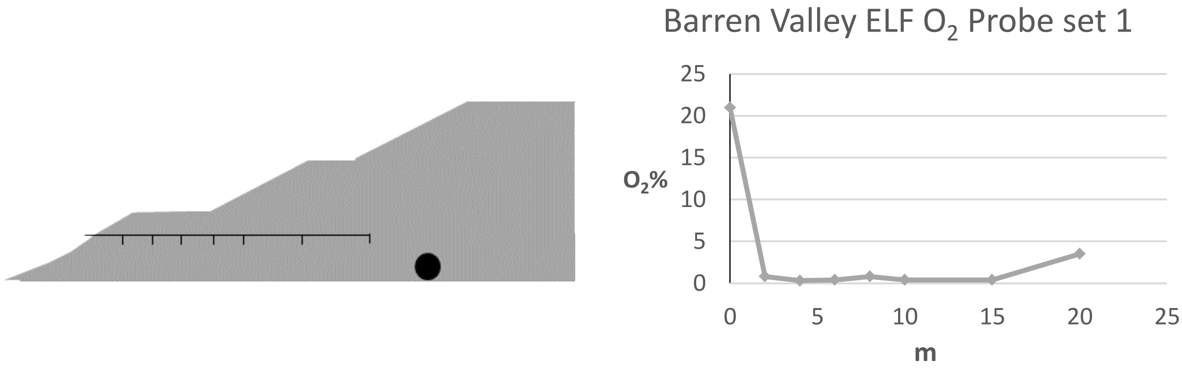


**Figure 5.** Oxygen probes installed in waste rock dumps provide insight into the amount of rock that is undergoing oxidation and the presence or absence of oxygen ingress pathways that can be driven by changes in barometric pressure. The schematic shows the location of oxygen measurement points compared to a batter, dump lifts and underdrain and the chart shows O2 content of gas within the dump (Pope et al., 2016).

## Aquatic Ecology Research and Tools

Aquatic ecologists within the research team used a model for food web (Figure 6) interactions within natural New Zealand streams and investigated tolerance to change in water quality parameters for different trophic levels within the food web. These underpinning studies are important because the RMA legislation in New Zealand works on effects based consent conditions and so objective information on measured effects is critical for decision making related to environmental disturbance caused by mining (or other activity).

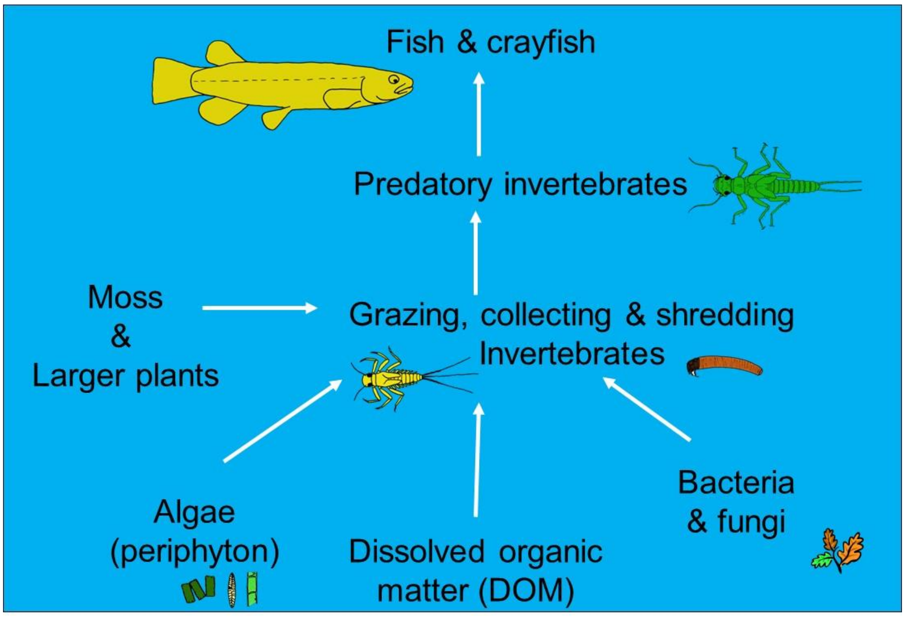


**Figure 6.** Food web model (after John Harding, University of Canterbury)

The impact of pH and metals such as Fe (also Al, Zn, As and Sb) on the diversity of invertebrates fish and algae have been measured (Figure 7, 8 & 9). These studies provide baseline information on un-impacted environments as well as information on the level of impact that might be expected when water quality changes.

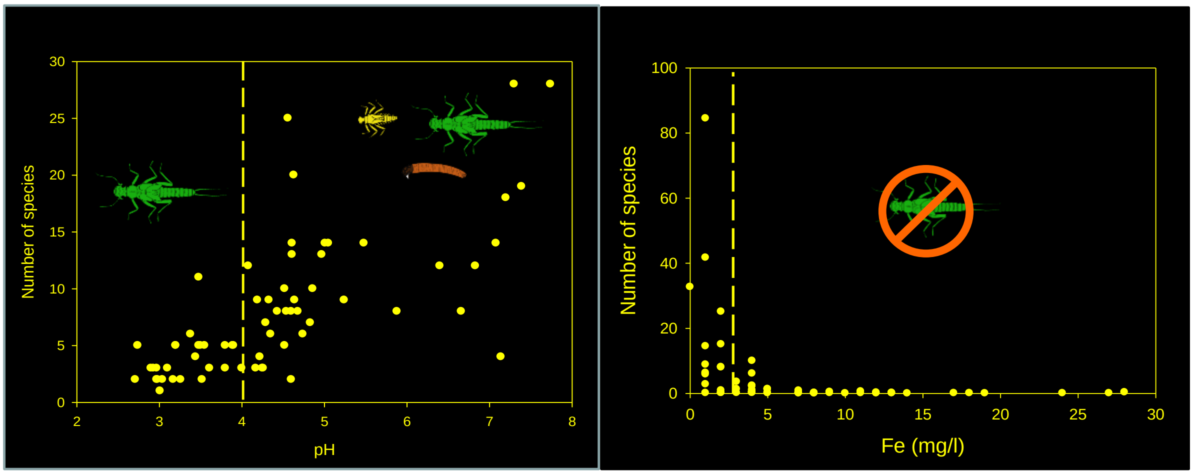


**Figure 7.** Invertebrate diversity with changes in pH and Fe concentration (after John Harding, University of Canterbury)

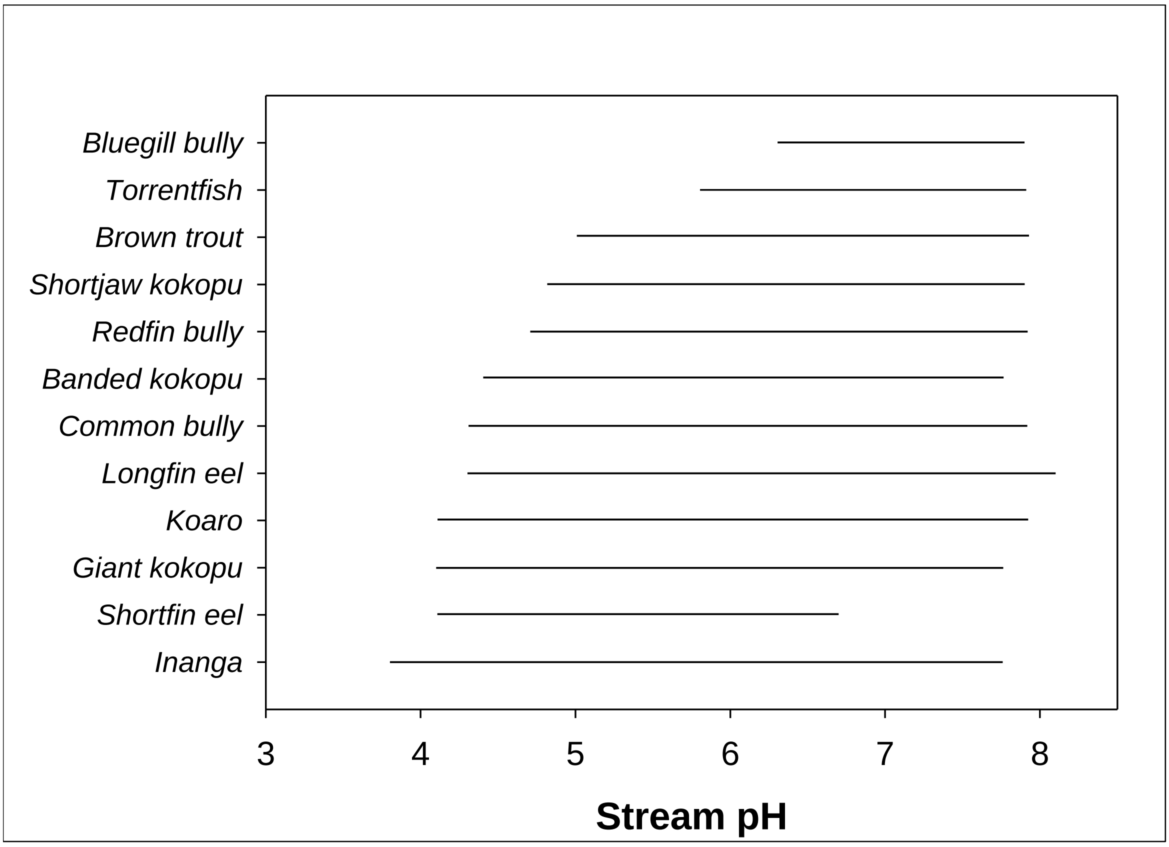


**Figure 8.** The occurrence of different NZ fish throughout the pH range 3-8 (Greig 2010).

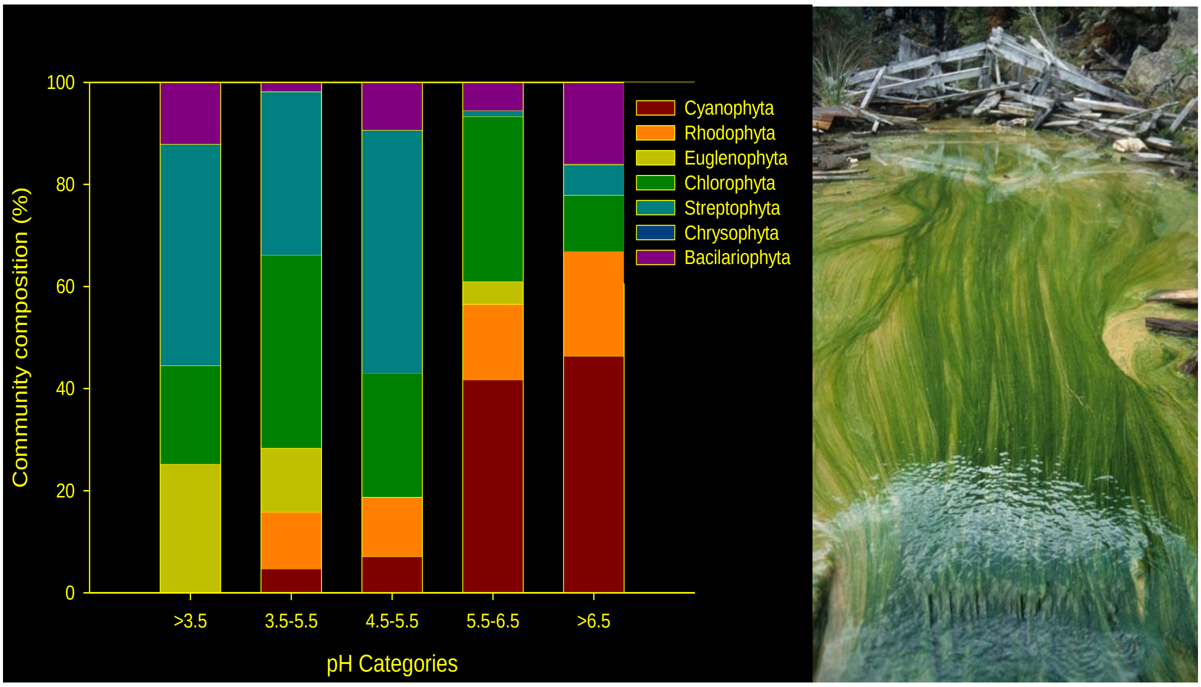


**Figure 9.** Tolerance of algae to different pH and photo of limited diversity algae biofilm that can occur when food web is not in balance, (after John Harding, University of Canterbury)

## Water Treatment Research

Water treatment technologies can be divided into two types, 1) active water treatment where plant operations and reagent dosing are constantly monitored and 2) passive treatment where chemical or bio-geochemical processes are enhanced to deliver water treatment. In general, active treatment is ordered off the shelf from chemical engineering companies whereas passive treatment is an area where geochemical research can improve, refine and develop systems. For this reason the CMER research team have focussed on passive treatment innovation.

The CMER team have focussed on issues that are of interest to the New Zealand minerals sector through consultation with mining companies and regulators. Some of the metals we have focussed on (Figure 10) include, As, Fe, Al, Zn, Ni, Mn & Sb.

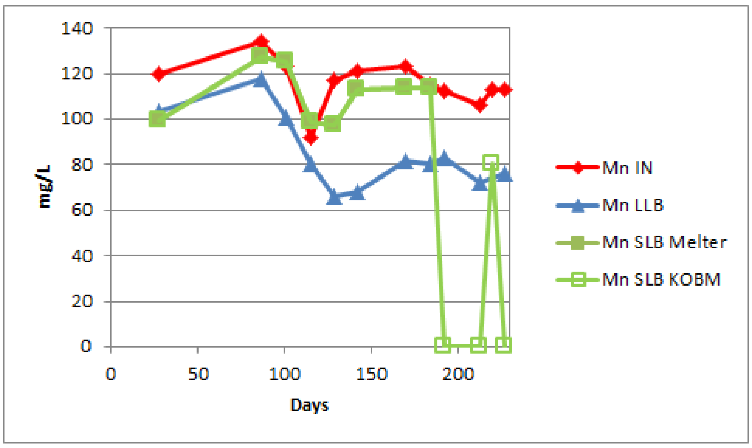


**Figure 10.** Removal of Manganese by passive treatment is difficult because Mn is soluble at circum-neutral pH. Figure shows field trials of Mn removal by two different methods.

Sulphate removal from mine impacted water by passive treatment is difficult. The CMER research team completed research on accelerated bioreactors for sulphate removal. Laboratory trials resulted in a 10 to 20 fold improvement in the speed with which sulphate removal can be achieved and we are currently discussing opportunities for field trials within NZ and internationally.

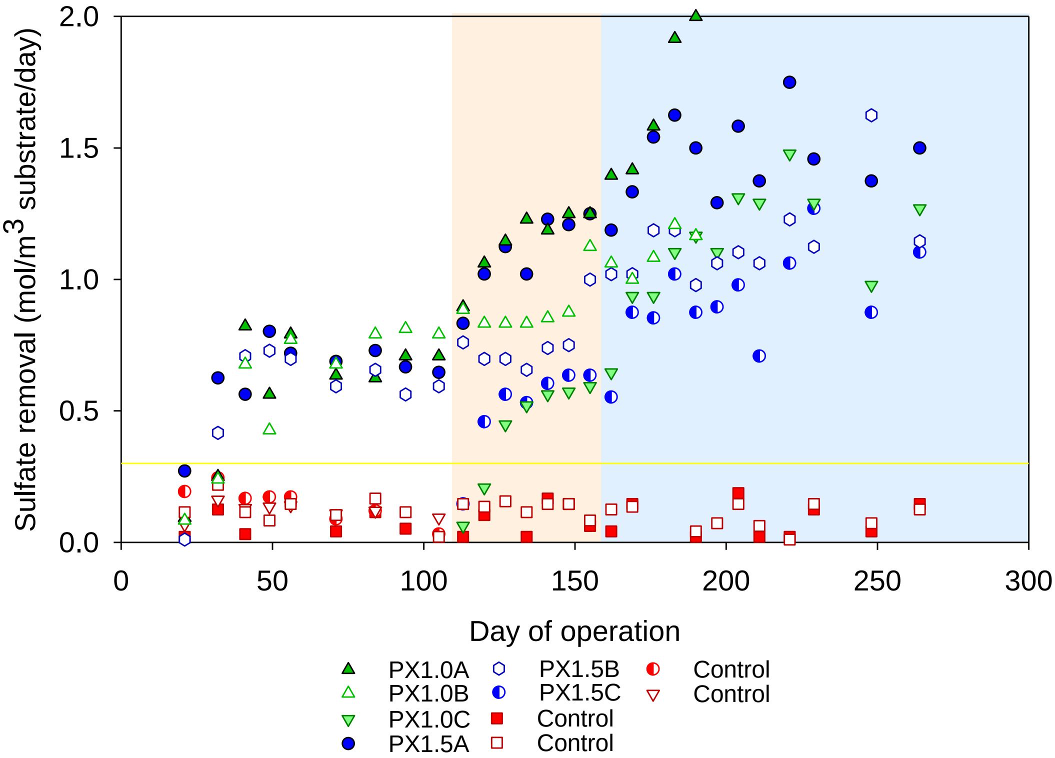


**Figure 11.** 10 to 20 fold improved sulphate removal through accelerated bioreactors developed by the CMER research team (Christenson et al., 2017)

## Terrestrial Ecology Research and Tools

The speed and success of rehabilitation at mine sites is determined by a complex array of physical, chemical, microbial and ecological factors. Simple elegant solutions for rehabilitation can be developed on a site specific basis if the underlying critical success factors are well understood and these can out-perform complex and costly rehabilitation processes where success factors are misunderstood.

The rehabilitation research completed by the CMER is summarised in a rehabilitation score card that identifies 5 assessment steps

1) Define success – desired rehabilitation outcomes
2) Avoidance impacts where possible
3) Identify criteria that underpin success at all sites
4) Identify additional criteria for native ecosystems (if relevant)
5) Determine non-ecological closure requirements

Terrestrial rehabilitation research case studies completed by the CMER research team have investigated many factors that influence the speed and success of rehabilitation under different environmental conditions for example planting media (Figure 12).

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**Figure 12**. Influence on soil type and availability on short to medium term (5-10y) rehab outcomes (photos from Robyn Simcock)

## Key Documents and Outputs

Throughout the programmes completed by the CMER research team several encompassing documents have been produced including the Mine Drainage Framework (Cavanagh et al., 2010), the Minerals Environment Framework (Cavanagh et al., 2015a) and the Mine Environment Life Cycle Guides which are in the final stages release. (Cavanagh et al., 2015b).

In addition to the key encompassing documents, many conference papers containing baseline geochemical data, trials of water treatment methods, innovations in water treatment methods, assessment of rehabilitation approaches, geochemical models and other minerals sector environmental research are published each year. Usually the CMER research team publishes 5-10 papers at NZ Branch AusIMM events, 5-10 papers at international conference events each year. The most innovative of these papers are written up for peer reviewed journal publication to disseminate New Zealand minerals sector environmental research.

Two journal special editions have been produced in New Zealand Journal of Geology and Geophysics and the international journal Mine Water and the Environment (Pope, 2010; Pope and Craw, 2015). In addition, over the last 2 years 7 papers have been submitted to New Zealand Journal of Geology and Geophysics and these will be linked to form a virtual special edition.

## Summary

Minerals sector environmental research for the last 14 years has been completed by CRL Energy, Landcare Research, University of Otago, University of Canterbury and O'Kane Consultants NZ. Throughout this time this research team has released 3 key summary documents, that latest of which will be complete in September 2018. In addition, the research team has completed more than 190 conference papers and journal articles that present and disseminate key data and interpretations. Many of the outputs can be found at www.cmer.nz along with contact details for the research team members.

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