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Evidence

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Treatment of polluting discharges from abandoned metal mines: investigation of passive compost bioreactor systems

Project summary SC090024/S3

Waters draining from abandoned metal mines pollute up to 3,000 km of rivers in England and Wales and prevent these rivers from achieving 'good ecological and chemical status' under the European Water Framework Directive (WFD). This study was to help the Environment Agency, the Coal Authority and Defra develop a programme of mine water remediation which minimises construction and operating costs.

The report summarises the development of a passive treatment technology to remove metals from mine waters. Researchers at Newcastle University operated laboratory and pilot-scale compost bioreactors to remove metals, particularly zinc which is the most common pollutant in metal mine drainage.

The study found that, on average, more than 90% of the total zinc was removed in columns operated in the laboratory. In a pilot-scale system (3.75 m^3 tank) at Nenthead (Cumbria), an average of 68% of total zinc was removed. The difference appears to be primarily related to the larger scale of the system rather than environmental conditions, although there was evidence that the pilot-scale reactor did not perform as well when ambient temperature was low.

The technology works by passing the mine water through a mixture of compost, wood chips, activated digested sewage sludge and limestone. The main process removing metals in these compost bioreactors is bacterial sulphate reduction which generates sulphide ions that bind with metals and are then precipitated as solids. There was clear evidence of these processes taking place in the columns and pilot-scale system. This was shown by geochemical modelling, and chemical analysis of the compost substrate. Other mechanisms such as sorption onto reactive surfaces within the treatment media will also remove metals.

A larger pilot system was operated at the Cwm Rheidol mine in Wales. This discharge has a much more acidic pH and contains higher concentrations of iron than the main study site at Nenthead.

The reactor successfully reduced acidity and removed zinc. However, the high iron concentrations caused difficulties due to clogging. The higher zinc concentration also led to a greater accumulation of zinc in the substrate which did not appear to affect performance within the study period but may in the longer term.

The hydraulic residence time describes how long water takes to pass through the treatment system. This determines the size of treatment systems and area of land needed. Hydraulic performance varied between and within systems. It appears that preferential flow paths may develop but may be short-lived. Design of full-scale systems should factor in the possibility of shorter residence times as a result of this. The design residence time in this study was 19 hours. However, the pilot-scale system performed successfully with a shorter actual residence time of 12–14 hours. Further work is recommended to understand how performance varies with residence time.

Temperature appears to play an important role in the removal of metals. This seems to be related to the suitability of conditions for sulphate reducing bacteria (SRB), and/or the reducing conditions that they require. Again, this may influence the performance of larger scale systems.

Compost-based treatment systems rely on microbial activity to remove metals. Over the longer term (years), the initial food source (digested sewage sludge and compost) for the bacteria will be depleted and so the generation of sulphides to bind the metals may be too low. The study investigated whether adding carbon in the form of brewery wastes would improve performance.

Short-term results were ambiguous. Over the longer term it appeared that continuous additions of small amounts of carbon were beneficial to the pilot-scale system, but it took time for this to be manifested in improved performance. This is an area for further investigation.

Microbial analyses successfully identified sulphate reducing bacteria (SRB), with *Desulfobulbus* and *Desulfovibrio* predominating. The genetic sequences identified in the pilot-scale system were closely related to those previously identified in treatment systems receiving metal-rich waste and in natural sediments contaminated with metals. It is not possible to conclude how important bacterial sulphate reduction is for metal removal and further work to quantify its importance is recommended.

An important consideration in building compost-based treatment systems at full-scale is how long they will work before the compost needs to be replaced. Unfortunately, this could not be determined based on the pilot plant which operated effectively for only 2 years.

Preliminary assessments suggest that the substrate from the compost-based vertical flow ponds may be classified as hazardous waste due to the elevated concentrations of zinc. Metal recovery tests, using hydrochloric acid to recover metals from the substrate, suggest that there is clear potential to recover metals. This might reduce substrate disposal costs if it could be re-classified as non-hazardous waste. Further work is required to establish the most cost-effective way to manage this material.

The first full-scale application of this technology in England started operating in March 2014 at the Force Crag mine site in Cumbria. The report discusses how the results of the pilot-scale trial at Nenthead were used to inform the design of the Force Crag treatment system, which comprises two parallel compost units, each with a water surface area of approximately 800 m^2. Monitoring of the Force Crag system will be used to assist in the design of future systems.

This summary relates to information from project SC090024, reported in detail in the following output:

Report: SC090024/R3
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