

PASSIVE TOTAL METAL REMOVAL FROM ACID MINE DRAINAGE USING DISPERSED ALKALINE SUBSTRATES

Francisco Macías^{*1}, Manuel A. Caraballo¹, Jose M. Nieto¹, Tobias S. Rötting², Carlos Ayora³

¹Geology Department, University of Huelva, Campus "El Carmen", E-21071 Huelva, Spain. Email:
francisco.macias@dgeo.uhu.es

² Technical University of Catalonia (UPC), Hydrogeology Group, E-08034 Barcelona, Spain.

³Institute of Environmental Assessment and Water Research, IDAEA – CSIC, Jordi Girona 18, 08034 Barcelona, Spain.

Abstract

Conventional passive remediation systems cannot be applied to treat high metal polluted acid mine drainage (AMD) because clogging problems and/or coating of reactive grains disable the system. The alternative could be the use of fine grain reactive (to be consumed before coating) dispersed into a high porosity matrix (to maintain the permeability despite of solid precipitates). This dispersed alkaline substrate (DAS) passive treatment system remediation consists of limestone sand for trivalent metal removal and MgO powder for divalent metal elimination, dispersed in a wood flake matrix. It has been tested at pilot scale where it eliminated all dissolved metals from an AMD with high metal concentrations. An essential part of the good performance of DAS treatment is the natural attenuation in a lagoon prior to DAS treatment, as it oxidizes part of the Fe(II) load and precipitates it as Fe(III) oxyhydroxides.

Keywords: acid mine drainage, dispersed alkaline substrate, natural attenuation, metal removal.

Introduction

Acid Mine Drainage (AMD) is one of the principal environmental problems caused by sulphide mining activity. A clear example for this pollution is the Iberian Pyrite Belt (IPB), where two of the main rivers, Tinto and Odiel, present high levels of AMD pollution. Conventional passive treatment systems cannot be used to remediate AMD with high metal concentrations, because clogging and loss of reactivity occurs quickly. In order to overcome these problem, a dispersed alkaline substrate (DAS) made up of calcite sand dispersed in wood flakes was developed at laboratory (Rotting et al. 2008a), pilot (Rötting et al., 2008b), and full scale (Caraballo et al., 2008, 2009). However, total metal removal was not achieved in such previous experiences due to the high pH required to precipitate solid phases of divalent metals such as Zn, Mn, Cd, Co and Ni. This summary shows the first results from a new pilot experience under operation, based on the AMD treatment by adding a DAS system with caustic

magnesia (MgO), subsequent to the already tested DAS of calcite. The MgO–DAS performance had been already tested at laboratory column scale (Rötting et al, 2008c).

Methods

The treatment system was installed in the abandoned mine complex “Monte Romero” in Cueva de la Mora village (Almonaster la Real, Huelva, Spain) (Fig. 1A). The system is subdivided in two different parts: (1) a natural attenuation pretreatment in a lagoon and (2) the DAS passive treatment system. A lagoon with 100 m³ of capacity stores the AMD from the mine shaft and by microbial activity an important quantity of Fe is oxidized and precipitated. A pipe takes the AMD from the lagoon to the input of DAS treatment, which is infiltrated into two tanks of 3 m³ in volume filled with calcite–DAS reactive mixture and one tank of 1 m³ filled with MgO–DAS mixture, and connected in series with four decantation ponds with 6 m³ of capacity (Fig. 1B). The AMD emerging from the mine shaft displayed a pH near 3, a net acidity over 1800 mg/L as CaCO₃ equivalents and contains a mean concentrations of 440 mg/L Zn, 330 mg/L Fe (95% Fe(II)), 3600 mg/L sulphate, 250 mg/L Ca, 100 mg/L Al, 15 mg/L Mn and 0.1–3 mg/L Cu, As, Pb, Cr, Cd, Co and Ni. The flow of the AMD in the system is regulated at the input of the first tank to 1 L/min, to obtain a residence time of 1.5 days in each limestone tank, 3 days in each decantation pond and 0.5 days in the MgO tank. The hydrochemistry of the water was sampled at different points throughout the main parts of the system at least twice a month. The physicochemical parameters were measurement in situ, and the major chemical composition was analyzed by ICP–OES.

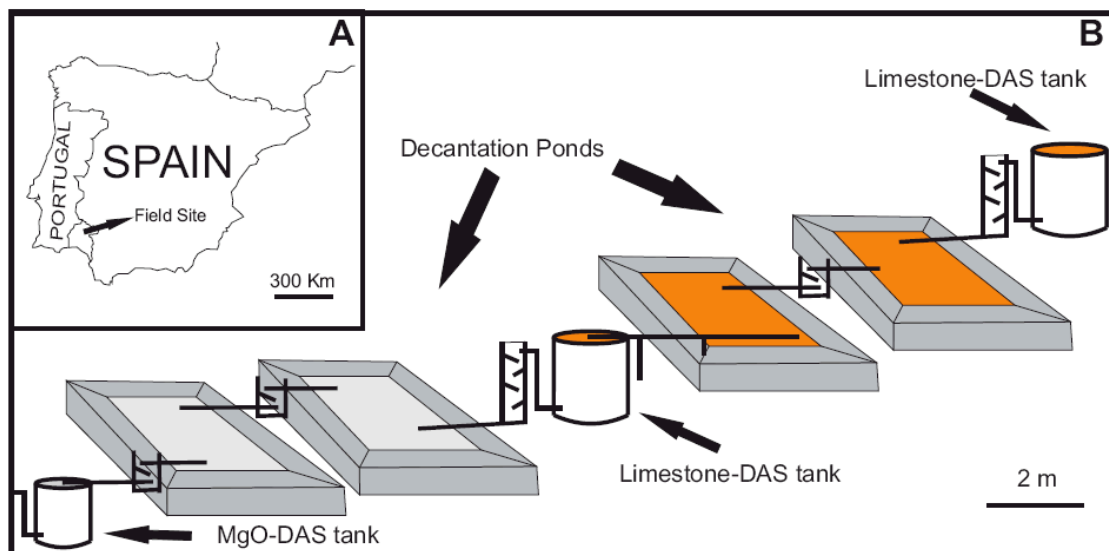


Figure 1 Location of field site (A) and schematic view of DAS passive treatment system (B).

Results and discussion

The monitoring performed during 4 months has shown a total metal removal from AMD. As can be observed in Fig. 2A in the natural attenuation pretreatment in the lagoon there is an important Fe removal, from 330 to 250 mg/L, together with which at least 70% of total As is eliminated (Fig. 2B). In the limestone-DAS, pH value increased from 2.8 to 6 due to calcite dissolution, and Fe and Al oxyhydroxides (schwertmannite and basaluminite) precipitated removing completely both metals from the water. Moreover, As, Cu, Cr and Pb were also eliminated (Fig. 2), sorbed and coprecipitated with the hydroxides. Finally, magnesium oxide hydration to $Mg(OH)_2$ and subsequent dissolution increased pH from 6 to 8.5 causing the precipitation of divalent metal (Zn, Mn, Cd, Co and Ni) solid phases (hydroxides and carbonates) and achieving their complete removal from the water (Fig. 2).

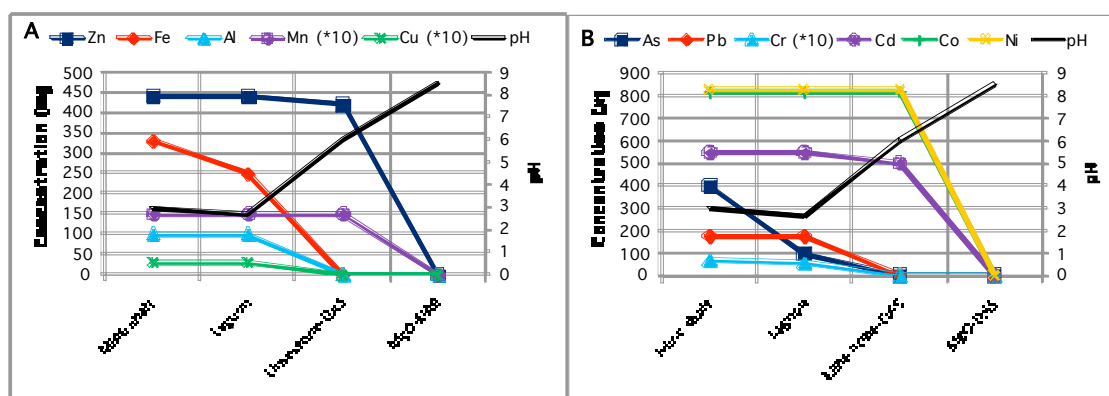


Figure 2 Major elements and pH (A) and trace elements and pH (B) distribution at the outflow points of the different components of the system.

Conclusions

A pilot scale passive remediation system, made up of a natural attenuation lagoon, two limestone-DAS tanks and a MgO-DAS tank has been able to eliminate all dissolved metals from an AMD source with high metal concentrations. An essential aspect was the installation of a lagoon prior to DAS, as it oxidized and precipitated a significant load of Fe and improved the DAS performance.

References

1. Caraballo M.A., Rötting T.S., Macías F., Nieto J.M. y Ayora C. (2009). Field multi-step limestone and MgO passive system to treat acid mine drainage with high metal concentrations. *Appl. Geochem.*, 24, 2301-2311

2. Caraballo M.A., Macías F., Rötting T.S., Nieto J.M. y Ayora C. (2008). Funcionamiento Geoquímico de un Sistema Calizo de Tratamiento Pasivo de Aguas Ácidas de Mina (Faja Pirítica Ibérica, Huelva). *Macla*, 9, 61–62
3. Rotting, TS; Thomas, RC; Ayora, C, Carrera J. (2008a): Passive treatment of acid mine drainage with high metal concentrations using dispersed alkaline substrate. *Journal of Environmental Quality*, 37: 1741–1751
4. Rötting T.S., Caraballo M.A., Serrano J.A., Ayora C. y Carrera J. (2008b). Field application of calcite Dispersed Alkaline Substrate (calcite–DAS) for passive treatment of acid mine drainage with high Al and metal concentrations. *Appl. Geochem.*, 23, 1660–1674.
5. Rötting, T.S.; Ayora, C.; Carrera, J. (2008c) Improved passive treatment of high Zn and Mn concentrations using Caustic Magnesia (MgO): Particle size effects. *Environmental Science & Technology*, 24 (42), 9370–9377.