A comparison of charcoal- and slag-based constructed wetlands for acid mine drainage remediation

Craig Sheridan*, Kevin Harding, Edward Koller and Antonio De Pretto
Industrial and Mining Water Research Unit, School of Chemical and Metallurgical Engineering, University of the Witwatersrand, Private Bag 3, Wits, 2050, South Africa

Abstract

Subsurface-flow constructed wetlands (CW) with charcoal- or slag-based bed matrices were investigated for their potential use in remediating acid mine drainage (AMD). A CW is effectively a reactor in which some components of the wastewater are broken down by the organisms occurring within the CW, whilst others may be degraded by physico-chemical processes or a combination thereof. Two 200 ℓ small-scale CWs were built at the University. Commercially available charcoal and <19 mm basic oxygen furnace (BOF) slag were used as the bed matrices and the units were planted with a variety of plants. The units were exposed to an artificial AMD. The results showed that the systems removed almost all soluble iron and more than 75% of the sulphate. Both CWs were able to increase the pH of the AMD.

Keywords: AMD, charcoal, slag, constructed wetlands, remediation

INTRODUCTION

Background

Acid mine drainage (AMD) is liquid drainage from existing or historic mining operations which is typically characterised by low pH and high concentrations of heavy metals such as iron and manganese, in addition to high sulphate concentrations (Peppas et al., 2000; Potgieter-Vermaak et al., 2006). It is mainly associated with mining and quarrying, and is formed when sulphide-bearing minerals are oxidised in the presence of water and oxygen (Potgieter-Vermaak et al., 2006; Akcil and Koldas, 2006; Lindsay et al., 2011). In the AMD formation process, water which passes through abandoned or existing mines, tailings dumps or waste rock, reacts with the exposed iron-sulphide minerals. These iron-sulphide minerals are oxidised, usually by oxygen, resulting in acidic, sulphate-rich liquid being formed, with iron and other heavy metals present in their soluble form (Ziemkiewicz, 1998; Potgieter-Vermaak et al., 2006). The metal content of AMD is a result of the type and composition of the material found in the mineral being oxidised (Akcil and Koldas, 2006).

AMD has long been considered an environmental hazard (Sheoran and Sheoran, 2006) and can cause long-term damage to waterways and to the biodiversity of ecosystems that rely on these waterways (Akcil and Koldas, 2006). In addition to its acidic nature, some AMD effluents contain cyanides, and/or heavy and toxic metals. In literature, it has been proposed that the heavy metal content of AMD is of greater environmental concern than the acidity of the effluent (Sheoran and Sheoran, 2006). AMD presents a particular problem for South Africa, where large deposits of natural reserves, most notably gold and coal, occur (SouthAfrica.info, 2013). As such, mining of these resources is one of the largest industries in the country. The current production of AMD is primarily as a result of current and historic coal and gold mining operations (Potgieter-Vermaak et al., 2006; Tutu et al., 2008). The extraction of these minerals from mines, whether open-pit or shaft, often results in wastewater and effluent (Akcil and Koldas, 2006). Furthermore, because of the high cost of treating AMD, a trend has developed in South Africa in which mining companies submit to the closure of an AMD-affected mine in an attempt to avoid costs associated with treating the AMD (Labuschagne et al., 2005). Within the Gauteng Province of South Africa, the presence of soluble, and hence mobile, uranium poses an additional threat to potentially impacted receptors of AMD (Tutu et al., 2008).

Treating AMD

Treatment options

Various strategies for AMD treatment and mitigation have been proposed including primary prevention (the prevention of acid-producing processes), secondary control (the prevention of acid migration or movement after formation) and tertiary control (the collection and treatment of effluent). Primary prevention is not always feasible as the prediction of the potential of a process to create AMD is exceedingly challenging and costly (USEPA, 1994). Furthermore, this would vary from site to site and between mines as the AMD compositions frequently differ. Secondary control is often not feasible as there is no standardised method for ranking, measuring, and reducing AMD (Akcil and Koldas, 2006). Tertiary control is typically conducted by a number of different methods including, but not limited to, lime neutralisation (Sheoran and Sheoran, 2006), Gypsum cation-anion exchange (Akcil and Koldas, 2006), reverse osmosis (Squires et al. 1983), etc. However, active treatment is expensive and, as such; AMD is often left untreated (Diz, 1997). Thus, there is a need for a cheap, effective passive treatment system which is efficient at removing AMD.

This paper was originally presented at the 2012 Water Institute of Southern Africa (WISA) Biennial Conference, Cape Town, 6–10 May 2012.

* To whom all correspondence should be addressed.
☎ +27 11 717-7592; e-mail: craig.sheridan@wits.ac.za