The feasibility of a permeable reactive barrier to treat acidic sulphate- and nitrate-contaminated groundwater

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Abstract

Manufacturing of fertilisers at a site in Johannesburg, South Africa, has resulted in the localised contamination of the shallow groundwater. The latter migrates through the weathered granite zone and emerges as base flow to the natural drainage system that ultimately exits the site. The water quality is acidic and is contaminated with respect to nitrate, sulphate, aluminium, fluoride and manganese. Treatment of this water is therefore necessary before discharge.

In situ passive rehabilitation of groundwater using a permeable reactive barrier offers a potentially cheaper alternative to conventional treatment technologies for acidic groundwater. Feasibility criteria used in this study were based on the suitability of the site for the installation of a permeable reactive barrier (PRB) and on the amenability of contaminants for treatment using locally available reactive media. The suitability of the reactive media was assessed from laboratory leach tests on reactive materials (mushroom compost, dolomite and limestone). These tests were followed by batch testing of various composites of the mushroom compost and the neutralisation gravel media (dolomite and limestone for comparison).

The results of the study indicated that the site conditions were potentially suitable for the installation of a PRB but that the mushroom compost is not suitable as a carbon source. This was indicated by the limited success achieved in reducing sulphate concentration and the poor quality of the leachate with respect to sodium, chloride, ammonia and potassium. The neutralisation capacity of the dolomite aggregate was similar to that of the limestone for the batch tests. However, it can be expected that the long-term performance would be inhibited by clogging and armouring by aluminium and manganese precipitates.

Keywords: permeable reactive barrier, nitrate, groundwater, dolomite

Introduction

A large fertiliser manufacturing facility near Johannesburg, South Africa, has been in operation since 1896. Various activities have been undertaken on the site, from the manufacture of explosives for the military to the production of fertilisers and associated chemicals. Site assessments of the soil, surface and groundwater quality show that the seepage of contaminated water from the historical fertiliser factory area has resulted in the localised contamination of the shallow groundwater (SRK, 2002).

The shallow groundwater migrates through the highly weathered granite zone and emerges as base flow to the stream flowing through the contaminated area. The stream flows to the southwest where it joins an east-west tributary of the main river flowing through the site (Fig. 2). The flow of 3.1 m^3/h (flow varies from 1.3 m^3/h to 20 m^3/h) is acidic with concentrations of nitrate, sulphate, aluminium, fluoride and manganese in excess of the recommended receiving water quality objectives (Table 1).

The current treatment strategy for wastewater and effluent is the addition of lime to neutralise the water to a pH of 7. The water is gravitated to an evaporation dam and excess water is sprayed onto grasslands for nitrogen uptake. Effluent minimisation and alternative treatment strategies are being considered to reduce the impact on groundwater and to improve the quality in streams to within the compliance levels stipulated in the effluent site permit.

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The initial proposal for rehabilitation of the site's contaminated groundwater was for the installation of a seepage cut-off trench immediately down-gradient of the factory area where the majority of the contamination emanated (SRK, 2001). Subsequent investigations indicated that the depth to bedrock is extremely variable (0.5 m to >12 m) making the installation of a cut-off trench along the proposed trench line neither practical nor effective for intercepting groundwater emerging into the stream further down-gradient (SRK, 2003).

A more practical option would be to intercept the groundwater where it is laterally constrained within the channelled stream approximately 1km down-gradient of the factory and where the depth to bedrock is shallower than that typically associated with the deep weathering profile on the slopes of the granite outcrop higher up the hill (SRK, 2003). *In situ* passive rehabilitation of groundwater using a permeable reactive barrier at this point could offer a potentially cheaper, low maintenance and self-sustaining alternative to pumping this water up the hill to the effluent treatment plant.

A permeable reactive barrier (PRB) is defined as 'an engineered treatment zone of reactive media that is placed in the subsurface and designed to intercept a contaminant plume, provide a flow path through the reactive media and transform the contaminants into an environmentally acceptable form to attain remediation concentration goals down-gradient of the barrier' (Carey et al., 2002).

An anoxic limestone drain (ALD) comprising a buried bed of limestone is an example of a PRB. The acidic water reacts with the limestone aggregate and results in the addition of alkalinity to the water. Reducing conditions are induced to limit the potential for armouring by the precipitation of iron or manganese oxides on the aggregate. A carbon source may be mixed with the limestone to enhance reducing conditions. A typical