Prediction of the environmental impact and sustainability of large-scale irrigation with gypsiferous mine-water on groundwater resources

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Abstract

Irrigation of agricultural crops is one of the most cost-effective options for the utilisation of gypsiferous mine wastewater. In addition, it creates the opportunity to produce crops during the dry season. Gypsum is a slightly soluble salt and concentrating the gypsiferous soil solution through crop evapotranspiration precipitates gypsum in the soil profile, removing it from the water system and reducing the potential for groundwater pollution. In previous research, it was found that crops can be commercially produced under irrigation with gypsiferous mine-water with no obvious impact on groundwater in the short term (3 years). It was, however, recommended that monitoring should continue to confirm findings over a longer period and for different conditions. A research project was therefore initiated in 2001 to determine the impact of irrigation with several gypsiferous water/soil combinations on crop performance, soil properties and groundwater quality. Field trials were carried out in South Africa on three mines: Kleinkopjé and New Vaal Collieries (Anglo Coal), and at Syferfontein (Sasol). Different crop and pasture species were grown on different soil types under centre-pivot irrigation with different mine-water qualities.

Intensive monitoring systems were established in each irrigated field to determine the components of the soil-water and salt balance. Boreholes were also installed to monitor groundwater level and quality. Field water and salt balance data were used for calibration and validation of the mechanistic, generic crop, Soil-Water Balance (SWB) Model. The results of the field trials indicated that high crop and pasture yields can be obtained, provided site selection, land preparation, fertilisation and irrigation water management are appropriate. The results of the soil-water and salt balance studies indicated that considerable volumes of mine-water can be used and substantial amounts of salts can be removed from the water system through precipitation of gypsum in the soil profile. The groundwater impact was limited based on borehole measurements, indicating the presence of a zone of attenuation between the cropped soil profile and groundwater, but this should be monitored over a longer period. With appropriate management, water and salt runoff, and under specific conditions, drainage and salts leached can be intercepted, thereby minimising unwanted impacts on groundwater. Thirty-year scenario simulations were run with SWB and the generated salt loads from this model were used as input into a separate groundwater model in order to predict the likely long-term effects of irrigation with gypsiferous mine-water on groundwater. The results of these simulations showed that while salts reached the groundwater, there was a drop in concentration of the plume as it moved away from the irrigated area. This was due largely to dilution by infiltration from rainfall recharge and the dispersive characteristics of the aquifer. The simulations also showed the importance of matching the amount of drainage from an irrigated site with the transmissivity and storage properties of the aquifer below. These results suggest that large-scale irrigation with gypsiferous water could be viable if irrigated fields are carefully sited to prevent waterlogging and are well managed. A site-specific approach is essential.

Keywords: irrigation, gypsiferous, mine-water, groundwater, simulations, SWB

Introduction

Mining in South Africa generates large volumes of mine wastewater that have the potential to adversely affect an already scarce water resource if not properly managed (Tanner et al., 1999). Disposal of mine wastewater is a world-wide problem, occurring wherever operating mines, as well as closed underground and open-cast workings, are found (Pulles et al., 1995). The type of wastewater emanating from mines depends largely on the chemical properties of the geological materials that come into contact with the water (Thompson, 1980). The concentrations of salts and other constituents frequently render such waters unsuitable for direct discharge to the river systems, except in periods of high rainfall when adequate dilution capacity is present, and controlled release is permitted by the regulatory authorities (Pulles et al., 1996). In many cases the mine effluent is gypsiferous, meaning that it is dominated by calcium and sulphate ions. This occurs when acid mine drainage (AMD) is neutralised by naturally occurring calcite or dolomite, or by active liming, which may be required to correct pH and precipitate out metals (Van Staden, 1979).

The potential of gypsiferous mine-water for use in crop irrigation was first evaluated in South Africa by Du Plessis (1983), using a steady-state chemical equilibrium model (Oster and

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