On the use of electrical resistivity methods in monitoring infiltration of salt fluxes in dry coal ash dumps in Mpumalanga, South Africa

Innocent Muchingami[1,4]*, Jacobus Nel[5], Yongxin Xu[1], Gideon Steyl[2] and Kelley Reynolds[3]

[1]*Department of Earth Sciences, University of the Western Cape, Bellville, South Africa*

[2]*Institute for Groundwater Studies, University of Free State, Bloemfontein, South Africa*

[3]*Applied Chemistry and Microbiology, Sustainability, Eskom Research, Technology and Development, Rosherville, South Africa*

[4]*Department of Applied Physics, National University of Science and Technology, Bulawayo, Zimbabwe*

[5]*GCS Water & Environment (Pty) Ltd, Johannesburg, South Africa*

ABSTRACT

One of the principal environmental concerns relating to coal combustion waste disposal is the potential for groundwater contamination from salt fluxes and trace elements that may be leached into the underlying groundwater system. Since changes in moisture and salt concentrations usually provide contrasts in electrical properties against the host media, electrical resistivity methods can be used to monitor ingression of solute plumes as well as to detect any preferential flow paths within the ash medium. In this study, 2D electrical resistivity tomography was used to monitor brine (10% NaCl) water ingression through the unsaturated zone of a dry coal ash dump at a power station, Mpumalanga, South Africa. This was after the initial laboratory determination of the relation between electrical resistivity and moisture/salt content for the ash dump. The results showed that infiltration plume progression was more pronounced in the vertical direction, suggesting that moisture movement is mainly due to gravitational pull. There was no evidence of preferential flow within the ash medium, although the different infiltration rates for different sites suggested different permeability within the unsaturated zone.

Keywords: coal ash dumps, brine infiltration, cementation factor, electrical resistivity tomography, time lapse survey

INTRODUCTION

Despite environmental concern, coal-fuelled thermal power stations remain the main sources of electricity generation in most developing countries. For instance, more than 90% of South Africa's electricity is generated from the combustion of coal (Kruger and Krueger, 2005). However, large quantities of solid residues (ash) remain after the combustion of coal during the electricity generation process. These large volumes of ash are disposed of in holding ponds or ash heaps, which are often referred to as ash dumps. The environmental impact of ash dumps consists of at least two aspects:

- emission and deposition of enormous amounts of coal ash, polluting air, water and soil with ash particles (including the problem of huge ash dumps); and
- leaching of microelements (including toxic heavy metals) as well as major salts from wastewater used for dust suppression.

Thus, there is a need to implement a close monitoring mechanism for the environmental impact assessment of the dangers associated with such ash dumps. However, in order to implement an efficient monitoring scheme, a thorough knowledge of the migration of solute fluxes within the ash dump is required.

Since changes in moisture and salt concentrations usually provide contrasts in electrical properties in the host media, electrical resistivity methods can be used as a tool in monitoring the progression of the water/salt plumes, as well as to detect any preferential hydraulic paths within the ash medium. Several studies have used electrical resistivity techniques to investigate changes in resistivity because of contaminant migration through the unsaturated zone (e.g., Greenhouse and Harris, 1983; Macfarlane et al., 1983; Bevc and Morrison, 1991; Muhktar et al., 2000; Abdullahi et al., 2011). Rogers and Kean (1980) reported successful monitoring of groundwater contamination at a fly ash disposal site. In particular, 2D electrical resistivity tomography (ERT) has frequently been used to monitor water infiltration into the soil or at waste disposal sites (e.g. Mukhtar et al., 2000). Barker and Moore (1998) reported a successful 2D ERT time-lapse survey for the infiltration of water in the unsaturated zone after 10 hours of irrigation in Birmingham, England. The same methods were also used to map unsaturated zone transport using the salt tracer methods (e.g. White, 1988; Bevc and Morrison, 1991; Kemna et al., 2002), and to delineate contaminant movement, (e.g. Osiensky and Donaldson, 1995; Benson et al., 1997; Atekwana et al., 2000; De la Vega et al., 2003 and Zume et al., 2006). ERT techniques can also be used to assess the flow of moisture in dry ash dumps, in order to develop an assessment of dynamic processes in the subsurface environment of the dump. Both natural infiltration processes and specifically designed tracer tests can be monitored over periods of time that can last from a few hours to several years (e.g. Arora et al., 2005).

In this study, 2D ERT techniques were used in a time-lapse infiltration survey at a power station's dry ash dump, in Mpumalanga, South Africa (Fig. 1). The ash rehabilitation procedure at the ash dump is summarised in Fig. 2.

The main objective of this research was to develop a field monitoring technique that will enable the assessment of potential solute transport in the unsaturated zone dry ash dumps. The specific objectives were:

* To whom all correspondence should be addressed.
☎ +27 21 959 2439; e-mail: ikmuchingami@gmail.com
Received 31 May 2012; accepted in revised form 9 July 2013.

http://dx.doi.org/10.4314/wsa.v39i4.7
Available on website http://www.wrc.org.za
ISSN 0378-4738 (Print) = Water SA Vol. 39 No. 4 July 2013
ISSN 1816-7950 (On-line) = Water SA Vol. 39 No. 4 July 2013