Comparison Between the Geohydrological Properties of Wet and Dry Ash Disposal Sites.

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KEYWORDS: wet, dry, ash disposal, geohydrologic properties, environmental impact

ABSTRACT

In South Africa coal ash and high salinity process water is co-disposed on both wet and dry ash disposal sites. The ash has the potential to adsorb some of the salts and act as a salt sink. If these salts are desorbed over time the ash disposal sites have the potential to impact on the ground and surface water resources. Geohydrological parameters can be used to describe and compare how water and salts enter and move through the subsurface environment. Identifying these parameters for ash disposal sites can benefit water resource managers to evaluate their potential environmental impact.

The resistivity values from the geophysics were used to identify areas with different EC linked to soluble salts and therefore potential impact on the environment should the salts leach from the ash. Pore water EC of the boreholes seem to be able to explain some of the electrical resistivity variability on each site, but not between the sites. The dry ash disposal facilities seem to have much higher salt concentration in the ash matrix. The low salt concentration of the wet ash disposal facilities do not imply less environmental impact, as the volume of water with the lower concentration salts are higher. The hydraulic properties give an indication of the relative infiltration rates with the dry ash site slightly higher than the wet ash site. The water infiltrating the dry ash sites must first saturate the ash to field capacity before it can start filtrating down.

Based on the above information the dry ash disposal sites will store higher concentration pore water and can accommodate some infiltrating water before if will start leaching to the subsurface. If this infiltrating water cannot be prevented, then the higher potential infiltration rates could leach the salts from the ash faster, compared to wet ash disposal. The environmental impact of the dry disposal sites would be significantly bigger due to the higher salt concentrations. The assessment of geohydroloical parameters have therefore helped in the comparison of the environmental risk posed by wet ad dry ash disposal sites.

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INTRO

In South Africa coal ash and high salinity process water is co-disposed on both wet and dry ash disposal sites. The ash has the potential to adsorb some of the salts and act as a salt sink. If these salts are desorbed over time the ash disposal sites have the potential to impact on the ground and surface water resources. The presence of high salinity process water and the fly ash hydraulic parameters can give significant information for determining probable leaching concentrations and zones of the ash disposal sites.

Geohydrological parameters can be used to describe and compare how water and salts enter and move through the subsurface environment. Identifying these parameters for ash disposal sites can benefit water resource managers to evaluate their potential environmental impact.

In order to solve this complex environmental problem a thorough knowledge and understanding of salt and water movement within this environment must be obtained. A comparison of the geohydrological properties will be made between the wet and dry sites to evaluate their risk to the environment.

The objectives of the paper are to determine the hydraulic and transport properties of ash and their impact on water (brine) flow and saturation through the dump. This data contributes to the conceptual models of the sites and can therefore assist in the assessment of potential environmental hazards and risks.

The objectives are the following:

- Use electrical resistivity geophysics as a non-intrusive method to identify salt and moisture concentrations in the ash disposal site. The electrical resistivity varies between different geological materials and depends mainly on variations in density, water content and dissolved ions (salts) in the subsurface.
- Drilling of boreholes for ash characterization and hydraulic testing.
- Determine in-situ hydraulic characteristics for the ash disposal sites.

METHODS

Geophysics

Measurement of the resistivity of the ground is carried out by transmitting a controlled current (I) between two electrodes pushed into the ground, while measuring the potential (V) between two other electrodes. Direct current (DC) or a very low frequency alternating current is used, and the method is often called DC-resistivity. The resistance (R) is calculated using Ohm's law. An Abem SAS 1000 terrameter and ES 464 switching unit were used for the field surveys. Four multicore cables and stainless steel pegs were used with the "roll-along" surveying method.

The RES2Dinv version 3.52-inversion program was used to invert the measured data after being manually and mathematically filtered. The 2-D model used by this program divides the subsurface into a number of rectangular blocks that will produce an apparent resistivity pseudo section that agrees with the actual measurements. [4,5]. A forward modelling subroutine is used to calculate the apparent resistivity values, and a non-linear least-squares optimisation technique is used for the inversion routine.

Drilling
A combination of Air Flush Coring and direct circulation air percussion drilling were used to drill the boreholes. Air flush Coring uses a conventional drilling rig and compressor with a specialized drill bit that cores the ash without the need for water or lubrication for cooling of the drill bit. The advantage to use this air drilling technique is that the coring method does not use water to cool down the drill bits as in normal rock coring providing samples that are chemically unchanged. Samples were collected at one meter intervals.

Moisture Content
Samples for moisture content were tightly sealed after drilling and transported to the lab. In the lab, a foil container was weighed to an accuracy of 0.01g before placing a small portion of ash in it. Once the combined weight of the container and the ash sample was recorded, the samples were placed in an oven and dried at 105°C for 24 hours. Samples were weighed for a second time. Moisture content of the ash was calculated as follows:

$$\phi = \frac{WetAsh - DryAsh}{DryAsh}$$ **Equation 1**

Where Ø = moisture content

Pore Water Electrical Conductivity (EC)
In order to measure the EC of the ash, 2g of oven dried ash was combined with 20ml of distilled water and mixed thoroughly. The sample was left to settle for 5-10min before being filtered through 0,45µm pore size filter. Once filtered, the EC was measured using a handheld EC meter. Pore water EC was calculated by multiplying the lab measured EC with 10 (to allow for the 1:10 dilution) and dividing by the moisture content of the original sample.

Hydraulics
Both constant head and falling head infiltration methods were used to calculate the hydraulic properties of the ash.
For the constant head method an infiltrometer using the Mariotte Bottle Principle was used to facilitate the constant head levels while recording the infiltration rate. The hydraulic conductivity is calculated using the Glover equation[1] (Equation 2) :

$$K_{sat} = \frac{CQ}{2\pi H^2}$$

Equation 2

Where:

Q = discharge rates from flow measuring reservoir
H = Height of water in the hole
R = Radius of the hole
C = Constant based on the depth of water column and radius of borehole

For high yielding holes the constant head infiltrometer could not sustain the flows for sufficient long periods and a falling head method was used instead. For the falling head method the hole is filled with water as quickly as possible at the start of the test and then allowed to infiltrate into the soil while measurements of head are recorded. The rate of infiltration is directly linked to the hydraulic conductivity. Water infiltration was repeated at least three times at each test site to ensure saturated conditions. The data derived from these holes were interpreted using the Bouwer and Rice equation [3] (Equation 3).

$$K = \frac{r_c^2 \ln(R_e / r_w)}{2d} \frac{1}{t} \ln \frac{h_o}{h_t}$$

Equation 3

Where:

K = Hydraulic conductivity
r_c = radius of the casing where the rise of the water level is measured.
R_e = radial distance over which the difference in head is dissipated
h_o = Head in piezometer at $t_o = 0$
h_t = Head in piezometer at $t > t_0$
r_w = effective radius of piezometers
d = length of the open section of piezometer

DATA

The geophysics was used to map variations in electrical resistance that are related to salt and water content. The results of the electrical resistivity are shown in Figure 1 and were used to position exploration boreholes. Results of moisture content and electrical conductivity (used as a surrogate for total dissolved solids) are shown for two boreholes on each dump (Figure 2).
Figure 3 shows the results of a number of hydraulic tests conducted in the vicinity of the boreholes shown in Figure 1.

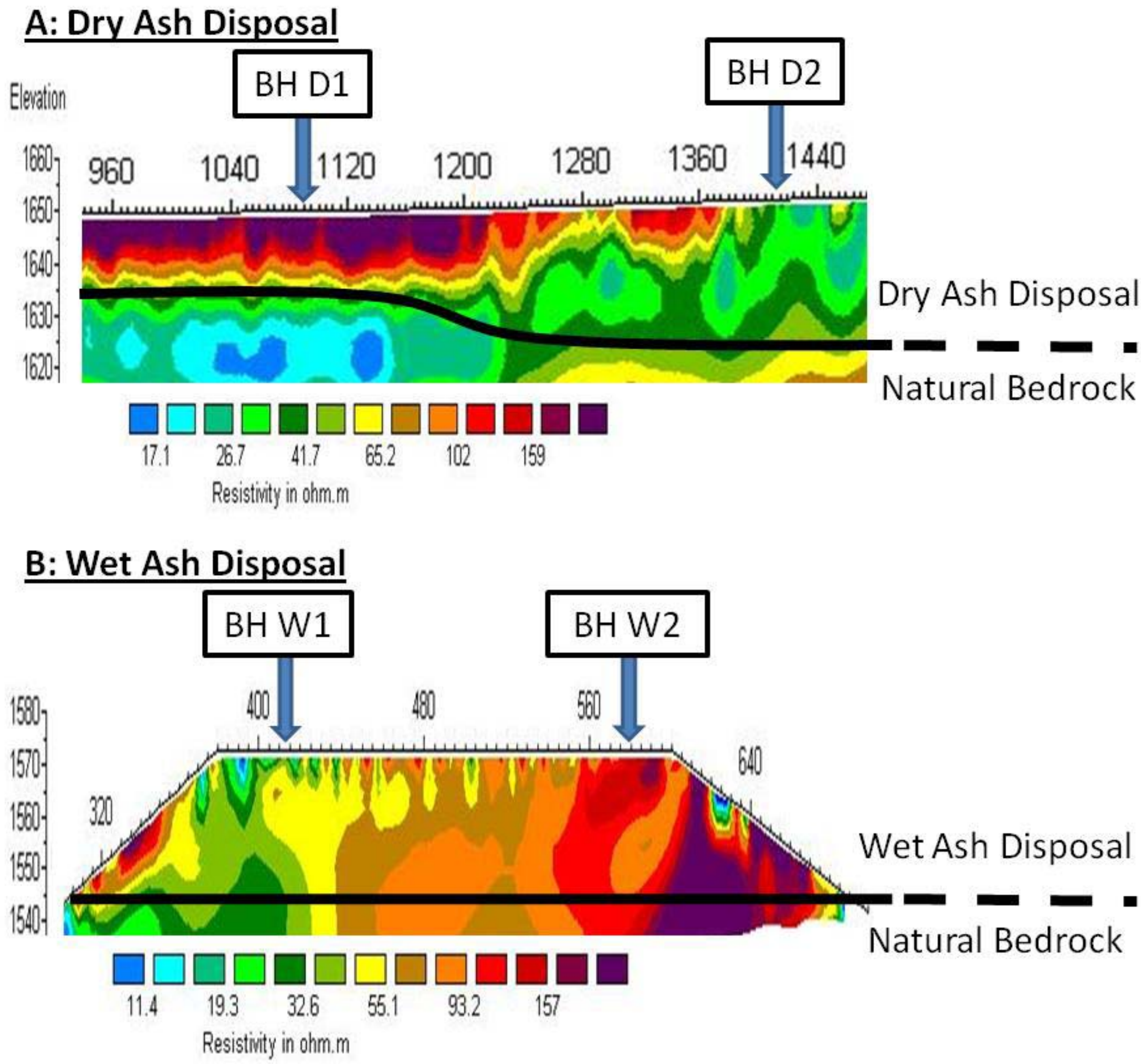

Figure 1: Comparison between 2D electrical resistivity profiles of a Dry (A) ash disposal site and a Wet (B) ash disposal site. Borehole positions where additional data was gathered is also shown at both sites.

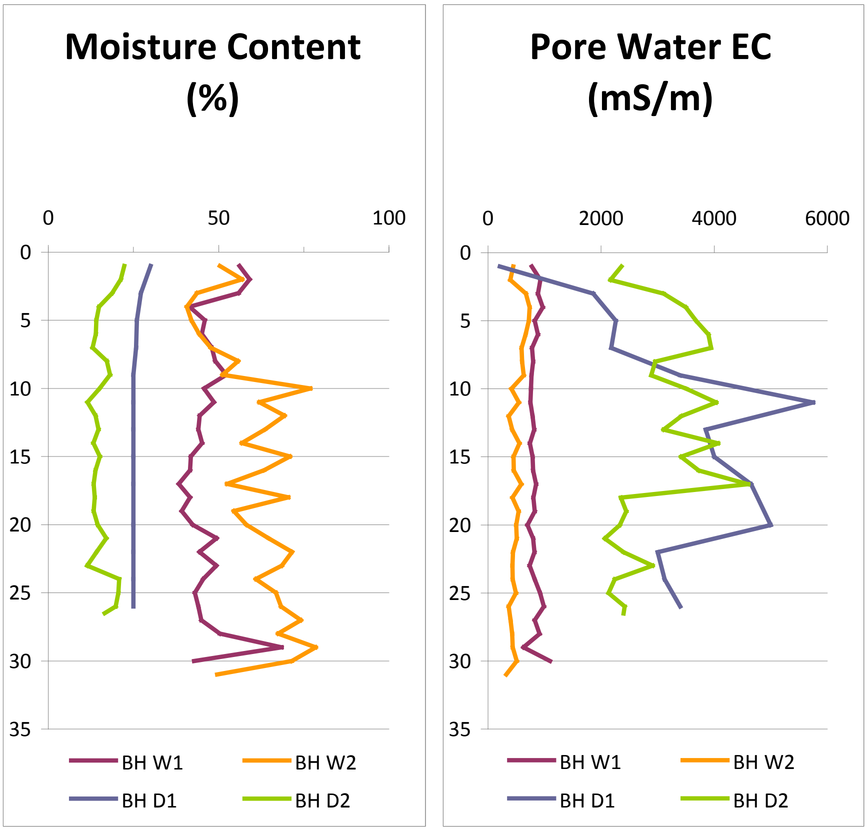

Figure 2: Comparison between the moisture content and pore water electrical conductivity for wet and dry ash disposal sites.

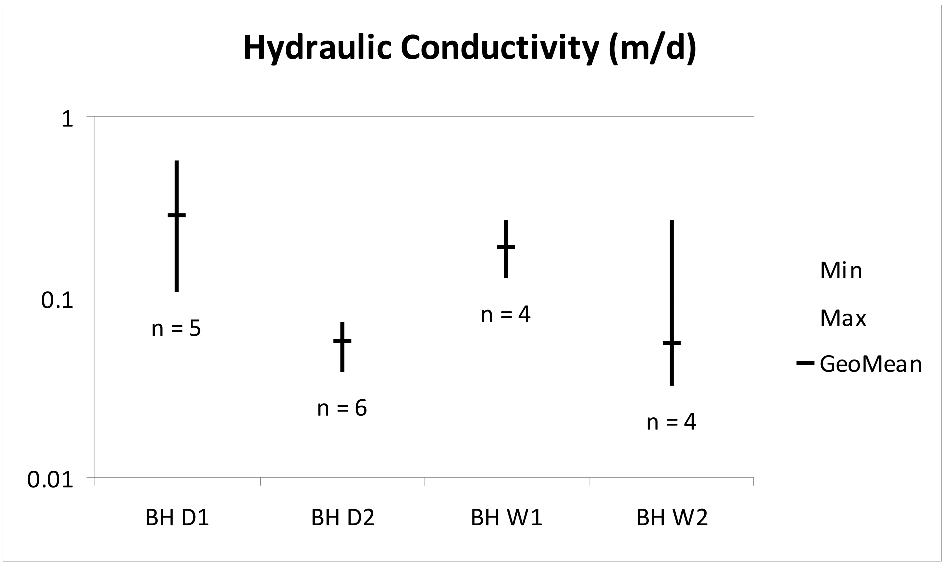

Figure 3: Comparison between hydraulic conductivity for boreholes drilled on the wet and dry ash disposal sites (High - low – Geometric Mean plot).

DISCUSSION

Electrical resistivity values for both the dry and wet ash disposal sites show very similar ranges of between 11 and 200 ohm.m. Both sites have areas with high resistivity (Figure 1) in the order of 160 ohm.m and areas with low resistivity in the order of 15 ohm.m. The pore water EC (Figure 2) at shallow depth for BH D1 is much lower than for BH D2 and correlates well with the higher resistivity at BH D1. This suggests that the low resistivity values measured at the dry ash disposal site has higher EC and therefore soluble salts compared to the high resistivity areas. The wet ash disposal site shows lower resistivity values at BH W1 compared to BH W2. This compares well to the higher pore water EC measured at BH W1 compared to BH W2. The resistivity values from the geophysics can therefore be used to identify areas with different EC linked to soluble salts and therefore potential impact on the environment should the salts leach from the ash.

Pore water EC of the boreholes seems to be able to explain some of the electrical resistivity variability on each site, but not between the sites. BH D2 and BH W1 was drilled into ash with similar electrical resistivity of about 40 ohm.m. The EC of soluable salts in these two holes are significantly different with BH D2 showing values around 3000 mS/m and BH W1 showing values around 500 mS/m. The moisture content of the ash might be the link here, with BH D2 showing moisture content values of about 20%, while BH W1 shows moisture content values of 50 to 60%. The lower moisture content of BH D2 can increase the resistivity, even though the salt content is higher in BH D2.

The dry ash disposal facilities seem to have much higher salt concentration in the ash matrix. The low salt concentration of the wet ash disposal facilities do not imply less environmental impact, as the volume of water with the lower concentration salts are higher (Figure 2). The salts in both systems are available to leach if water manages to flow through the ash dump/dam.

The hydraulic properties give an indication of the relative infiltration rates with the dry ash site slightly higher than the wet ash site. The water infiltrating the dry ash sites must first saturate the ash to field capacity before it can start filtrating down. The field capacity of the ash disposal sites is between 35% and 42% moisture content. [2] The dry ash disposal sites can therefore accept some infiltrating water before it starts leaching out the bottom of the site, while the wet disposal sites are over saturated and would leach out the bottom for all infiltrating water on the site.

RECOMMENDATION

Electrical resistivity profiling has been shown to identify areas of higher salt concentration in both wet and dry ash disposal sites. The concentration of salts in the pore water of the dry ash disposal site were significantly higher than that of the wet ash with values of 3000 mS/m and 500 mS/m for the dry and wet ash sites respectively. The moisture content values for the dry ash disposal sites were measured at 20 to 25%, while the wet sites had values of 50 to 60%. With a field capacity of 35% the wet ash sites will leach saline water out of the sites from any infiltrating water, while the dry site can accommodate some moisture before reaching field capacity. The dry disposal sites show slightly higher infiltration rates compared to the wet disposal sites. This means that water infiltrating the dry disposal sites will move through the dump faster and potentially leach the salts from the ash matrix faster.

Based on the above information the dry ash disposal sites stores higher concentration pore water and can accommodate some infiltrating water before if will start leaching to the subsurface. If this infiltrating water cannot be prevented, then the higher water infiltration rates on the dry disposal sites will leach the salts from the ash faster compared to wet ash disposal. The environmental impact under these conditions will be significantly bigger due to the higher salt concentrations. The assessment of geohydroloical parameters have therefore helped in the comparison of the environmental risk posed by wet ad dry ash disposal sites.

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