Hydraulic and Transport Properties of Ash Dumps

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ABSTRACT

Coal ash disposal in South Africa is accomplished by either wet disposal as slurry into ash dams or dry disposal with a conveyor belt system. Coal ash and high salinity process water are co-disposed on ash dams and dumps with the intention of capturing the salts in the ash matrix. In order to evaluate the sustainability of the ash dumps as a salt sink this study aims to characterize the hydraulic and transport properties of the ash dumps on both a laboratory and field scale.

The laboratory experiments include Darcy constant head infiltration tests, tracer tests. The field scale test includes slug hydraulic tests and a combined dilution and natural gradient tracer test. These methods can effectively calculate the hydraulic conductivity and effective porosity for both field and laboratory scale.

Hydraulic conductivities in the laboratory display a geometric mean of 0.180 m/day whereas field hydraulic conductivities display a geometric mean of 0.02 m/day. Effective porosity on a laboratory scale show values of 30% compared to 20% of field scale studies. The experiments in the laboratory therefore give over estimates of the real field condition but it still provides excellent information to conduct field scale studies.

The ash dump from a hydrological perspective cannot be classified as a sustainable salt sink, seeing that it has the ability to transmit processed water.

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INTRODUCTION

The disposal of ash in South Africa occur as two types, either as wet placing or dry placing and is defined as ash dams and ash dumps. Wet placing of ash takes place when the ash is disposed as slurry that consists of 1:10 ratio of ash and process water into an ash dam. Dry placing on the other hand takes place when the ash is disposed with a moisture content of about 10% and is much dryer than the slurry. The dry placed ash is treated with process water to enhance dust suppression. The treatment of ash with brine might pose problems, with regards to the leaching of salt in to the subsurface aquifer. It is therefore imperative to understand the hydrological nature of ash dumps.

The literature shows that the hydraulic and transport properties of fly ash have been studied globally through a number of experiments. These experiments include; hydrodynamic columns fly ash ammenmend, hydraulic barrier, physical and chemical properties and transport modeling. The hydraulic conductivity for amended fly ash varies in the ranges of (0.009-2.88) meters per day [3], for hydrogeological investigations, hydraulic conductivity values between 0.16, 1.95 meters per day are established at lab scale, and 2.24 meters per day are established at field scale [4]. Studies related to moisture content of ash permit hydraulic conductivities of 10 meters per day [2] and for studies related to the physical properties of fly ash, values of 0.002-0.1 meters per day are recorded [1]. Values for the permeability of fly ash are suggested to be in the ranges of 0.00864-864 meters per day after permeability tests were completed [5].

The objective of this study is: (i) to make use of the appropriate investigative tools on both laboratory and field scale to acquire hydraulic and transport parameters of ash. (ii) Compare the hydraulic and transport properties on both laboratory and field scale studies. (iii) To define the hydraulic and transport properties, that will assist in the evaluation of the ash dumps as a sustainable salt sink.

CONCEPTUAL MODEL

The ash is irrigated with process water, with high concentrations of saline water (90% NaCl). The saline water infiltrates into the ash dump and causes some of the salts to leach out on to the side of the ash dump. These processes can conceptually be described as the inputs on to the ash dump.

The ash dump can be divided into an unsaturated and saturated zone. The unsaturated zone exhibit moisture content of between 20-30%l, whereas the saturated zone are 2-3 m above the base. The bottom of the ash dump is covered with clay from the weathered dolerite bedrock; this in effect causes the salts to leach out on the sides of the ash dump.

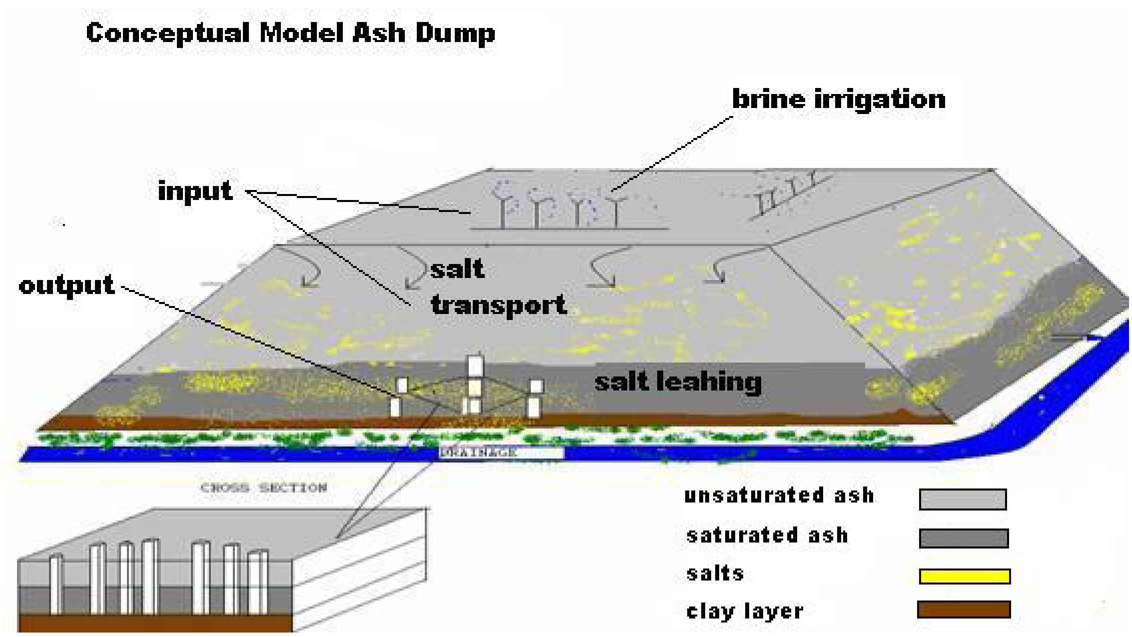

Figure 1 Conceptual Model of ash dump

MATERIALS AND METHODS

Lab Hydraulic Tests

The aim of a Darcy test is to obtain hydraulic conductivity of consolidated fly ash core obtained from air flush core drilling in the field (Figure 2). The sample preparation included the waterproofing of the sides of the core and the capping of the cores for accurate flow through the ash cores. Six ash cores of different depths were subjected to saturated hydraulic conditions to conduct the Darcy Test.

Figure 2 Air Flush Core collected in the field for Darcy experiment

The Darcy equation relates the hydraulic gradient (i) and flow area (A) to the discharge (Q) through the use of the hydraulic conductivity (K). The Darcy equation can be written as: flux was measured at meters per day (Equation. 1).

For the Darcy test on the core a known constant hydraulic head was applied to the one side, with the outflow height controlled as well. The gradient could be obtained by dividing the head difference by the length of the core. Measurements of the water flowing through the core commenced as soon as the water started flowing though. Full saturation levels for the core were assumed after a steady state was reached in the flow. The Darcy flux was obtained by collecting volumetric rates of flow through the ash core at fixed time intervals (Figure.3)

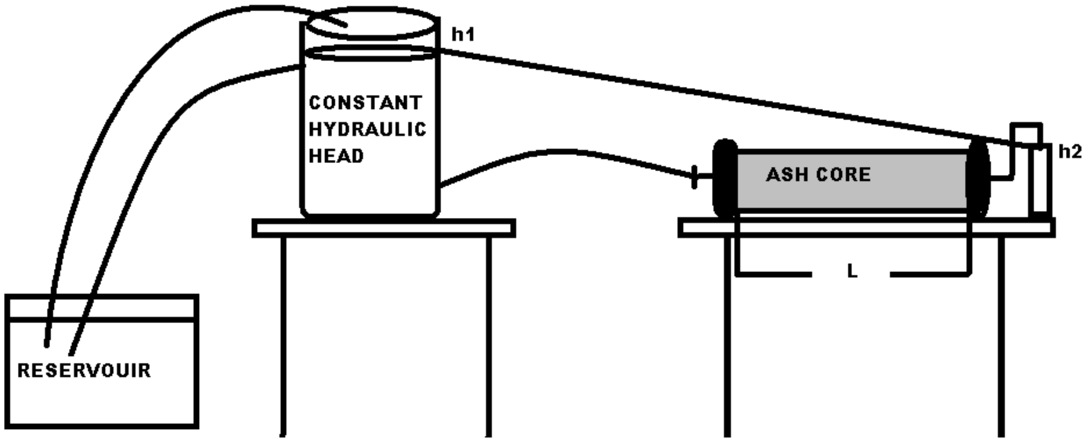

Figure 3 Diagrammatic Sketch of Darcy experimental setup

$$q = KiA \quad (1)$$

Lab Tracer

Tracer testing was performed on the ash core by adding 10ml fluorescent dye and NaCl as a tracer into the tracer injection pipe (Fig.8). With this information, the effective porosity can be determined (Equation 2.)

$$(n_e) = q/v \quad (2)$$

FIELD STUDY

The field tests were performed on the base of the ash dump within the saturated zone. The sites were chosen because most of the outflow occurred in the vicinity of this part of the dump. The conditions were therefore appropriate to meet the experimental objectives and also the measure the conceptual understanding of the site.

Slug Tests

The slug tests are performed by removing water through the use of a bailer from the piezometers to record the rise in water level to initial water level. The water level fluctuation is measured by using an Electric conductivity meter.

The data is interpreted by using the Bouwer and Rice interpretation method that estimates the saturated hydraulic conductivity.

Field Tracer Test

250g of salt is diluted into 500ml of water that is instantaneously injected into the injection piezometers. The rate of salt diluted in the injection well is then measured with a Solinst TLC calibrated with standard calibration.

Under the conditions of natural hydraulic gradient and instantaneous tracer injection, the decay of tracer concentration injected in an isolated segment of a single well (the injection borehole) due to advective dilution by groundwater flow is [3] (Equation 3).

$$q= W/\alpha At\ (Co/C) \qquad (3)$$

Natural Gradient Radial Divergent

250g of salt tracer is diluted into 500ml of water that is instantaneously injected into the injection piezometers and moves under the natural gradient of flow. The movement of the salt tracer through the ash dump is monitored by surrounding observation piezometers.

The flow time provided by the tracer test enable us to quantify the true velocity of the water through the ash. The input time of the tracer are measured and the output time, this in effect will give us an idea of the travel time of the tracer through the ash, which will produce the average velocity. With this information, the effective porosity can be determined by the following (Equation 4).

Figure 4 Tracer being injected at a piezometer and immediately monitored, surrounding piezometers were also monitored after tracer injection.

$$(n_e)=q/v) \qquad (1)$$

RESULTS

Laboratory Study

Table 1 Hydraulic Conductivity values with the included geometric mean value for the different cores at different depths obtained from the laboratory hydraulics.

Core	Depths (m)	Hydraulic Conductivity	Geometric mean
BH 81	4.5	0.11043	0.180306
BH 80	7	0.1375	
BH 79	11.9	0.069228	
BH 82	4.5	0.36226	
BH81	12	0.1625	
BH 80	4	0.23992	

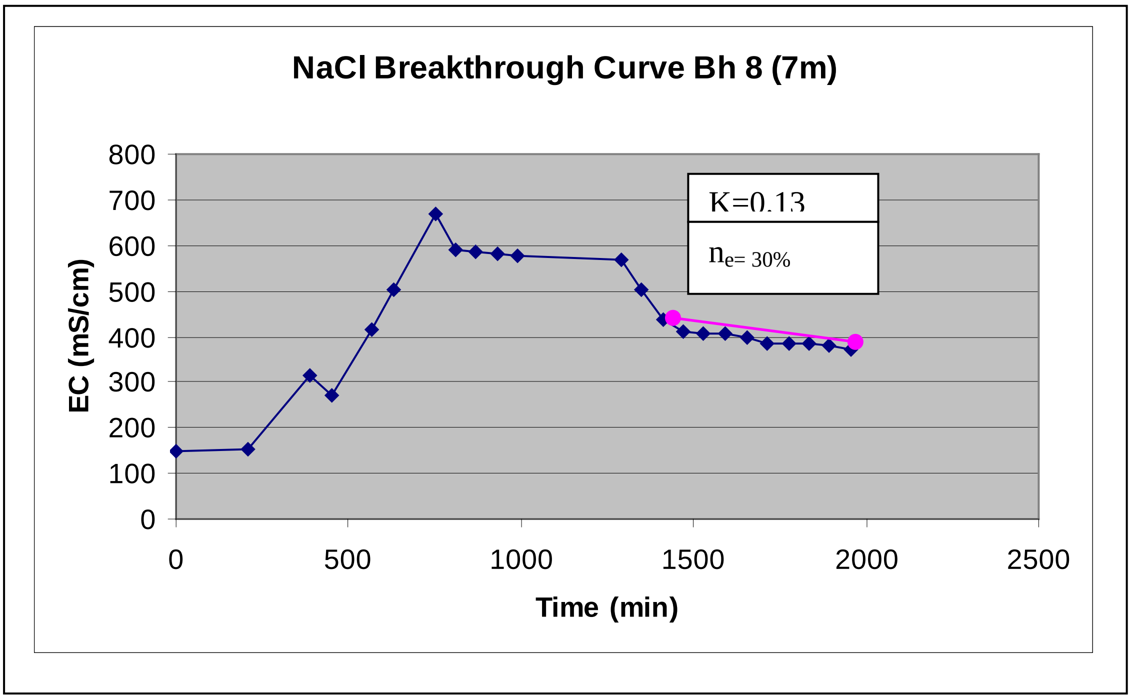

Figure 5 Breakthrough graph used to interpret effective porosity

Field Study

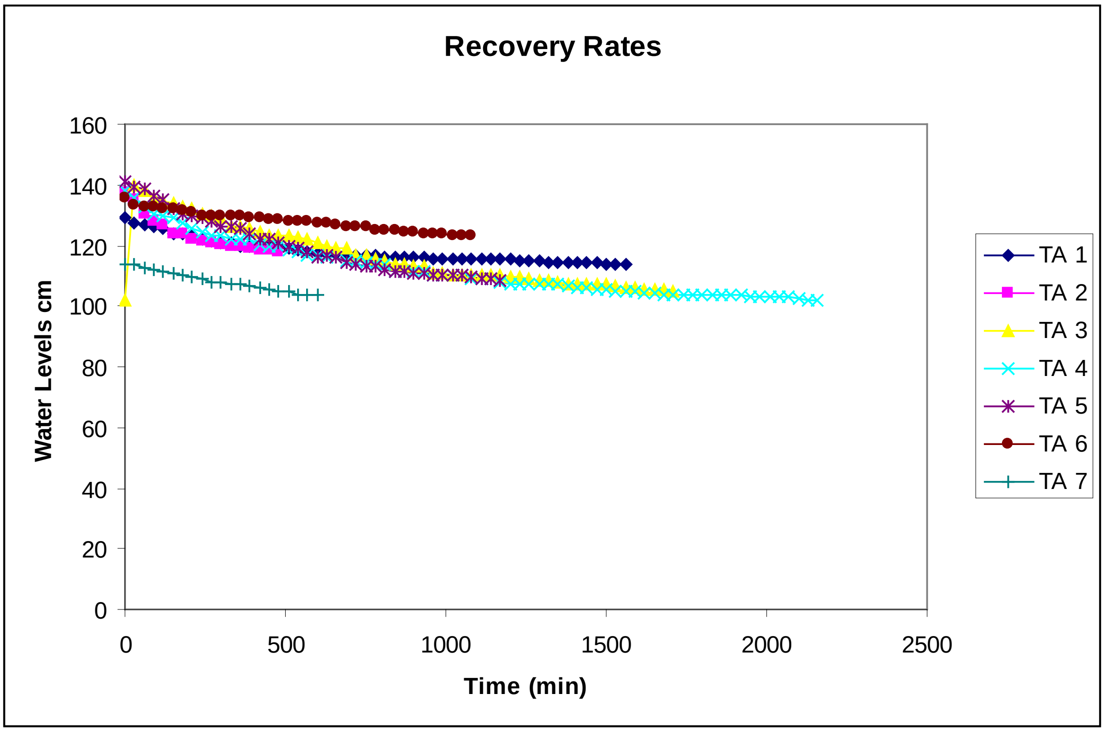

Figure 6 recoveries subsequent to removal with bailer – well field 1

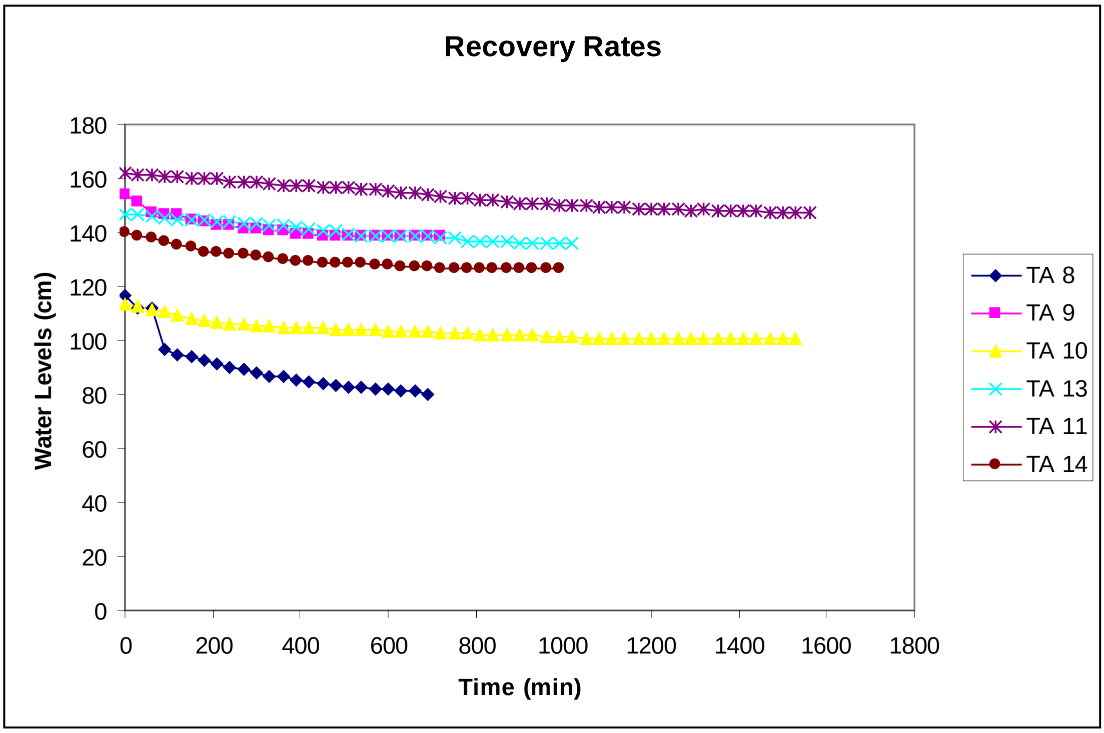

Figure 7 recoveries subsequent to removal with bailer – well field 2

Table 2 Hydraulic Conductivity values including the geometric mean value of field scale hydraulic tests

Piezometers	Hydraulic Conductivity (m/day)	Geometric Mean (m/day)
		0.02458
TA 1	0.024	
TA 2	0.01	
TA 3	0,029	
TA 4	0.017	
TA 5	0.02	
TA 6	0.032	
TA 7	0.031	
TA 8	0.0092	
TA 9	0.0088	
TA 10	0.0098	
TA 12	0.02	
TA 13	0.027	
TA 14	0.071	

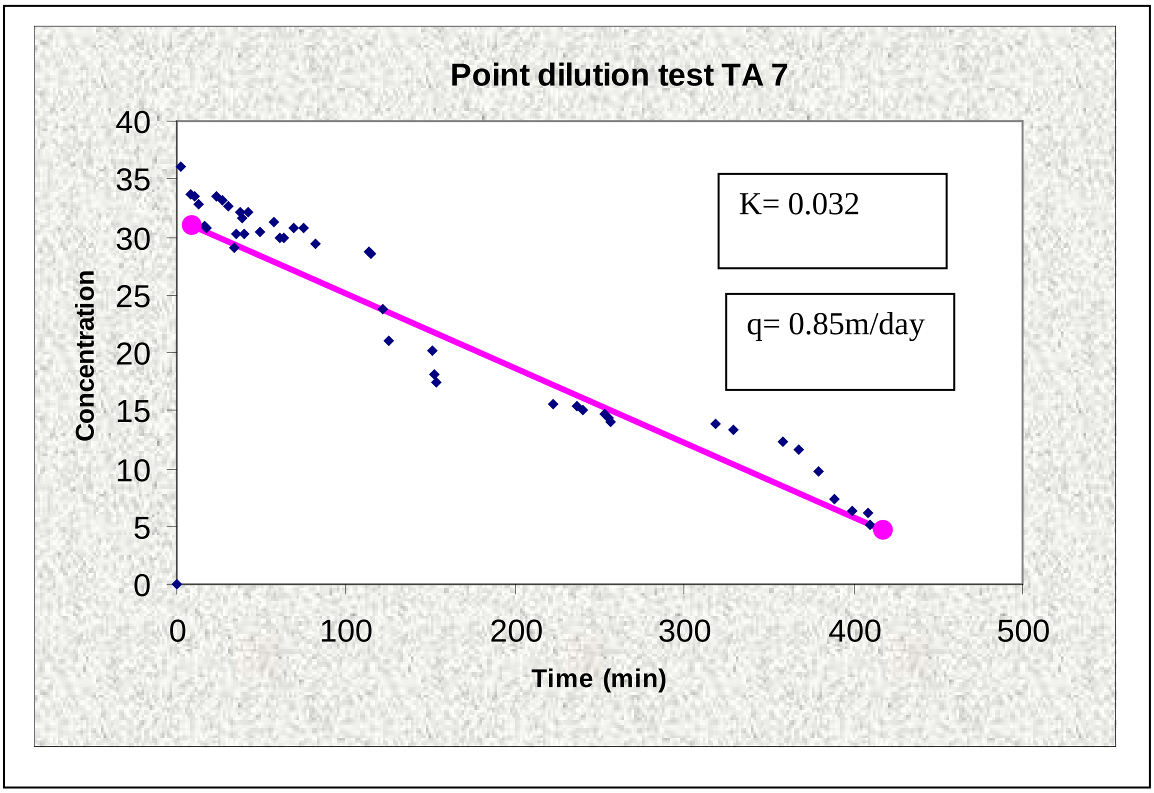

Figure 8 Tracer Dilution data subsequent NaCl injection TA 7

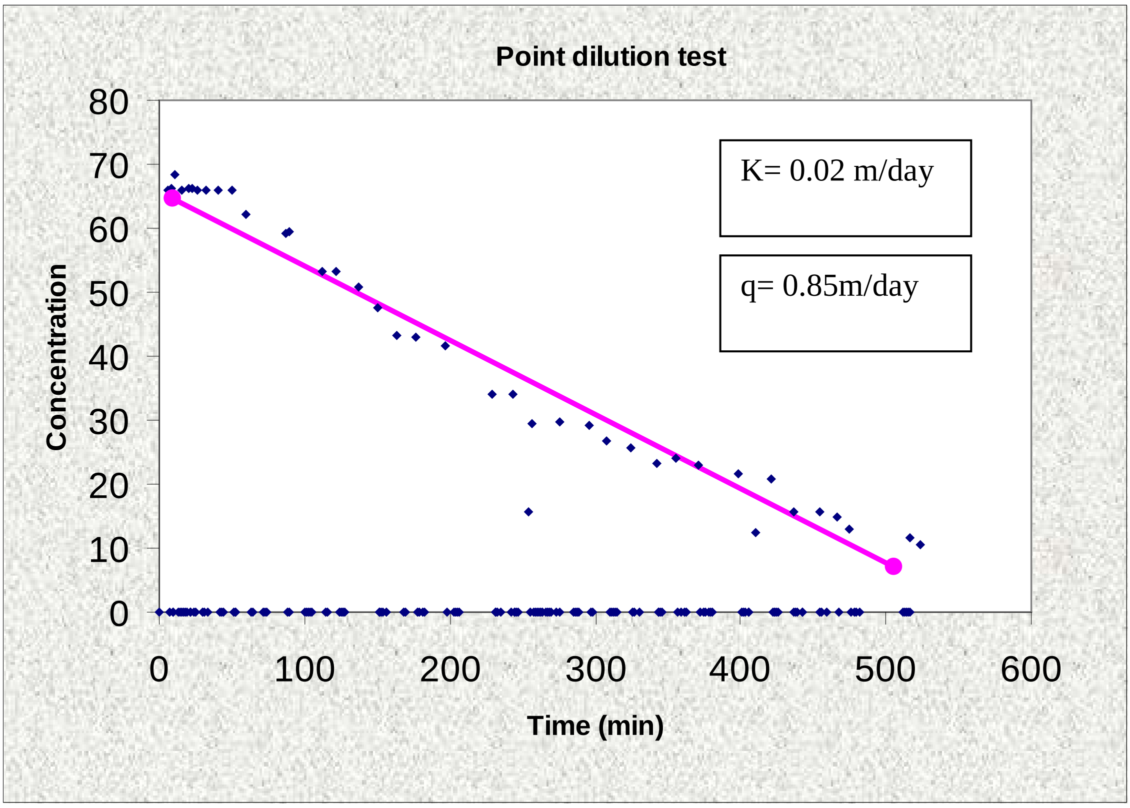

Figure 9 Tracer Dilution Data subsequent to NaCl injection TA 14

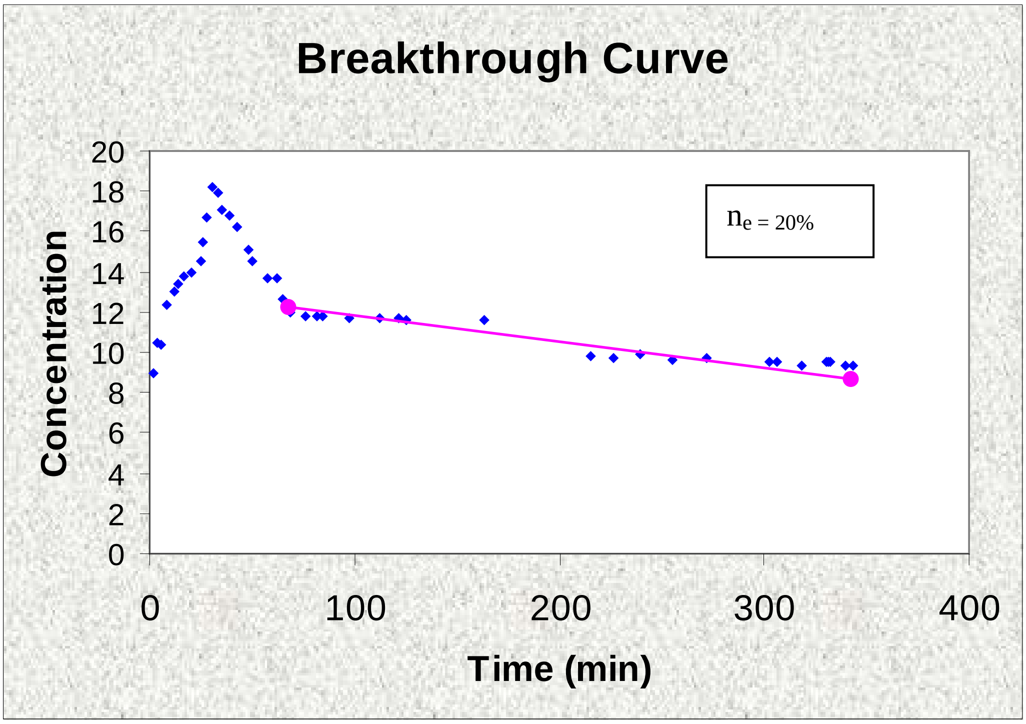

Figure 10 Natural Gradient Radial Divergent tracer TA 6

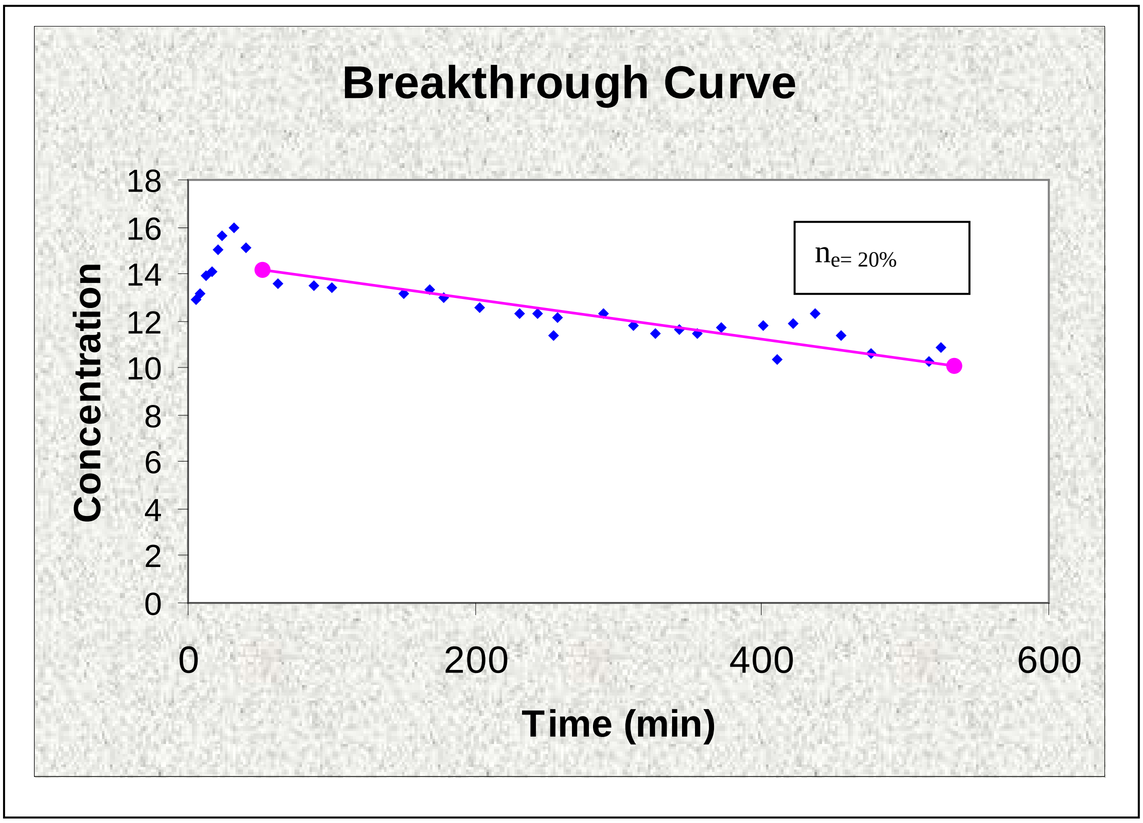

Figure 11 Natural Gradient Radial Divergent TA 13

DISCUSSION

Effective porosity accumulates to 30 % according to laboratory tracer test conducted.

Darcian velocities for the individual tracer dilution piezometers are calculated at 0.85 m/day. The effective porosity was calculated to be 20%, indicating that only 20% of pores allow flow trough the medium (Figure 10 and 11)

Hydraulic conductivities for the laboratory studies display values of a magnitude higher than that of the field scale studies (Table 1). This can also be accounted for the effective porosities that display values of 30% in the laboratory but 20 % in the field. The experiments in the laboratory therefore give over estimates of the real field condition but it still provides excellent information to conduct field scale studies.

CONCLUSION

Hydraulic and transport properties of ash has been evaluated on both a laboratory and field scale study by utilizing the appropriate investigative tools. Limitations can be expected from laboratory studies, seeing that it does not always cover the approximate field capacity. However it provides a platform for parameter estimates and to conduct the necessary field experiments. Laboratory and field scale studies clearly suggests that the ash dumps are permeable (has the ability to transmit fluids) to fluid flow. This can be accounted by the hydraulic conductivity. Movement of processed water through the ash can effectively move through the ash dump, accounted by effective porosity calculations. The ash dump from a hydrological perspective cannot be classified as a sustainable salt sink, seeing that it has the ability to transmit processed water.

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