Managing the Groundwater Impact of Mine Water Treatment Waste

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Abstract
The eMalahleni Water Reclamation Scheme near Witbank, South Africa, collects excess mine water from several coal mines. The treatment process gives rise to two main waste streams: brine and dewatered gypsum sludge cake. The waste is to be disposed at a nearby coal discard facility. To obtain regulatory authorisation, the project proponents needed to demonstrate that the incremental increase in water quality impacts at the facility was negligible.
Contaminant source terms for the coal discards, coal fines, gypsum cake and brine materials were developed. This paper considers the coal fines source term, including the change from hydraulic deposition of coal fines to dry deposition.
Seepage quality modelling showed that sulphate loads would increase by less than 1%.

Key words: treatment, groundwater, modelling, geochemistry, gypsum, brine, coal discards, source term, coal fines

Introduction

The eMalahleni Water Reclamation Scheme near Witbank, South Africa, is a joint initiative by Anglo Coal and BHP-Billiton Energy Coal South Africa. The scheme collects excess mine water from several coal mines in the vicinity. The saline and acidic water is treated using reverse osmosis to potable standard and sold to the local municipality for domestic use. The treatment process gives rise to two main waste streams: brine and dewatered gypsum sludge cake.
In the case of eMalahleni, regulators have permitted disposal of the waste streams at a nearby disposal facility used to co-dispose coal discards and coal fines. The brine is held in two ponds adjacent to the facility. The gypsum cake is deposited in a cell within the facility and, in later phases, in a separate module adjacent to the facility. To obtain authorisation, the project proponents needed to demonstrate that the incremental increase in water quality impacts at the facility was negligible.
Contaminant source terms for the various materials contained in the facility were developed based on geochemical characterisation results. Source terms were developed for the coal discards, coal fines, gypsum cake and brine materials. A fifth material termed "yellow buoy" was also characterised.
Base case modelling considered the life cycle of the facility as a combined discard and coal fines disposal facility, including the change from hydraulic deposition of coal fines to dry deposition after 16 years of operation.
This paper outlines the source term characterisation for the coal fines and the incremental impact impact of mine water treatment waste on the sulphate load from the facility.

Methodology

The methodology applied to the study comprised the following tasks:

- Develop source terms for materials present or proposed in the disposal facility, including coal fines.
- Develop a numerical model to evaluate the receding phreatic surface (and consequent seepage rates) after the change in coal fines deposition strategy from wet to dry.
- Assess the incremental impact on groundwater of the disposal of mine water treatment waste at the facility.

Results

For the sake of brevity, only the source term characterisation of the coal fines is presented in this paper.

The source term for each material in the facility consists of two components: the rate of seepage from the material and the quality of seepage.

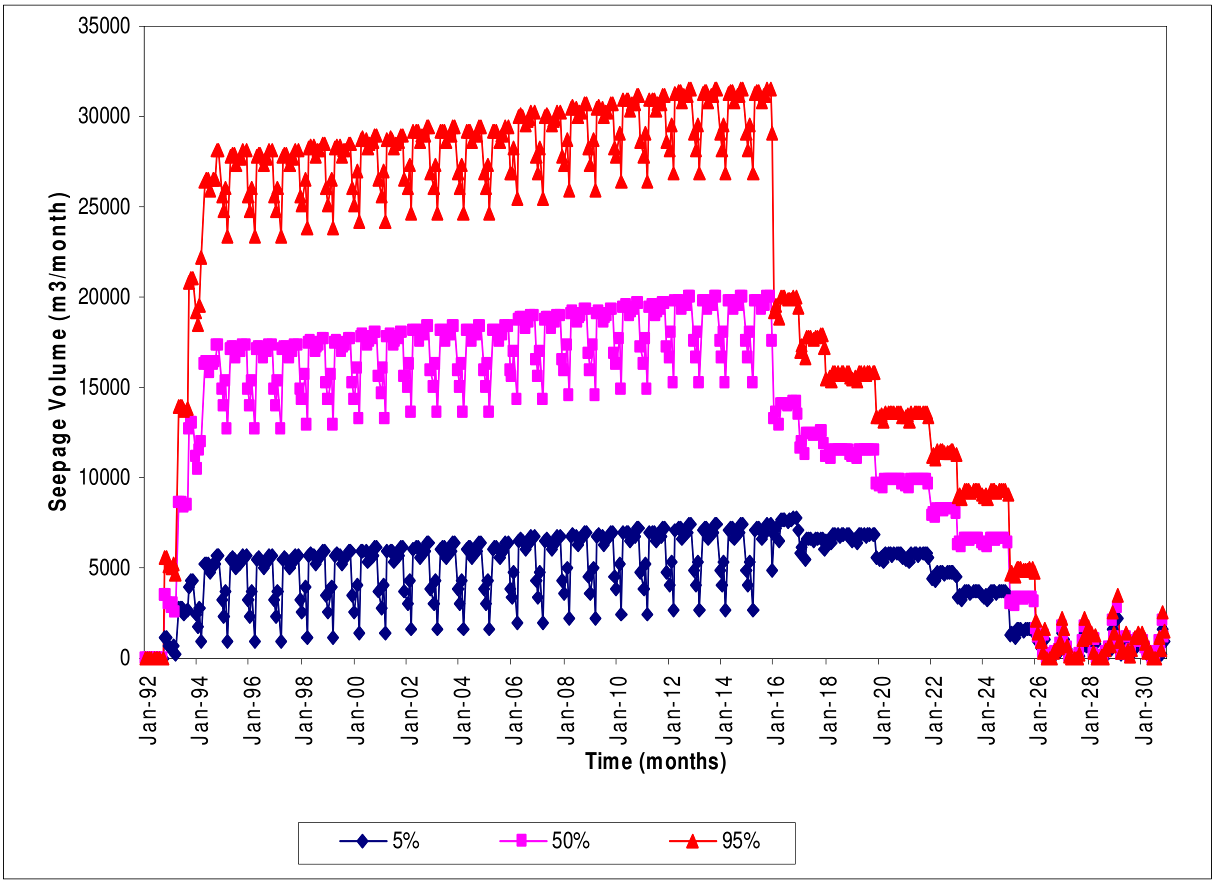
Seepage Rates

Initially coal fines will be deposited as a slurry and seepage from the coal fines will be driven by saturated flow processes from the pool of supernatant water. The pool size is managed by a penstock discharge system with coal fines material deposited in a circle around the penstock to ensure a beach profile that will drain water towards the penstock.

Flow as a result of the hydraulic head in the pool is determined by the saturated permeability of the coal fines, the height of the deposit and the saturated permeability of the underlying materials.

A water balance approach (based on 1D Darcian equations) was followed in modelling likely seepage volumes from the coal fines compartment and took account of factors such as: design and beach profile of the compartment, penstock discharge rates, toe seepage rates, material properties and management of pool form, position and size (Figure 1).

***Figure 1** Time series graph of seepage rates from saturated coal fines.*



Seepage from the dry deposition of coal fines was assessed by unsaturated flow modelling.

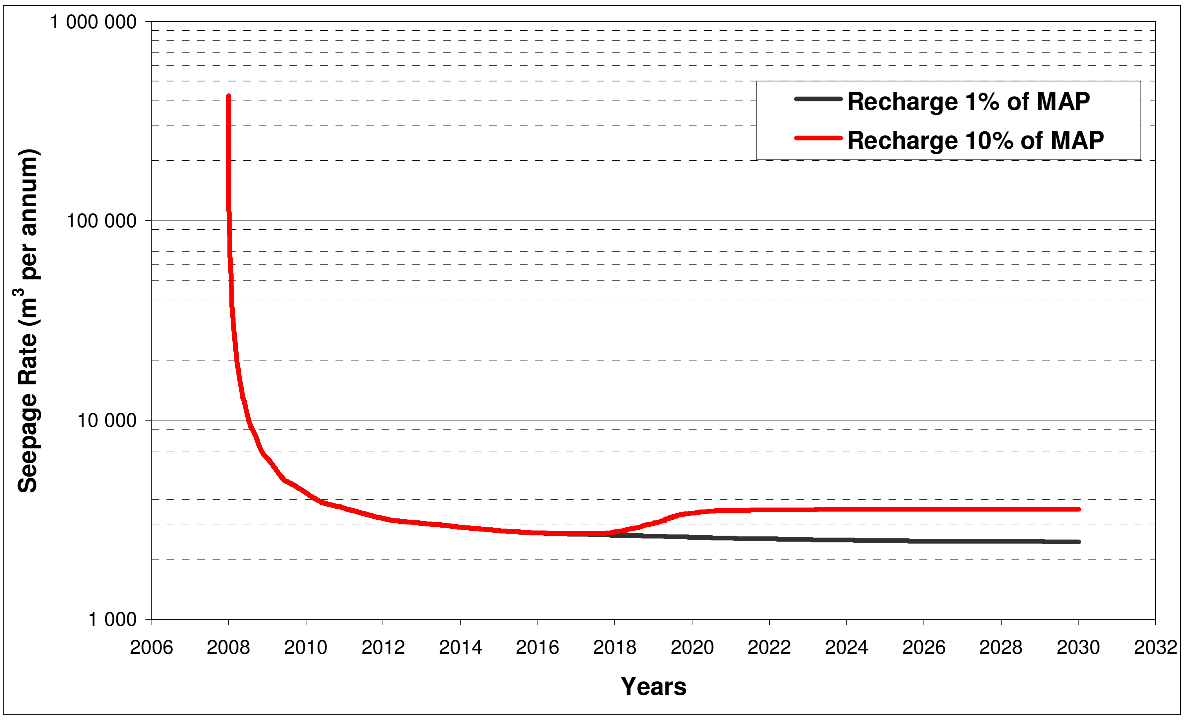
Unsaturated Flow Modelling

After 16 years of operation, wet coal fines deposition will be replaced by dry deposition. At this time seepage from the coal fines would be driven by an increasing component of unsaturated flow.

The VadozeW modelling code was used to develop a two-dimensional cross-section of a unit column of fines material of height 20 m which is the proposed final height of the coal fines compartment on closure. The initial conditions set in the model assumed that the coal fines were saturated to a height of 10 m with a moisture content of 6% in the overlying 10 m of dry-deposited fines.

The seepage volumes through the column up to 15 years after closure was determined. Recharge rates of 1% and 10% of Mean Annual Precipitation (MAP) were applied to the top of the column to assess the impact of recharge on seepage. These modelled recharge rates are assumed to be the upper and lower limits of the range of likely field seepage rates for fine-grained material such as coal fines (Figure 2).

Figure 2 *Unsaturated flow model results of estimated seepage rates from a unit column of coal fines.*



The saturated and unsaturated seepage curves were combined to reflect the changeover from wet to dry deposition.

Seepage Quality

Process water used to pump coal fine slurry to the coal fines compartment is considered to be in equilibrium with coal fines and is therefore expected to be a good indicator of seepage quality (Table 1).

Table 1 *Concentrations of key parameters in water in equilibrium with coal fines.*

Parameter	**Coal Fines Dam**
pH	3.6
TDS (mg/kg)	5 469
Acidity (mg/l)	559
Alkalinity (mg/l)	na
Ca (mg/l)	541
Mg (mg/l)	208
Na (mg/l)	105
Sulphate (mg/l)	2 944
Mn (mg/l)	18
Fe (mg/l)	257

Discussion

One-dimensional saturated flow results were calculated for 5, 50 and 95 percentile cases to reflect uncertainties in coal fines hydraulic conductivity values and variation in pool size. The annual variation in seepage rates arises from the seasonal rainfall component of seepage (Figure 1).

The unsaturated flow model results indicate that seepage rate through the base of the coal fines compartment will decrease rapidly after the commencement of dry deposition as the phreatic surface declines towards the base of the disposal facility (Figure 2).

At a recharge rate of 1% MAP, the volume of water added to the coal fines is sufficient to maintain the natural moisture content of the fines and the seepage rate declines to an asymptotic value of approximately 2 500 m^3 per annum (black line in Figure 2). However, a recharge rate of 10% adds excess water to the coal fines resulting in the development of a wetting front which declines towards the base of the facility. This wetting front reaches the base of the facility some years later and results in a raising of the seepage asymptote compared to 1% recharge. Based on the modelling results, the seepage rate associated with a recharge rate of 10% MAP is approximately 3 500 m^3.

The coal fines water is acidic (pH 3.6) with a sulphate concentration of the order of 3 000 mg/l which suggests that gypsum precipitation (from the addition of $CaCO_3$/CaO in the treatment process) controls sulphate concentration.

The sulphate load from both coal fines and coal discard deposition at the facility was the baseline against which the additional impact of mine water treatment waste was originally assessed for permitting purposes (Table 2). The results show that deposition of mine water tratment waste would increase sulphate loads by less than 1%.

Table 2 *Average loads of sulphate for each component of the disposal facility.*

Parameter Loads (Ton/annum)	**Phase**	**Discard Dump**	**Coal Fines Dam**	**Yellow Bouy Dam**	**Gypsum Module 1**	**Gypsum Module 2**
SO_4 loads	Operational Phase	2 257	607	19	8	14
	Closure Phase	1 053	228	5	2	6

Conclusion

The incremental increase in sulphate load due to the deposition of mine water treatment waste at the facility was assessed to be less than 1% of the baseline sulphate load from co-deposition of coal fines and discard.

The modelling results supported the successful application for authorisation of the eMalahleni Scheme. The work conducted emphasises that, while treatment of excess mine water represents a significant reduction in environmental risk, management of the residual impact of coal discard remains a challenge to the local coal mining industry.