

EXECUTIVE SUMMARY

Improvements in membrane processes have made it economically feasible to treat mine-water to a drinking water quality and to sell it to municipalities. Reverse osmosis is often selected for the treatment of water from coal mines. This treatment results in a brine, or concentrated salt stream, which has to be managed as a waste. Current projects being investigated and implemented result in a brine with total dissolved solids (TDS) concentrations of between 17 500 mg/l and 51 000 mg/l.

Disposal options for brine include: treatment and/or authorisation for disposal to surface water resources; authorisation to discharge to sewer; deep well injection; spray irrigation; mechanical or thermal evaporation; or evaporation ponds. Evaporation ponds have been the preferred disposal option to date for the coal mining operations being considered in this project. One of the key factors influencing the design of evaporation ponds is the evaporation rate. The evaporation rates for water are readily available for most areas in South Africa. The high salinity in the brine however will reduce this evaporation rate.

The aim of the study is to conduct a literature survey to obtain reported evaporation rates on saline solutions and to carry out field investigations to measure the evaporation rate of brine solutions and compare this against that of a standard water sample.

The correct sizing of an evaporation pond depends on the accurate calculation of the evaporation rate. Typically the larger the surface area, the greater the rate of evaporation from the pond, however the relationship is not linear and a number of other factors also play a role.

The climatic factors affecting the rate of evaporation include:

- Temperature – heating the water molecules to the required temperature,
- Humidity – if the humidity levels are high, less evaporation occurs,
- Solar radiation – providing heat to enable evaporation,
- Wind – to blow away the saturated air in order to allow further evaporation to occur.

Dissolved salt in the water results in a lower saturation vapour pressure, due to the decreased chemical potential of the water, and thus results in a lower evaporation rate. The second Law of Thermodynamics implies that an increase in ion activity as a result of the presence of a solute reduces the chemical potential of a liquid solvent and also the rate of spontaneous transformation of a liquid phase into a vapour phase (Kokya and Kokya, 2006).

Procedures for calculating evaporation indicate that evaporation rate is directly proportional to vapour pressure. The vapour pressure of saline water is lower than that of fresh water resulting in a reduction in evaporation (Mickley, 2001). Cohesive forces between the dissolved ions and water may also inhibit evaporation, as it will be more difficult for the water molecules to vaporise (Miller, 1989)

Leaney and Christen (2000) indicated that the evaporation rate decreases exponentially with increasing salinity. Evaporation rates of fresh water are easily available from hydrological databases. The evaporation rates of saline solutions are normally calculated by multiplying the rate of evaporation of water by a salinity factor (Mickley, 2001).

The type of salt dissolved has an effect on the humidity at which evaporation will stop, for example there will be no evaporation from a water body saturated with sodium chloride during periods when the humidity is above 70%. With other salts, evaporation may cease at lower humidity levels (Leaney and Christen, 2000).

Field investigations were carried out in order to obtain a comparison between evaporation on synthetic solutions made-up to represent various brine concentrations and potable water.

Evaporation on an actual brine sample was compared to the synthetic solution at the eMalahleni Water Reclamation Plant iv

in order to verify that the synthetic solutions are a reasonable representation of the evaporation rate on actual brines.

A Davis Pro2 weather station was purchased In order to understand the impact of climatic conditions on evaporation rates. The weather station has the ability to monitor temperature, humidity, rainfall, wind speed, wind direction, and solar intensity. In order to be able to replicate data at various sites requiring evaporation ponds, it was necessary to use standard equipment, thus standard A-Pans were used to measure the evaporation rates. Due to the risk of corrosion, the pans were coated with a grey corrosion proofing paint. Level readings were taken daily, except on public holidays and weekends.

Initial results indicated that stratification occurred in the evaporation pans, impacting on the results obtained. The experimental procedure was modified to include daily mixing in the pans. Results obtained are presented in Table ES1.

Table ES1: Statistical analyses excluding eMalahleni Water Reclamation Plant out of range data points of salinity factors calculated at GAA Offices and EWRP. GAA Offices

	eMalahleni	Kilbarchan	Optimum	Actual Brine	Synthetic Brine
5 Percentile	35	40	34	56	56
25 Percentile	50	57	51	66	67
50 Percentile	82	79	63	77	75
75 Percentile	96	97	75	88	86
95 Percentile	100	100	100	93	90
Average	74	74	65	77	75

An average salinity factor of 74% was calculated for eMalahleni and Kilbarchan synthetic solutions and 65% for the Optimum synthetic solution. This indicated that the salinity factor is influenced by both the concentration and the composition of the brine.

The actual and synthetic brine solution set up at eMalahleni displayed similar results, as shown in Table ES1. This confirmed that synthetic solutions can be used during the design phase of a project in order to determine a salinity factor, prior to the construction of a brine pond.

The following recommendations were made:

- Undertake investigations in a controlled environment in order to better understand the impact of various climatic conditions on the evaporation rate and salinity factor.
- Use a sensitive automated level indication on the pans and record data at more regular intervals (hourly or every 30 minutes) in order to enable a better comparison with climatic data.
- Investigate specific salts in order to improve the understanding of the composition of brine on the salinity factor.