Drinking Water from Mine Water Using the HiPRO® Process – Optimum Coal Mine Water Reclamation Plant

E. Karakatsanis[1], V.E. Cogho[2]

[1] Keyplan (Pty) Ltd, Johannesburg, Gauteng, South Africa; email: kathy@keyplan.co.za
[2] Optimum Coal Mine, Department Environment and Projects, Pullenshope, Mpumalanga, South Africa; vik.cogho@optimumcoal.com

Abstract Optimum Coal Mine comprises numerous defunct, active and future mining sections, whose activities have a significant impact on surface and groundwater resources. In order for the mine to continue with their mining operations in the catchment, substantial measures were implemented in order to ensure the environmental integrity and economic use of the area's water resources [1]. One of these measures was the construction of the Optimum Coal Mine Water Reclamation Plant (15ML/day Product Water), which uses Keyplan's HiPRO® Process to actively treat the excess mine water to drinking water standard. This in-house developed technology makes use of multiple stages of Ultrafiltration and Reverse Osmosis membrane systems which produce super-saturated brine streams, from which sparingly soluble salts may be released in Precipitation Reactors. The following distinctive features of the HiPRO® Process were key in its selection as the preferred technology:

- Large Scale Commercially Proven Sustainable Operation
- >98% Water Recovery
- High Quality Drinking Water (SANS highest standard)
- Minimum Waste Generation
- Potentially Useful By-products

In addition, the HiPRO® Process needed to be developed further to cater for the unique attributes of the Optimum Coal Mine water as well as experience learned from previous applications. Most notably was the neutral pH of the mine water feed, which resulted in the removal of the Pretreatment Neutralisation Reactors and inclusion of Ozone for Iron and Manganese oxidation.

Key Words acid mine drainage, gypsum precipitation

Background

Optimum Coal Mine comprises numerous defunct, active and future mining sections. The mine is situated in Pullenshope, Mpumalanga, South Africa and is a multi-product mine with a contract to supply the nearby Hendrina Power Station with coal until 2018.

In 1998, new water related legislation was promulgated. To comply with this legislation, the mine conducted a study and a water balance was put together which included optimized reuse of affected water by the mining operation Although numerous water management actions are needed to be implemented by the mine, an accumulation of 15ML/day of affected water still needed to be managed. This was decided to be treated by means of a Water Treatment Plant.

After consideration of various proposals for the Water Treatment Plant, Keyplan's HiPRO® Process was selected, with the following key attributes [1]:

- >98% Water Recovery
- Minimum Waste Generation
- High Quality Drinking Water (SANS highest standard)
- Large Scale Commercially Proven Technology – eMalahleni Water Reclamation Project

Mine Water Reclamation Project

The Mine Water Reclamation Project is comprised of the following areas:

Mine Water Collection & Transfer

The source of the feed water to the Water Treatment Plant is from the Evaporation Dam, which is the central depository of impacted water on the Optimum Mine complex. The Evaporation Dam is situated approximately 2km from the Water Treatment Plant and is at an elevation sufficient for gravity feed [2].

Close assessment of the feed water quality allows the following to be observed:

- The pH of the Mine Water is relatively neutral, thus negating the need for upfront neutralisation, by means of limestone, as traditionally expected from acid mine drainage.
- Mn and Fe levels are low; only a small amount of oxidation prior to membrane treatment.
- High calcium and sulphate levels as can be typically observed in acid mine drainage
- Associated with the neutral pH is a higher than expected alkalinity, which together with the high magnesium levels will contribute to lime consumption.
- Low potassium and chloride, means that during the precipitation reactions, the sulphates will not need to compete for the calcium and thus very high recoveries exceeding 98% may be achieved.

Mine Water Treatment Plant

The Mine Water Treatment Plant technology is based on Keyplan's High Recovery Precipitating Reverse Osmosis (HiPRO®) Process and consists of 3 stages, each configured with Pretreatment, Ultrafiltration and Reverse Osmosis (Figure 1). Each stage produces treated water of potable water quality, via the Reverse Osmosis unit process, while the reject produced becomes the feed for the next stage. In doing so, greater than 98% overall plant recovery can be achieved with minimal waste production.

Pretreatment

Due to the neutral pH and low iron & manganese content of the Optimum Mine Water, there is no need for upfront primary neutralisation. Although low levels of iron and manganese are evident in the feed water, there is a need for their removal to levels suitable for RO treatment. Ozone

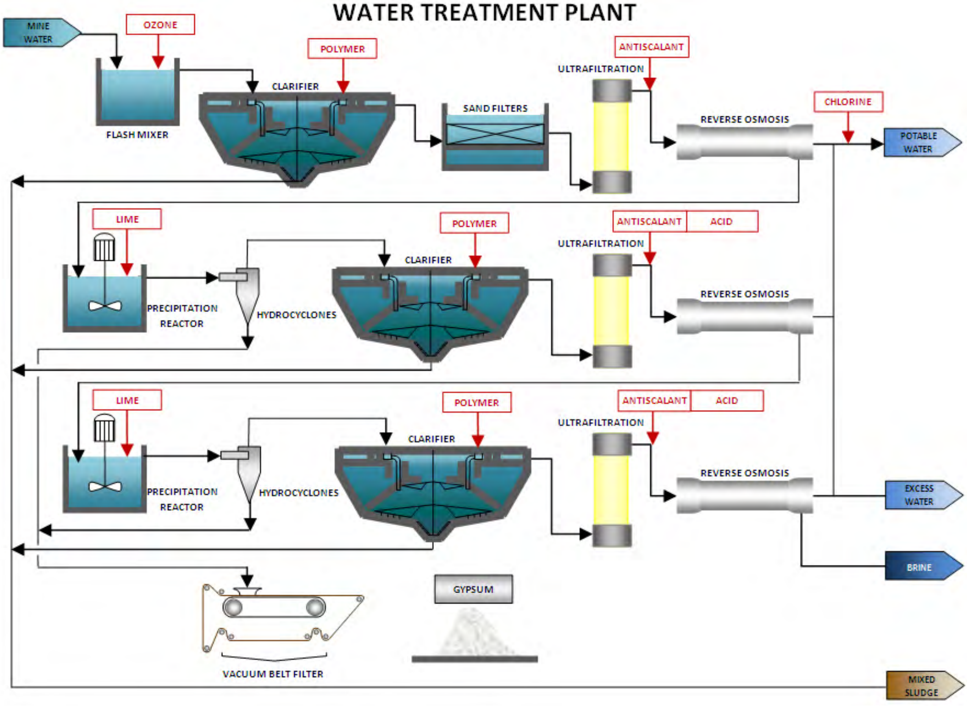

Figure 1 *Overall Mine Water Treatment Plant Configuration*

was the preferred route for iron and manganese removal. After ozonation, any solid debris in the mine water feed, together with the oxidised iron and manganese, will settle out in the Stage 1 Clarifiers. An anionic polymer flocculant is dosed into the clarifier feed water in order to promote solids agglomeration. The Stage 1 Clarified Water is then filtered through Sand Filters prior to further treatment via Ultrafiltration.

Pretreatment in Stage 2 & 3 is quite different to that of Stage 1, due to the nature of the feed water. Stage 2 & 3 is fed with RO reject from the previous stage, which is in a state of supersaturation. The salts in the reject are removed by means of precipitation at an elevated pH, which is achieved by the addition of lime. Gypsum and magnesium hydroxide are the salts that predominantly precipitate in the Precipitation Reactors and they are kept in suspension by means of large agitators in the Reactors. The slurry in the Reactors is classified by means of Hydrocyclones. The hydrocyclone overflow, containing the small particles, is introduced into the respective Stage 2 or 3 Clarifier. The underflow from the Hydrocyclones contains the larger gypsum particles, which are subsequently dewatered by means of a Vacuum Belt Filter.

Ultrafiltration

Ultrafiltration is the final solids-removal process before introducing the water to the RO's. Each UF Skid has 38 modules installed (maximum 44 available). The UF's are operated in dead-end mode and each skid is intermittently backwashed in order to remove the entrained solids. As per the Sand Filters, the backwash water collects in the Plants Drains Sump and returned to the Flash Mixer for further treatment.

Operation of the UF System automatically initiates the dosing of antiscallant, in preparation for RO treatment. Due to the neutral nature of the feed water, it has the potential for $CaCO_3$ scaling. In order to protect the UF's from this source fouling the antiscallant is dosed upstream of the UF's in Stage 1. In the case of the Stage 2 & 3 UF's, antiscallant is dosed post UF'S. In addition, sulphuric acid is dosed in the UF product water for pH correction prior to the RO's. The antiscallant dosing and acid correction is implemented post UF's so that any small precipitates of calcium sulphate remaining in suspension after clarification, may still be removed by the UF's.

Reverse Osmosis

The final treatment process is Reverse Osmosis. The design of the RO Skids for each stage is specific to the feed water quality and subsequent allowable recovery. The Stage 1 RO feed water typically has a $CaSO_4$ saturation level of 90—95%, but the recovery is limited by the $CaCO_3$ scaling potential. The maximum permissible Stage 1 RO recovery is therefore 70%. In addition, the Stage 1 RO design has made use of Nanofiltration (NF) membranes in order to allow for the passage of the monovalent bicarbonate ion into the permeate. This has a twofold advantage in that stability is provided to the low salinity permeate and that the lower levels of bicarbonate in the reject will place less demand on lime in the Stage 2 Precipitation Reactors.

The Stage 2 & 3 RO designs differ in their allowable recoveries as a result of the ability of the Precipitating Reactors to remove $CaSO_4$. Therefore, the allowable recoveries of the Stage 2 & 3 RO's are 65% and 60% respectively. The permeate stream from each RO Skid is collected in the common permeate header and routed to Potable Water Distribution. The reject from each stage is routed to the next stage, with a small amount of Stage 3 reject routed to the Brine Pond.

Treated Water Collection and Distribution

The Mine Water Treatment Plant has the capacity to produce 15ML/day of treated water, with a peak capacity of 18.75ML/day. Potable Water and Excess Water are produced [2].

Waste Disposal

The Mine Water Treatment Plant operates at 98% overall recovery. The remaining water stream is released with the three waste streams produced by the plant; Mixed Sludge, Gypsum and Brine.

Conclusions

There are various justifiable processes to treat Acid Mine Drainage, each with its own process and economical advantages and disadvantages. A comparison of these technologies would invariably be an intensive study on its own, especially with consideration of the feed water quality (acidity, calcium/sulphate and magnesium levels etc) being integral in the evaluation. The selection of a preferred water treatment technology is ultimately a balance of economic and process performance parameters. For the case of the Optimum Water Treatment Plant the following key process attributes are noteworthy:

- >98% Water Recovery
- High Quality Drinking Water (SANS highest standard)
- Minimum Waste Generation
  Brine: <0.012 m^3/m^3 feed
  Mixed Sludge (dewatered): <0.006 m^3/m^3 feed
  Gypsum Slurry (dewatered): <0.0015 m^3/m^3 feed
- Potentially Useful By-products – gypsum
- Operating Cost (March 2010)
  Variable: ≈ R5.00/m^3 (excl. Power)
  Fixed: ≈ R2.50/m^3

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