Water reuse in the mining industry – a resource, financial and socio-economic imperative

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Abstract

In the mining industry water was historically seen as one of many services and not a lot of focus was given to ensure its reliable and sustainable use. Not only is the efficient use of water a commercial and environmental imperative, but also of strategic importance. The cost of water in the larger scheme of mining cost is relatively small, but if the water supply is not available or not reliable the cost of mining suddenly increases as a result of production inefficiencies. Water security on a mine is therefore of cardinal importance and the case study presented will demonstrate how water security was improved significantly through a number of logical steps.

As part of developing a sustainable solution it was necessary to develop an integrated water balance for all water circuits on the mine. After analysing various water demand centres, water circuits, water volumes and water quality requirements for each type of water, for the current and future water footprint, water inefficiencies and potential water reuse interventions were identified.

A central component of the reuse interventions was a water reuse treatment plant to treat the eutrophic, mildly acidic and brackish water from the return water dam. As a result of various unknowns in terms of the water balance, water demands and plant size, scenarios were developed to test the sensitivity of certain assumptions on the water treatment works capital and operating cost.

The water reuse facility has been in operation for more than 12 months and based on actual water savings and operating cost savings the capital invested is projected to be paid back in less than 4 years. What is even more remarkable is the fact that the potable water use was reduced by 50%. Some of this water will be used for future production expansion and it could also be used for expanding potable water supply to neighbouring communities.

The case study demonstrates that with a proper understanding of mine water circuits many water reuse opportunities exist and that water reuse is not only an imperative from a water resource perspective, but also from a financial and socio-economic perspective. Ultimately the water security of the mine has improved significantly and with associated benefits in lower water input costs as well as lower probability of production stops due to water shortages.

Keywords: Dissolved air flotation, mine water, mine water balance, water treatment, water reuse.

Introduction

The Bafokeng Rasimone Platinum Mine (BRPM) is a Joint Venture between Anglo Platinum and Bafokeng Platinum Resources located on the Western Limb of the Bushveld Igneous Complex approximately 30 km from the town of Rustenburg in the North West Province and immediately south of the Pilanesberg Complex. BRPM has been in operation since 1999 and comprises a number of shafts, a concentrator facility and a central logistics area.

The water supply to BRPM originates from the Magalies Water Vaalkop System.

Since the development of BRPM numerous new mining developments have taken place along the Pilanesburg which have increased the water demand from the area placing more strain on the already stressed water supply system.

The constrained water supply system severely impacted the mining industry in Rustenburg with limited supply to BRPM and increased potable water cost. In order to mitigate the risk of limited water supply BRPM decided to embark on a process to become less dependent on potable water as its primary water supply source and explore the feasibility of re-using local water sources.

In South Africa water reclamation is not only a legal requirement, but also provides strategic and in some cases even financial benefits. Since around 2004 BRPM has been in a water surplus scenario in the sense that not all water discharged to the return water dams could be reclaimed. Since the end of 2009 this situation was aggravated by the fact that the mine's filtration plant could not cope with the quality of the return water dam. BRPM was in the fortunate position that they have the facility to store surplus water in open cast pits, but this was only a temporary arrangement for a number of reasons. Firstly the water storage is not authorised in terms of DWS legislation, secondly there is evidence that the water in the pits could potentially pollute the ground water and finally the open cast pits can overflow and also pollute the surface water sources. It was therefore essential that the open cast pits be emptied and retained in that condition.

BRPM commissioned Bigen Africa to investigate the current problems experienced with the water reclamation circuit and present a solution.

Methodology

Water Balance

As part of developing a sustainable solution it was necessary to develop an integrated water balance for mining, minerals processing, the tailings return water facility and the sewage treatment plant. A number of water demand zones were identified and the inflow and outflow streams from these demand zones were identified. The streams were categorised according to the three different water quality supplies available:

- A potable water stream feeding offices and ablution facilities, reagent make up water, underground drinking water system and cooling water system
- A clear water stream feeding gland seal water system, washing and spraying systems
- A process water stream feeding crushing and milling processes and mining processes

In order to quantify the flow into and from each of the zones flow meters on each of the streams feeding into and from each zone were identified. A detailed analysis of the demand zones and meters revealed that an accurate water balance could not be set up for the entire demand zone as not all the flows were metered. In the case where a meter was installed the average consumption was calculated based on the historic consumption. In some cases inferences had to be made as a result of insufficient flow data.

Water Reclamation Potential

After analysing various water demand centres (Zones), water circuits, water volumes and water quality requirements for each type of water, for the current and future water footprint it was concluded that the current average water reclamation potential from local water sources was 3 900 m^3/d. The current pipeline system could transfer a theoretical maximum of 9 800 m^3/d. The reclamation was constrained as a result of the current WTW not being able to treat the return water dam water to a suitable quality.

The current return water dam reclamation potential is largely dependent on the amount of tailings deposited as well as the evaporation losses. As the tailings return flows were not measured two scenarios were considered, one in which the evaporation losses are linked to the wetted area and the average evaporation rate for the area and another for a much larger area with an average evaporation rate. In the case of a low SG tailings pumped to the tailings dams the current return water dam reclamation potential was estimated at between 8 500 m^3/d and 9 700 m^3/d for high and low evaporation rates.

Based on production data it appeared that more water entered the return water dam than predicted. Using an average tailings SG (produced over 11 consecutive months) of 1.6 a water reclamation potential of 6 229 m^3/d was indicated by the water balance. However, of this 3 980 m^3/d was used for the Ultraseps. If the water demand for gland service water of 2 100 m^3/d is deducted from this, 149 m^3/d is not recovered from the return water dam and will overflow into the open cast pits. The evaporation loss in the open cast pits will be more than 149 m^3/d. In fact the evaporation is estimated at about 900 m^3/d. It was, however, known that the open cast pits have been filling up since 2004. It was therefore evident that more than 900 m^3/d was required in order to fill the open cast pits. The under-prediction of the return water dam reclamation potential was attributed to errors in the tailings SG measurements, over-prediction of the evaporation losses and under-prediction of the water recovered from underground sources. After making some informed corrections the water reclamation potential was estimated therefore closer to 7 500 m^3/d.

The future reclamation potential would therefore more than double if the production capacity is increased as planned. In order to optimise the potable water use in the largest potable water use zone it was decided to focus the water reclamation efforts in the Concentrator area. Another practical reason for this decision was that the return water pipes already fed to the Concentrator area and will therefore require the least amount of modifications in order to utilise the existing return water pipeline and pumping station.

Concentrator water quality and quantity requirements

The current Concentrator water treatment system is unable to utilize the return water dam quality and a large portion of the clear water requirements were being supplemented from the potable water system. The various quality streams that could potentially be supplied from the reclamation plant included the reagent makeup water, gland service water, fire water, water for sprays, screens, milling and Ultraseps and drinking water.

Water Source Characterisation

The return water dam was identified as the largest source of process water for reclamation and required the characterisation of the water quality. Based on the water quality measurements, the return water dam water was classified as mildly acidic and brackish, while the salinity levels are primarily due to the high levels of Sulphates (600 mg/L), Chlorides (180 mg/L), Nitrates (147 mg/L), calcium (223 mg/L), magnesium (129 mg/L) and Sodium (204 mg/L). The Nitrate level was not only attributed to the treated wastewater, but to the nature of the ore processed as well as the explosives used underground. The nutrient load into the return water dam was more than sufficient for algae to proliferate and also support other fauna. Chlorophyll-a counts were in the order of 60 μg/L. As a result the water was highly coloured (48 Pt Co units) with a medium turbidity of about 6 NTU. (Dissolved organic carbon, chemical oxygen demand and high faecal coliform counts indicate that the return water dam is not fit for human consumption.) Metal levels were low with only Mn and Ni exceeding 0.04 mg/L. The silicon concentrations were quite high at 10 mg/L. Laboratory work confirmed that silicon could not be removed by means of coagulation and flocculation.

Water Reclamation Plant Conceptual Design

The most practical location for the water reclamation plant (WRP) was as close as possible to the largest demand centre, i.e. the concentrator and an area where technical support is close by. The initially conceptualised treatment train would be able to treat water for a number of water quality and quantity streams that have been identified. It was realised at the time that all the water may not have to be treated to the highest standard and that the implementation of the UF and downstream processes need to be implemented at a later stage. The full treatment train comprised the following unit process:

- Abstraction, raw water pumping and transfer
- Mixing and aeration
- Coagulation and flocculation

- Dissolved Air Flotation
- Ultrafiltration (UF)
- Reverse Osmosis (RO)
- Gas stripping and Stabilisation
- Disinfection
- Storage
- Sludge and brine disposal

As a result of various unknowns in terms of the water balance, water demands and plant size scenarios were developed to test the sensitivity of certain assumptions on the water treatment works capital and operating cost. **Water balance scenarios** were used to determine the water reclamation potential with changing evaporation rate and tailings specific gravity. **Treatment plant scenarios** were used to determine to what extent the water available in the return water dam could be optimally utilised. The scenarios were developed for various degrees of potable water use, cooling water use, reagent makeup water use and gland service water use. Plant scenario 1 developed a water treatment works treating only for gland service water needs. Plant scenario 2 developed a plant for gland service water needs, reagent makeup water needs and cooling water needs. Plant scenario 3 developed a plant that can meet all of the above plus potable water supply to the concentrator area. The capital and operating cost for the various plant scenarios were determined for the production rate at increased capacity, high SG and high evaporation loss (adjusted) water balance option. In order to maximise the water reclamation potential plant scenario 3 was selected and the outcome was in order to maximise the return water yield a water treatment plant with a capacity of 4 000 m^3/d is required. In this case a DAF unit process with a capacity of 4 000 m^3/d and UF and RO unit process with a capacity of 1 000 m^3/d will be required. All the unit processes can be sized for 4 modules per unit process.

Results and discussion

It was eventually decided to implement the WRP in two phases, only Phase 1, i.e. the industrial water quality stream. This stream replaces potable water to the gland service water system at the concentrator. Construction of Phase 1 of the WRP has been completed and was implemented using the FIDIC Plant and Design-Build (Yellow Book) form of Contract. The first phase was completed within budget and is currently in operation producing about 3 Ml/d producing DAF clarified water of < 1 NTU.

Figure 1 *– Dissolved air flotation units inside the WRP*

From a water **resource perspective** many benefits can be listed such as reduced water footprint, reduced unintended infiltration of mine water into surrounding aquifers, reduced demand on regional water resources and infrastructure. Reduced water use also opens up opportunities for other water users to access water that would not have been available in the project was not implemented.

The **financial perspective** also present a win-win solution. The BRPM water reuse facility has at the time been in operation for nearly 24 months and based on actual water savings and operating cost savings the capital invested is projected to be paid back in less than 4 years. The savings will continue to accrue and will soon result in savings in multiples of the initial investment. The reduced top-up water required from Magalies Water and associated savings over the next 10 years assuming the current 2,64 ml/day reduced potable water usage from Magalies Water can result in a R100 million saving as indicated in the figure below.

Socio-economic benefits are not immediately evident, but many benefits can be listed. The plant required additional personnel to operate and contributed towards job creation. The negative impact of impacting local water resources has been significantly reduced which improves access to local potable water sources. Reduced consumption also improved access of communities to potable water from regional water sources.

Conclusion

The approach in addressing the mine water quality issues demonstrates that a water balance is not merely a legal requirement but a source of intelligence and presents current and future water re-use and reclamation opportunities. This Water Reclamation Plant was at the time the first dissolved air flotation reclamation system used on a platinum mine to reduce the potable water consumption for gland service water.

The BRPM case study demonstrates that with a proper understanding of mine water circuits many water reuse opportunities exist and that water reuse is not only an imperative from a water resource perspective, but also from a financial and socio-economic perspective. Not only did the water security of BRPM mine improved significantly, but it also has indirectly improved the water security of the neighbouring communities as well as the regional water supply security of the entire Magalies Water system.

Incremental improvement such as these will in future contribute to the triple bottom line of mining companies in Africa.