Mine water pinch – Increasing reuse/recycle efficiency while optimising water treatment on a mine sites

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Abstract

Mining companies are challenged to improve their recycling/reuse efficiency to limit the amount of clean water they might contaminate. This often results in a trade-off between expensive water treatment systems, that may not be an ultimate benefit to the project (e.g. high energy or carbon cost affecting ESG metrics) or continuing to import better quality water from the catchment. The Mine Water Pinch process is a tool that can be applied to optimise water reuse/recycling by identifying water users where high quality water may not be needed and aligning these uses with existing lower quality water streams on the site, allowing direct reuse with limited or no treatment. This paper outlines a modified water pinch procedure appropriate for use on mining projects. Two case studies are presented to demonstrate the process and the potential of the mine water pinch analysis.

Keywords: Mine water pinch, sustainability, ESG, mine water reuse/recycling, water efficiency, water saving

Introduction

Firm commitments on water stewardship and transparency around water use and managing water more effectively at site level have been made by members of the International Council for Mining and Metals (ICMM), (ICMM 2021). Mining companies focused on increasing recycling/reuse efficiency to limit the amount of clean water they contaminate are often faced with expensive or high energy consumption water treatment systems that may not be an ultimate benefit to the project (e.g. high energy or carbon cost, affecting ESG metrics). This typically results from focus on "end-of-pipe" treatment where all water streams were combined, and the combined stream treated to an acceptable quality for reuse. Innovative cost-effective options are required to support these mines in meeting their efficiency targets and balancing energy and carbon commitments. Various tools and methodologies are required to find suitable and transparent solutions to optimise investments in this area without compromising energy and carbon commitments. The Mine Water Pinch process is a tool that can be applied to optimise water reuse while limiting treatment efforts.

The Mine Water Pinch procedure aims to identify site specific water users where high quality water may not be needed and align these uses with existing lower quality water streams on the site, allowing reuse with limited or no treatment. The process has the further advantage of potentially limiting overall treatment requirements since segregated water streams result in a smaller volume of water requiring treatment to high quality or specific pollutants only present in some streams can be specifically targeted at a point where the pollutant is more concentrated and likely more easily removed, and potentially recovered for reuse or sale, whilst also reducing the volume of water requiring specialised treatment.

"Water pinch involves a set of systematic formal techniques to handle the complex problem of hierarchical water allocation to a system consisting of a number of processes, and choosing the best combination of strategies" (Brouckaert et al. 2005). The process is specific to the manufacturing industry and industrial sectors and involves a large number of quality and flow monitoring data of multiple water streams, more commonly available in the industrial sector. The key value of this approach is that it is a systematic approach and involves hierarchical water allocation by allocating your best source water first to the most sensitive processes allowing the best potential for reuse/recycling with minimal treatment.

Mine sites typically have access to less detailed monitoring data and tend to have one or two large storage reservoirs, capturing all contact water and distributing this water across the site for various water uses. When water of a better quality is needed, the mine contact water from the storage structure is either treated at end-of-pipe and recycled or water is imported from an external water source. While this approach is often practical and simplifies operational inputs, it may involve increased costs and complexities of water treatment. An alternative approach would be multiple separate storages and treatment facilities across the site. This option involves high infrastructure investment to separate and monitor all streams and is not necessarily optimised with treatment and discharge in one area and purchasing of new water in other areas. The mine water pinch process aims to achieve something more balanced through moderate segregation, monitoring, and reuse of the most impactful water streams as indicated in the example provided in Fig. 1.

Mine Water Pinch Methodology

The Water Pinch methodology developed by Brouckaert et al. (2005) for the industrial sector, places a lot of focus on understanding individual uses and sources. To complete the process an in-depth understanding of the various unit operations and process sensitivities to contaminants in the source water streams is required.

In the mining environment, more limited water quality analyses are performed, and less information is available on processing water quality constraints. Mines also occupy a greater footprint area and tend to experience higher variability in water quality and water availability associated with seasonal effects. To accommodate the challenges specific to the mining industry the Mine Water Pinch process was developed to modify the original concept set out for industry by Brouckaert et al. (2005). Table 1 sets out the Mine Water

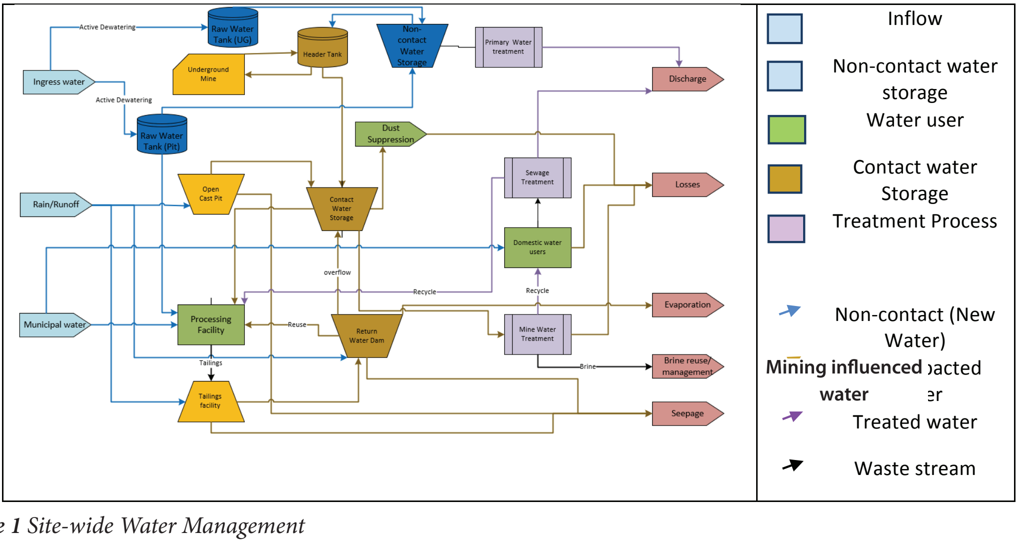


Figure 1 *Site-wide Water Management*

Table 1 *Mine Water Pinch Methodology adapted from Brouckaert* et al. *(2005) applied to Industry*

Step	Industry Water Pinch Methodology (Brouckaert *et al*. 2005)	Developed Mine Water Pinch Methodology
1	Produce a water flow diagram for the site.	High level spatially orientated block flow diagrams were produced with separate detailed area specific diagrams indicating water sources and sinks. This provided the project team with an indication of where the sources and sinks were and the distance one would need to pump these sources if uses were identified in a different area.
2	Assess flow and quality data for sources streams, uses and discharges.	Assess flow and quality data for sources streams, uses and discharges. Where possible sources (based on water quality) and uses (based on water quality constraint and location) were grouped, simplifying the assessment.
3	Undertake rapid screening and pre-screening exercise to identify streams to be included in the investigation.	Focus areas were identified based on-site specific objectives; this included, but was not limited to processes found to be sensitive to contaminants, processes currently using new (fresh) water sources and sources with good water quality. This process enabled the project team to identify key constituents of concern.
4	Reconcile data and produce a consistent mass balance, such that the inlet and outlet conditions of the water using network is known.	Assess the water balance and in cases where a salt balance is not available, produce a simplified salt balance. Prepare water pinch charts were prepared for focus areas and key constituents of concern, taking into account water sources being considered for the uses identified. (Refer to Fig. 2 for an example). In addition to this, box and whisker charts and time series charts were prepared for the water sources in order to understand the seasonal variation in flow and quality associated with the source water.
5	Simplify the network to exclude process streams that do not offer scope for integration.	Revisit water use constraints and investigate opportunities for blended source water streams in order to optimise the reuse options. Explore substitution opportunities, substituting better quality water with a poorer source, isolating streams based on quality and investigate treatment options.
6	Determine the optimal design.	
7	Investigate sensitive processes close to the pinch and assess opportunities for relaxed constraints or treated source water	
8	Revisit step 4 with updated design options	Consider location of source data in relation to the use, water quality fluctuations for the wet and dry seasons and where possible, determine high level implementation and operational costs for the opportunities identified. Prepare an action list for further investigations on opportunities requiring additional assessments, e.g. Dynamic salt balances based on proposed reticulation changes.
9	Check suitability of design – simulation	
10	Implement if feasible	Implement if feasible.

Pinch Approach which was then applied to our mining case studies.

A typical Water Pinch chart was prepared as part of Step 4 of the methodology as presented in Fig. 2. The red line represents the water uses and the blue line represents the source waters. The length of the line is an indication of the volume of water required. Municipal water was excluded in this example as reducing the use of municipal water was one of the key focus areas identified. In the case of sources, we used the average water quality and in the case of uses, we indicated the worst water quality that can be used. The green highlighted area on the graph where the blue line does not overlap the red line essentially represents the deficit and water either has to be imported or treated to meet this deficit. The intention is to iteratively increase the overlap to reduce this quantity. The portion of the blue line on the highlighted in purple that does not overlap with the red line represents the volume of effluent that still needs to be stored/managed on site after implementation of the pinch solutions. The highlighted sources indicate blending opportunities.

Mine Water Pinch charts are developed for various key constituents of concern identified in Step 3 and are reviewed simultaneously in order to identify recycle/reuse opportunities. Separate charts were prepared for streams

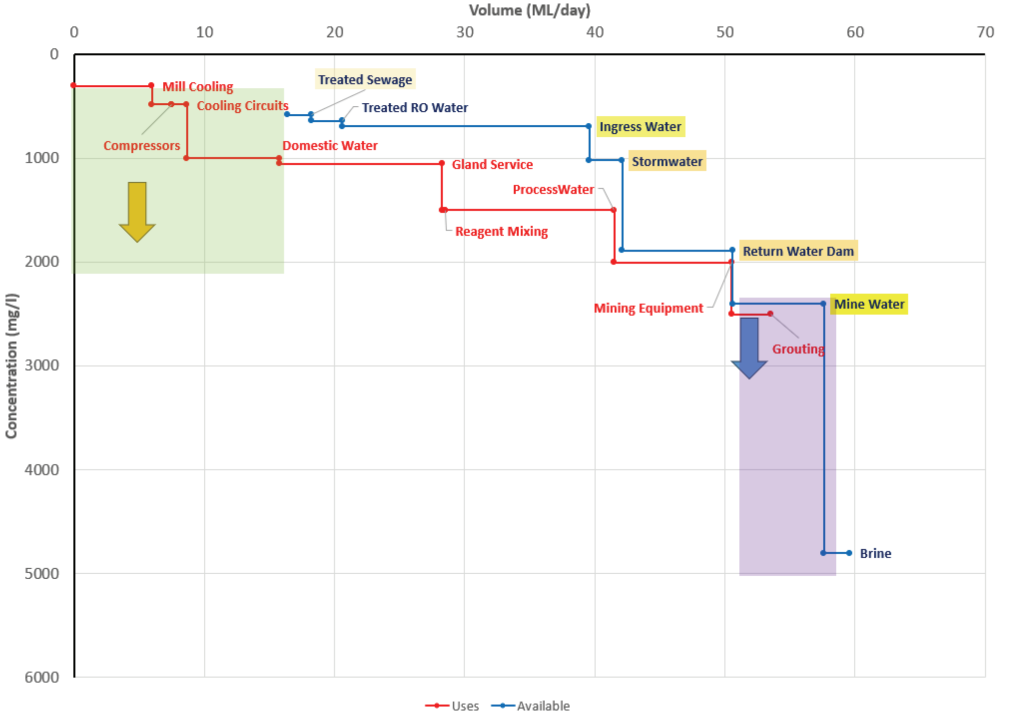


Figure 2 Example Mine Water Pinch Chart using TDS as the Constituent of Concern

with high seasonal variability being proposed for sensitive uses using the 95th percentile water quality data to assess the opportunities under seasonal variability.

The Water Pinch charts can be interrogated to identify opportunities. Where an available water stream is higher on the graph than a use, it is potentially available for that use without treatment; however, the priority is to assign the best quality water to the most constrained water requirements within geographical and financial viability constraints. For example, the following opportunities can be identified by examining Fig. 2:

1. The constraints provided for mill cooling, compressors and cooling circuits is of a better quality than the water currently available. These constraints were revisited with the site. It was noted that the aim was to improve the number of recycles by using a better water quality. This could be achieved through either changing the blend of the treated water from the current RO plant or adding an instream electro-coagulation treatment on the compressors. (orange arrow on chart)
2. Opportunities for blending mine water, stormwater and return water dam water with some ingress water were investigated, whilst ensuring that sufficient ingress water is kept available for areas requiring better water quality. (Highlighted sources)
3. Opportunities for using brine in the grouting process are being investigated. A chemical modelling exercise indicated that this is a possibility. Follow up laboratory tests have been recommended to confirm this possibility. (Blue Arrow)

By implementing these opportunities, the blue line can be shifted, reducing the volume of water imported on the site. The assessment indicates that the site is still water negative and will be required from an external source to meet its needs.

Case Studies

Case Study 1: Separating water sources at a processing facility

In this case study, site has three storages tanks at the processing facility. These tanks are kept at 95 % capacity and topped up with any source water available on site. The water in the tanks are then diluted with municipal water when the TDS of the water in the tanks is too high. High levels of corrosion were also noted across the processing plant, due to high chloride in the mining influenced water. The site has high volumes of ingress water and projections indicate that the site will become water positive in the next five years.

Three changes were proposed:

1. Active dewatering at the underground mining areas and open pits which enabled isolating a good water quality stream for use in sensitive uses and allow for diverting the clean, unaffected water.
2. Reuse of mining influenced water at the underground mining areas where the equipment is less sensitive to the fluctuations in water quality.
3. Isolating the feed water tanks at the processing plant and using better water quality for processes sensitive to TDS.

Future studies proposed to assess these options include a financial modelling exercise to determine the cost of isolating the ingress water and retrofitting the storage tanks and piping network at the processing plant to ensure that the take with cleaner water supplies the sensitive areas in the plant and a dynamic salt balance to understand the effects of the proposed changes on the water quality in the return water dam and mine affected water streams.

The recommended studies support development of the basic engineering to allow the cost/energy use of each option versus recycle/reuse efficiency savings to be assessed allowing the site owner to focus investment.

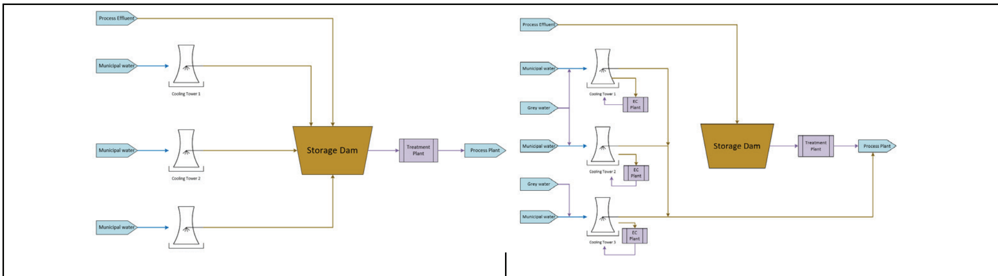
Case Study 2: Isolating cleaner streams for reuse and introducing treated grey water to reduce potable water consumption.

The current practice on this site was to use municipal water at the compressors and allow the blowdown to drain to a dam also receiving effluent streams from the processing plant. This resulted in the relatively clean blow-down water mixing with a poor-quality effluent stream. The Water Pinch Charts developed for the site indicated that the water quality in the storage dams available was not suited for reuse at the compressors or metals recovery area. The streams draining to the dam were revisited, and it was found that that the blow-down stream with better quality water can be isolated and reused directly at the metals recovery area. An electro-coagulation technology process proposed enabled site to blend treated grey water with the municipal water. The water quality in the storage dams fluctuated considerably. The proposed changes also allowed for blowdown water to be separated from the storage dam water when water quality in the dams is poor. The proposed modifications resulted in 58 % saving in water costs, 1 % saving in power and a 50 % saving in maintenance costs.

Pilot testing is proposed on the Electrocoagulation units to assess the performance on the Grey water/Municipal water blend.

Conclusions

The adapted Mine Water Pinch methodology developed as part of this study can be used as a systematic tool to identify reuse and recycle opportunities and reduce overall water treatment costs in the mining industry. The procedure outlined in this paper has been tested and demonstrated on the presented mine site case studies and has also been applied on other sites with other minerals being beneficiated. Key aspects of a successful mine water pinch study include a strong understanding of the site-wide water and salt



Current practice	Proposed changes

Figure 3 *Proposed reticulation changes to reduce the use of municipal water*

balance and water use constraints, working with the site personnel to understand key challenges on site and process upsets, inconsistencies that can occur and any previous water reuse studies or investigations carried out by site, and involvement of an integrated team of specialists who understand the water balance and variability in water availability, a water treatment team to advise on the appropriate level of treatment required, and an infrastructure design team to advise on potential costs associated with process changes. The Mine Water Pinch process can be applied to both identify opportunities to improve recycling/reuse efficiency at mining and mineral processing sites as well as to trade off other approaches which may not consider treatment effort (energy and cost) allowing mining companies a transparent approach to direct investment against their ESG targets.

The Mine Water Pinch approach is intended to be an iterative process with incremental economically viable solutions being identified resulting in continuous improvement as one pinch point is alleviated and the next can be identified and addressed.

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