Water management and treatment in the closure phase: Case studies and the associated challenges

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Abstract

Water management, in particular, perpetual water treatment, whether caused by the mine waste or orebody geochemistry or required due to laws and regulations, has been a challenge for mines going into closure and for legacy sites. The treatment of water and the potential social, economic and environmental impacts after the mine has stopped operating is a challenge most mining companies face. In many cases, the challenges are created by bad closure planning and promises made to stakeholders during the operational life without thinking of the consequences of these promises post-closure. This paper presents case studies of the various challenges associated with water management during closure and how they were dealt with, good and bad outcomes, on sites across Africa, USA, Canada, Europe, and South America.

Closing a mine site is very rarely a walkaway scenario, especially when it comes to water treatment and the legacy issues it creates. Through various de-risking projects, work has been conducted on reviewing closure plans at sites approaching closure as well as legacy sites already in closure. Through these reviews, the highest costs and biggest headache associated with closure were typically, the commitment to perpetual water treatment, the treatment method selected, and the reasons that led to the decisions. In many cases, the reason for the perpetual water treatment requirements was due to social commitments made by the mine during operation without thinking of the consequences on closure. In other cases, as in the USA and Canada, the closure plan and perpetual water treatment were aligned to the various legislative guidelines and requirements without thinking out of the box or challenging the norm.

Steering away from active treatment as being the default option and out-of-the-box thinking could have solved most of the need for this expensive closure option. For example, using a combination of passive treatment options and the diversions and separation of streams at a site in Peru could potentially reduce the site closure liability by USD 150 million.

In most of the case studies presented in this paper, sound planning and management of water with an eye on closure could have avoided the associated social and environmental impacts. In this paper, an outline is presented of the various challenges identified and how they were dealt with to reduce future liabilities and de-risk existing closure projects.

Keywords: Mine closure, water treatment, perpetual treatment, environmental, social

Introduction

Mine rehabilitation and managing water, especially perpetual treatment due to mine waste or regulations, poses challenges for closing mines and legacy sites. This includes addressing social, economic, and environmental impacts post-operation. Many of these difficulties stem from inadequate closure planning and unfulfilled promises made during operations. This paper explores case studies from Africa, USA, Canada, Europe, and South America, illustrating the complexities of water management during closure and lessons learned. Our team has conducted de-risking projects, reviewing closure plans for sites nearing shutdown and addressing challenges at legacy sites.

Discussion

De-risking projects and case studies on work done at legacy sites as well as mines approaching closure across Africa, USA, Canada, Europe, and South America resulted in the following lessons which were the main reasons why there were challenges at mine closure in particular for water treatment:

1. Poor or no closure and rehabilitation (in this article the term rehabilitation is used and is synonymous with the term "reclamation") planning at the start and during the operational life of mine (LoM) as well as no incorporation of concurrent closure and rehabilitation into those plans. If these plans are compiled, they are very rarely updated unless required by legislation or permit conditions.
2. Very little work is done in the planning or implementation phases of the mine to eliminate the need for perpetual active water treatment or even to minimise the volumes requiring treatment.
3. Financial discount rates are used to justify the low cost assigned to perpetual water treatment and to avoid capital expenditure which would reduce the long-term liabilities. This leads to unrealistic evaluations of the true costs of long-term water treatment.
4. No clear message or strategy aimed at mine closure is developed and communicated to, and by, the mine personnel. As a result, social commitments and in particular commitments and promises to stakeholders (e.g. communities, governments, NGOs) lead to unrealistic closure plans with high associated costs in the closure phase of an operation.
5. The closure water balance is not understood or developed until very late in the LoM and this leads to poor decisions on water management, water infrastructure and treatment methods and durations at, and during closure.
6. The water management and treatment aspects of mine closure are rarely looked at and studied at a scale beyond the mine boundaries and as a result, regional opportunities to collaborate on water management during the LoM and at closure are not realised and utilised.
7. The norm is very rarely challenged or tested – "We will perpetually treat because that is what the legislation or permit requires of us".

In most cases, by the time the operation reaches its LoM and closure is less than five years away, the only mention of closure and rehabilitation, whether concurrent or not, is made in the original Environmental and Social Impact Assessment (ESIA) documents and the Environmental and Social Management Plan (ESMP) submitted for permitting purposes. Some updates as the mines expand are made to these above-mentioned plans and the closure chapters. However, these are generally not practical, have little to no planning or timelines for concurrent closure and rehabilitation, and the various studies required to bed down a closure plan (e.g., trial revegetation programs, closure water balances, pit lake studies and cover designs) are not mentioned and as a result, they are left until the LoM is imminent. Without these studies in place, it leaves the team in charge of closure and rehabilitation during the post-closure phase with the following challenges:

- Inaccurate closure budgets that are generally underestimated specifically for achieving desired landforms and covers (dumps, tailings, pit walls, mine workings), revegetation, water infrastructure (sedimentation ponds and stormwater channels) and water treatment are generally expensive and assumed to be perpetual to provide a worst-case scenario.
- No trials, case studies or test work to base water management practices and revegetation of slopes.
- No concurrent closure has taken place and as a result, all rehabilitation and landform shaping needs to be done in the post-closure phase when no funds are available and the mines are not making a profit, one has to keep infrastructure in place just for the closure and little to no interest from the management and shareholders.
- Water infrastructure like holding ponds, diversion channels, stormwater channels and sedimentation ponds are under designed.

- The infrastructure in place was designed with a focus on the operational phase and as a result, in most cases, a substantial amount of infrastructure likely needs to be redesigned and constructed, this aspect negatively affects the closure budget and time.
- Water treatment in most cases is active treatment with high chemical and pumping costs with no thought given to reducing volumes and contact water during the operational LoM.

The above challenges are increased because little concurrent closure has been planned and implemented during the LoM. At a mine in Peru, going into the closure and the post-closure phases, a review of the plans was conducted to determine where any improvements could be made to reduce costs, and also to highlight any learning for future work at other sites. From the above-mentioned review, some clear outcomes were that:

- Shaping and concurrent covering and vegetation of dumps and slopes not in use during the last five years of operation could have reduced liabilities at the time of closure by approximately USD 65 million.
- The above-mentioned concurrent closure and rehabilitation work could have resulted in the complete removal of one water treatment plant from the water treatment requirements due to reduced contaminated water flows which equated to a further USD 20M in potential liability reduction. This would have been the case due to the geochemical stabilisation of acid mine drainage sources like the heap leach facilities and waste rock dumps.
- Although a much smaller Capex value in the closure provisions, if diversion channel designs were optimised and constructed to closure standards during operation, these activities could have resulted in a further USD 7.5 million reduction in closure liability.

In line with the above, a separate study conducted at a mine in Argentina to review water management practices and infrastructure with an eye on closure again showed that no clear plans for closure were in place. This mine at the time of the review was just three years from closure and at the time upgrades as well as new diversion channels were put in place/in the process of being constructed to direct clean stormwater around contamination sources like waste rock dumps. These channels were however designed and built to operational specifications (lower storm return volumes) and not to closure specifications which is for a more severe storm event. This was a few years out from closure at which time a lot of effort and capital could have been saved if the planning team had closure in mind.

Another challenge that mines face in planning for closure is that internal communication and collaboration between the planning and operations team and the sustainability team (the staff usually tasked with rehabilitation and closure) may not be conducted effectively. A case study in Nevada showed that if closure plans were refined in conjunction with the planning and mining teams, then the concurrent closure and various initiatives conducted during the operation specifically around waste rock dumps and open pits could potentially reduce closure costs by USD 200 to 300 million. Luckily this specific mine was far enough from closure that a complete overall of the closure and rehabilitation plan with collaborative efforts between the departments allowed this cost saving to be realised. This however required out of the box thinking around pit lake water management, water management practices with an eye on reducing the volumes requiring treatment and doing as much as possible concurrent rehabilitation during the time left within the LoM. All of this was done while talking to the relevant authorities and involving them in the process which allowed buy in from them to sign off on the plans.

The above-mentioned challenges and findings from case studies could have been avoided by having clear closure and rehabilitation goals both on the planning side (closure and rehabilitation plan and strategy) as well as the implementation of those plans already during operation. Organizations that have managed to avoid these challenges or will avoid them in future have implemented the following approaches to closure:

- Development of a closure and rehabilitation strategy and plan that has annual targets and is updated at least every second year by a dedicated, in-house team of personnel across departments in charge of the successful and sustainable closure of the mine.
- The above-mentioned closure task force has an annual strategy session allowing the plan to be reviewed and updated, and the roles and studies required of outside service providers to be planned and implemented.
- The strategy and closure plan has clear goals and targets that are reviewed quarterly to track performance and ensure that the plans remain practical.
- Individual and mine management KPIs which relate to annual bonuses are linked to the concurrent closure and rehabilitation targets and whether they are achieved or not (quantitative and qualitative rehabilitation targets).

The above KPI approach is implemented in some organisations. However, the long-term environmental and social impacts are not included in management KPIs. If they are it is usually quantitative and not qualitative so there is an annual rush to meet targets and as a result, there are further issues later down the line. For example, targets for hectares levelled, topsoiled, and seeded, may be identified but the quality of the ongoing rehabilitation may not be included.

Through various reviews, there was a direct link between the social commitments made to communities and the challenges faced during the closure phase. At a mine site in Peru within months of closure, there were more than 150 community commitments directly linked to water supply and water management that were still unresolved or at least planned for. These commitments were made to the communities to allow quick solutions to issues during the operational phase without understanding the full long-term effect that these agreements and commitments would have on closure and the costs associated with them. These 150 commitments resulted in large closure costs items being required like water supply infrastructure into perpetuity which also required a large water treatment plant to be in place.

The above issue was a direct result of the mine not having clear plans in place that were communicated throughout the organisation. Just as Environmental and Social Governance [ESG] needs to be at the forefront and brought into discussions at all levels of a mine, so does closure. To resolve the above-mentioned challenges the mine team had to review all social commitments and go back to the communities to renegotiate or table new alternatives to satisfy the agreements made. This took time and delayed many of the closure activities.

A water management review of a legacy site in France revealed that throughout most of the mine operations as well as going into closure the water balance for the site, and more specifically the water balance at and during the closure phase for a large discard dump was not understood or adequately developed. As a result, perpetual water treatment was committed to and the company was in the process of designing and implementing a water treatment plant to treat water for the next 30 to 40 years. The dump in question was covered and vegetated but seepage and runoff from the dump (contact water) was still contaminated and needed treatment. A review and development of the water balance allowed a clear picture of the various flows on site to be developed and as a result, a more practical, passive solution to the discharge water quality issue could be developed.

South Africa has extensive mineral resources which are generally concentrated in various regions as a result of the geological formations and their setting in the country. Platinum Group Element (PGE) and Copper mines are generally concentrated along the northern part of the country, large coal mines are concentrated in the Mpumalanga coal fields and gold mines in and around the Witwatersrand, where the well-known south African gold fields are located across a vast area. Although these above-mentioned areas are very big in scale, there are a lot of mines that are in relatively close proximity to one another, and which are hydraulically interlinked that experience similar mine water management issues. A prime example of this is the Mpumalanga coal fields where large volumes of water require treatment and discharge during operation as well as in the closure phases of these mines. Similarly, the gold mines concentrated in the area around Johannesburg and beyond also have similar mine water management challenges. In the past these challenges were viewed in isolation and each mine developed and implemented its own strategy for management and treatment of water. However, in recent years a considerable amount of work has gone into collaboration of the various mines to find a holistic and in most cases basement wide solution to reduce the costs and appropriately spread it across all operations.

The challenge in the Mpumalanga coal fields where collaboration has been the greatest remains that even when regional options are assessed, the related legal and commercial aspects often get in the way between parties and negotiations fall apart quite early in the discussions. The value of collaboration and basin wide strategies is seen by everyone but at the higher management and commercial levels the deals cannot be finalised mainly due to liabilities and how to split those between the various parties.

For the Witwatersrand goldfields the problem is not technological. The various solutions can be compared and ranked and the best one selected. What is preventing the effective implementation of the best solution[s] is the regulatory and governance environment as the authorities and the mine operators can't agree on a management structure and particularly on a payment and revenue arrangement. Whilst these discussions are being held, the mining operations have mostly closed down and the companies are distancing themselves from any liability.

While the Mpumalanga Coalfields are still actively being mined and there have been several attempts to collaborate on a regional scale, it has been difficult to find common ground among the players in the region. The LoM for some larger operations extends into 30–50 years (assuming the world continues to rely on coal as part of the energy mix) and so the opportunity for planned regional mine closure and new socio-economic opportunities still exist. However, for true success, closure needs to include collaboration between mining companies who can benefit from the cost savings of working together as well as the political will to encourage or force these parties to work towards a regional solution. Current legislation, permitting and approvals, at least in a South African context, are only required for the effects within an individual fence boundary. If there was a legal requirement, the contractual negotiations would not fall down so easily and early in the process.

Planning for closure and rehabilitation in less settled mining jurisdictions with mining codes and legislation still in development, is sometimes easier and more practical due to new or old ideas not generally accepted elsewhere being put forward and tested or implemented. In countries like the USA, Australia and Canada the legislation or "usual" approach is very rarely challenged or tweaked. The excuse given is that legislators and the permitting authorities are not open to new ideas like pit lakes, passive treatment or in-pit deposition. However, a project at a gold mine in Montana that is in closure showed that reprocessing existing tailings and putting the new waste stream back into the open pit can reduce the surface liabilities as well as pay for most of the closure by selling the byproduct from the reprocessing. The reprocessing and removal of the surface TSF also resulted in the perpetual treatment of groundwater being removed from the closure plan. This was approved by the authorities only because it was tabled logically while taking the authorities on the journey from start to finish. In countries like the USA, there can be a lot more out-of-the-box thinking implemented that can be successful if the relationship between the authorities and the mines takes a collaborative approach to environmental solutions.

Conclusions

The lack of comprehensive closure planning throughout a mine's operational lifespan contributes to challenges during closure, particularly in managing water treatment. Concurrent closure and rehabilitation efforts are seldom executed during operations, leading to increased costs and inefficiencies. Insufficient efforts to minimize perpetual water treatment needs, along with unrealistic evaluations of long-term costs, exacerbate closure challenges, while inadequate communication and poor understanding of closure water balances further hinder effective closure strategies. From the various projects and case studies the most important aspects for a mining company to have in place to avoid the most common pitfalls of closure and rehabilitation are the following:

- A dedicated closure team that includes senior management needs to be in place consisting of members from all departments. This team needs to put together and drive a closure strategy and plan that is practical and updated regularly.
- The above-mentioned strategies and plans need to be communicated to the entire organisation and all stakeholders to ensure all parties are onboard and buy into the closure and rehabilitation process.
- Mine or business performance needs to be linked to closure and rehabilitation performance and as a result concurrent or ongoing closure throughout the LoM with clear targets needs to be in place.
- Management needs to be convinced of the wisdom of proper planning and capital expenditure during operation to avoid long term liabilities associated with perpetual water treatment.
- Cost models need to be developed which are truly reflective of the cost which will be incurred in long term water treatment and recognition that discounting typically leads to the elimination or underrepresentation of real costs.
- Studies, trials, modelling and construction needs to be done during the operational LoM with a clear view of what is required at closure.
- More needs to be done in complex/multi-operation mining areas to collaborate with other mines, a general ESG strategy to work together with other competitors or companies in the area can substantially reduce the burden of water treatment and other issues.
- The authorities responsible for the permitting of the water, social and environmental aspects of the operations need to be included in the mine closure and rehabilitation conversation from the start and be made part of the team.

Future Directions

Potential future topics for study and discussion that can further improve closure, water treatment and rehabilitation efforts include:

- Analysis and further work focusing on proactive measures or strategies for mining companies to address water management challenges and stakeholder commitments during the operational phase.
- Identifying and studying opportunities for collaboration among mining companies and regulatory authorities at regional levels to address water management challenges collectively, potentially leading to cost savings and more sustainable closure practices.

References

Due to the sensitivity of some of the information the names of the mines and companies are not provided and references to the reports containing this information are not noted. However, the work presented was completed by the authors and permission from Digby Wells Environmental to use the information by keeping confidentiality of the client has been provided.