Cover system performance monitoring for tailings – are we doing it correctly

Proper planning and monitoring of tailings storage facilities will ensure the best closure outcomes for key project stakeholders

Successful closure of tailings storage facilities (TSFs) is an environmental issue faced globally. During the initial feasibility and design phase, importance is rightly placed on the physical stability of above ground TSFs. However, it can be argued that aspects of closure planning are not often considered to the same extent by comparison. Hence, a key message of this article is that planning for the landform, as it is further developed and constructed, should ideally have alignment with closure planning, in order to optimise the economics of the operation as a whole. From a closure planning perspective, this should include appropriate attention to potential short-term and long-term environmental risk (for example stability of the TSF, but also water quality of seepage and surface run-off), as well as appropriate engagement with stakeholders and development of agreed upon closure objectives before the TSF is closed.

As a result of TSFs being permanent structures, and as such representing a legacy to the project, it is becoming more critical that their long-term risk be considered ‘part of the planning process up front’ so as to optimise their construction. Facets that often require greater emphasis include, but are not limited to the following: consideration for socio-environmental implications associated with TSF...
construction and subsequent closure. What are the physical, chemical, ecological and social conditions? Will there be long-term water quality issues, and if so, how will these be addressed? (Bjelkevik, 2011).

Closure plan development within the early stages of the project is fundamental and should be supported by the progressive development of the facility. TSF closure should provide an inherently stable landform, capable of long-term erosion prevention and suitable to the local surrounds (Department of Primary Industries, 2004). Minimal maintenance should be required following rehabilitation and post-closure of the project, and the closure design should be appropriate to the on-site conditions. The latter of these items is critical to the facility's overall post-closure success.

The greatest number of options for varying closure designs are within the early stages of a project. During the project life, options for closure are significantly decreased; at the same time costs to alter a design according to the most promising closure option are at their highest. Thus, it is critical to the venture to appropriately plan for closure of a facility prior to significant on-site developments (Mao and Kam, 2011) and in conjunction with a conceptual design that not only understands the basic requirements of the TSF (volume of tailings to be deposited; control measures to prevent seepage; deposition method, etc) but also how the facility will be rehabilitated, and when. Regular reference to the closure plan and appropriate updates are required.

Whilst it is understood there are many options for tailings rehabilitation, encapsulation through construction of an engineered cover system (limiting atmospheric interactions with reactive materials) may represent the most appropriate option to achieve successful rehabilitation.

This paper explores the utilisation of an engineered cover system for rehabilitation and closure of a TSF, and instrumentation requirements for use in monitoring the performance of a tailings waste cover system.

**Tailings storage facility closure planning**

Should closure planning studies determine that a cover system will be required for rehabilitation and closure, it must be appropriately designed early within the mine life. This approach may allow the required cover materials to be stockpiled close to the facility for construction use at a later date, or allow for a change to the mining schedule to excavate such materials as needed, thereby preventing the requirement of double handling. In parallel, during cover system design studies it is paramount to ensure that the proposed material thicknesses are achievable. For example, the most promising design may have been proposed without consideration of available material volumes, or their use elsewhere within the mine site, thereby developing a design that will not be constructed. Additionally, if material volumes decrease over time through a refined geochemical understanding or use elsewhere within the mine, it is necessary to revisit the cover system design and assess how a variation will affect the previously predicted performance.

**Cover system design**

Acid and metalliferous drainage (AMD) is a major environmental problem facing the mining industry today. AMD is the result of the combined chemical and biological oxidation of sulfide minerals and the release of associated metals, such as iron, aluminium, manganese and other heavy metals. Bare surface waste facilities generally have the highest possible net infiltration (net percolation), therefore the potential for seepage rates for a given material and climate may be substantial and environmentally damaging. Likewise, the exposed surface represents a potentially significant issue with respect to run-off water quality and volumes. As such, the use of an engineered cover system may be considered to control atmospheric interactions with reactive waste materials. By constructing a 'dry' cover system (ie one comprised of soil, growth medium or benign waste rock), or a 'wet' cover, the potential for AMD to be generated at a facility can be limited. The cover system then acts to control the ingress of oxygen to the reactive waste or the infiltration of meteoric water. As such, the design of a cover system can be complex and requires site-specific knowledge on various factors that have the capacity to alter the potential performance of a cover system.

It is common practice to construct single or multi-layered engineered cover systems to control AMD from reactive waste materials, such as tailings. Typically there are three principal objectives for a cover system over tailings:

- to function as an oxygen ingress barrier for the underlying waste material by maintaining a high degree of saturation within a layer of the cover system, thereby minimising the effective oxygen diffusion coefficient and ultimately controlling the flow of oxygen across the cover system.
- to function as a water infiltration barrier for the underlying waste material as a result of the presence of a low permeability layer and/or a moisture storage and release layer to provide a medium for establishing a sustainable vegetation cover that is consistent with the current and final land use of the area.
Cover systems can be simple or complex, ranging from a single layer of earthen material to several layers of different material types, including native soils, non-reactive tailings and/or waste rock, geosynthetic materials and oxygen-consuming organic materials. Factors that control the economic and technical feasibility of a cover system for a particular site include, but are not limited to: site climate conditions; vegetation conditions; soil properties and conditions; waste material properties and conditions; soil and waste material evolution; and surface topography. However, it is also important to put the TSF specifics into consideration of the larger site-wide closure plan. For example, studies may indicate that a multi-layer cover system represents the best option to limit rainfall infiltration and thus net percolation to reactive tailings materials. However, if the overall site-wide closure plan allows for drainage from the TSF to the mining void, and a pit lake at closure, then it may instead be advisable to construct a thinner or single-layer cover system to minimise salt uptake or surface erosion, in addition to reducing potential engineering and construction costs. This concept requires the mine planning to be undertaken in unison across the site, and where targeted studies have been undertaken, findings should be discussed within the site-wide context for appropriate decision-making to be undertaken.

Additionally, a cover system design should consider the potential for material variations and conduct sensitivity analysis to evaluate how a change in the proposed cover materials will affect the required performance. For example, a variation in material type may have adverse effects on vegetation establishment; net percolation rates to underlying materials; erosion prevention; and prevention of salt uptake, all which could be considered as closure criteria by a mine site.

**Cover system performance monitoring**

Once a cover system design has been decided upon, it is common practice to implement a monitoring system to assess its physical performance at the TSF. This concept allows for a design to be amended as necessary as actual field data is recorded. Additionally, it demonstrates that consideration is being paid to the most promising closure option/s and how they may perform in real terms, rather than implementing a design based on numerical models and a limited climate database.

The direct measurement of cover system field performance is considered to be state-of-the-art methodology (O’Kane, 2011). As such, care must be made when designing a system and choosing the number and type of sensors for installation. Performance monitoring trials can be costly to a venture. Costs are in terms of physical sensor costs, and calibration if required, but also on-site costs with regards to personnel and plant equipment utilised to construct a trial. Further costs are involved following installation to review the data, interpret its findings and complete any maintenance to equipment as required. Costs can also be considered in terms of time. Performance monitoring often occurs in excess of five years, and the longer the data has been collected for, the greater the volume of information available to inform closure planning and refine designs as necessary. However, the timescales considered must be relevant and acceptable to the mine. With instrumenting waste rock storage facilities, a cover system field trial may be compromised if the area is required for further material dumping or exploration. This thereby quickly terminates data collection where processing and mine planning may overrule closure planning and rehabilitation. Fortunately, this is rarely the case with TSFs and as such an area designated for rehabilitation is commonly at its final height and waste volume. However, timescale must be considered within the design and implementation phase.

The performance monitoring data collected can only be considered as good as the instrumentation plan designed and implemented. There are many ways in which a believed ‘successful’ cover system field trial may later be deemed as having failed, as further described within the following sections.

**Incorrect instrumentation choice**

As with the previous example where the cover system needs to be suited to the site-wide closure plan, the instrumentation utilised within a performance monitoring installation must have the capacity to demonstrate the success or otherwise of a given design. It is of particular relevance to focus on a potential weakness that has the capacity to impact on successful rehabilitation and TSF closure. For example, where the cover system's purpose is to limit net percolation, the monitoring should be focused on understanding the movement of water within the cover system itself, in addition to within the upper portion of the tailings waste. As such, instrumentation should be appropriate to collecting data relating to moisture and/or matric suction measurements. Monitoring analysis would then look at moisture fluxes across the cover system/tailings interface to understand the localised water balance. This data is further improved with the installation of a meteorological station within close proximity to compare rainfall events with cover system performance and potential for moisture storage.

**Poor installation methodology**
Monitoring equipment is commonly fragile and costly. As such, it is paramount that the correct and appropriate installation procedures are followed. Unlike installation within waste rock, which commonly comprises coarse particles with boulders and cobbles present, tailings waste is typically uniform in terms of its particle size distribution. As such installation within tailings material itself may not lead to sensor damage. However, care should be taken within sensor installation within the overlying cover system, in particular with regards to further building the cover profile if the trial is considered on the large scale, utilising run-of-mine plant equipment and construction methods. In addition, care should be made to ensure that instrumentation is accurately monitoring the medium they are intended to, rather than a seating or bedding unit they are installed within or on. Where sensors are installed deep within a profile, it may only be apparent that there is an issue following installation at a point where excavation and maintenance or replacement is not an option.

**Infrequent data collection**

Following appropriate sensor and instrumentation selection, another important aspect of cover system performance monitoring is determining the frequency of data collection. This further emphasises that a successful monitoring plan and design will have clearly defined what the monitoring data will be used for and ultimately how it can potentially effect TSF closure and rehabilitation.

It may be necessary to complete data collection from a full sensor profile within a cover system and tailings waste profile at multiple times during a day. Alternatively, some equipment may only need to record when a certain event is achieved. Failure to record a critical event or occurrence within the cover system has the potential to prevent the trial’s success.

**Appropriateness to project outcomes**

As previously described, commonly the use of a cover system is to control atmospheric interactions with reactive tailings waste. As such, this form of cover system should be instrumented to assess oxygen diffusion rates or pore gas concentrations directly. Methods to monitor the infiltration of water were previously discussed.

Following prolonged monitoring, an understanding should be developed as to how successfully the designed cover system is controlling the atmospheric interactions. With a cover system designed to limit water ingress, a further understanding of the moisture storage capacity of the cover system itself can be developed, information that can then feed into vegetation studies.

**Data verification**

While performance monitoring can be costly, the success of a project requires that sufficient data is collected and thus any data patterns verified. Often projects might contain one or two detailed monitoring profiles (comprising a high sensor frequency with depth), with supplementary profiles of reduced sensor frequency, or omitting certain sensor types. The secondary profiles allow for an indication of spatial variation to be developed while still collecting key performance monitoring data values.

Locations of the primary and secondary stations should be designed as such to reflect any variable conditions that may be present at the facility. For example, required differences in vegetation communities, grain size differences within cover system materials or meso-topographic conditions.

**Data capture length**

It might not be viable for a project to allow long-term performance monitoring at a given site. However, the longer data is collected for, the greater the confidence that can be placed in understanding the cover systems’ long-term performance. For example, if data collection is limited to three years, and these coincide with three below-average rainfall years, the project must rely on numerical and conceptual models to understand the cover systems’ performance when the potential storage capacity is overwhelmed. This is of particular importance within cover systems utilising the moisture ‘store-and-release’ concept. Additionally, vegetation establishment may play an important role in cover system behaviour and performance. However, it should be considered that vegetation community development may take a number of years, and as such the initial monitoring is not necessarily representative of long-term conditions (Howard et al, 2011). Where a TSF is being progressively rehabilitated, data collected after the first three to five years may lead to an alteration within the proposed design for the remainder of the facility, thus allowing a dynamic closure approach.

**Conclusion**

Where a cover system is to be constructed at a TSF for rehabilitation and closure, it may be considered advisable to install performance monitoring equipment. With this approach, over time a real understanding can be developed with regards to:

- how the cover system is performing
• how the cover materials are evolving with time and physical, chemical and/or biological changes to the profile
• how the design may require refinement to achieve the most promising closure outcome for a site. It is acknowledged that performance monitoring equipment and ongoing monitoring and data interpretation can be costly, and as such highlights why care and consideration must be taken when designing the trial and physical equipment installation.

References


