Issues for consideration when designing a growth medium layer for a reactive mine waste cover system

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ABSTRACT: Often in the design and construction of a barrier layer / growth medium cover system for reactive mine waste the focus of the design is on the barrier layer. While the importance of the barrier should not be discounted, neither should the importance of the overlying growth medium. Issues to consider when designing a growth medium layer for a cover system that incorporates a barrier layer include, but are certainly not limited to: a) particle size distribution and geochemical characteristics of the selected growth medium material; b) nutrient availability and cycling in the growth medium layer; c) the methodology used to place the growth medium material; d) potential impacts of site-specific physical, chemical and biological processes; and e) final landform design for the waste facility. In summary, the growth medium layer requires as much "design" attention as the barrier layer to ensure sustainable performance of a mine waste cover system.

1 INRODUCTION

Construction of a cover system over reactive waste rock or tailings is a technique used at numerous mine sites around the world to control acid mine drainage over the long term. A cover for a site located in a semi-humid or humid climate would typically include a layer of compacted fine-textured material (barrier layer) to reduce the ingress of atmospheric oxygen and net percolation of meteoric waters to the underlying waste material. A cover system with a barrier layer also requires an overlying layer to protect the integrity of the barrier layer and provide a medium for the growth of vegetation. This layer, referred to as the growth medium layer, also helps to reduce the percolation of meteoric waters to the underlying waste through storage and subsequent release of moisture to the atmosphere as a result of evapotranspiration.

A soil-atmosphere numerical model is typically used to determine the optimum cover system design for a waste storage facility, based on material characteristics and availability, as well as the local climate and hydrogeological conditions. The "optimum" cover system design generally implies the required minimum thickness for the various cover system layers to meet the desired or specified cover performance criteria. The initial or "modeled" performance of a cover system has the potential to decrease over time due to various site-specific physical, chemical and biological processes that will alter the as-built integrity and properties of the cover layers. It is essential that the cover system design account for these processes to reduce the uncertainty associated with long-term performance to an acceptable and defensible level. In essence, accounting for these site-specific processes provides the opportunity to minimize and/or manage risk that is generally associated with long-term performance of a cover system.

Issues to consider when designing a growth medium layer for a cover system that incorporates a barrier layer include, but are certainly not limited to:

- Particle size distribution and geochemical characteristics of the selected growth medium material;
- Nutrient availability and cycling in the growth medium layer;
- Material placement methodology to address potential segregation and *in situ* density issues;
- Potential impacts of site-specific physical, chemical and biological processes; and
- Final landform design for the waste facility.

Each of the above issues and their potential significance or impact in the design and performance of a growth medium layer is discussed briefly in this expanded abstract. Current "state-of-the-art" cover design numerical models are not capable of developing quantitative predictions of many of the issues listed above. Hence, identifying the site-specific processes that could impact on long-term performance and addressing them from a qualitative perspective, with experts in the different disciplines required, should form a key component in the cover design methodology.

2 MATERIAL PARTICLE SIZE DISTRIBUTION AND GEOCHEMICAL CHARACTERISTICS

The particle size distribution of the selected growth medium material is important from a revegetation (i.e. water holding capacity) and surface erosion perspective. The majority of plant available water in soils is held in soil pores formed by particles less than 2.0 mm in size. An "ideal" growth medium layer material should also possess an appreciable quantity of coarse-textured particles in relation to the quantity of fine-textured particles to reduce the susceptibility of the cover layer to water and wind erosion. In other words, a growth medium layer material should be well-graded as opposed to uniform, with particles ranging from silt- to cobble-size.

Several geochemical characteristics of a material should be known prior to determining its suitability for a cover system growth medium layer. The material, in particular for run-of-mine waste, should be relatively inert or barren to prevent contamination of surface water courses. The pH of the material should be suitable for the growth of the planted revegetation species, typically between 6.0 and 7.5 (Daniels & Zipper 1997). High levels of soluble salts are toxic to plants and also inhibit nutrient and water uptake; soils with water-extractable soluble salt levels greater than 5,000 ppm should be avoided (Daniels & Zipper 1997). Soils with high levels of soluble salts are also a concern from an ion exchange perspective when the underlying barrier layer possesses active clay minerals (James et al. 1997).

3 MATERIAL PLACEMENT METHODOLOGY

The use of a well-graded material for the growth medium layer in a cover system can lead to segregation during placement. This in turn can lead to preferential flow paths, or macro-pore flow, within the cover system. These flow paths, however, only become "active" during extreme rainfall events or when surface runoff promotes accumulated surface flow to the area of segregation. Once the meteoric waters percolate to depth, it is an extremely slow process to "pull" the moisture back to the surface because flow occurs in the matrix of the cover material. Smaller tip heads or lift thicknesses reduce the potential for segregation during construction of the growth medium layer.

Over compaction of the growth medium layer, particularly in the root zone, should be avoided during construction. Soil compaction restricts root growth and reduces the available water holding capacity of the growth medium. Daniels & Amos (1981) found compaction was the major soil factor limiting long-term revegetation success at a reclaimed mine site in Virginia. Compaction between 80% and 85% of the standard Proctor maximum dry density provides many of the stabilizing benefits of soil compaction without jeopardizing the viability of vegetation development and growth (Gray 2002).

4 NUTRIENT AVAILABILITY AND CYCLING

The ability of the growth medium layer to retain and recycle essential plant nutrients is critical to the development of a permanent and stable plant community for a mine waste cover system. Run-of-mine barren waste and natural granular borrow materials typically have low nutrient levels. When these materials are used for the growth medium layer, the cover surface should be amended with an organic-rich material such as topsoil or peat. For sloping surfaces, the organic material should be tilled into the granular material to prevent erosion of the organic material prior to establishing a permanent vegetation mat.

Assuming adequate initial soil conditions, Daniels & Zipper (1997) state the long-term productivity of the plant / soil system is dependent on the following major factors:

- the accumulation of soil organic matter and N;
- maintaining N-fixing legumes in the stand; and
- the establishment of an organic-P pool and the avoidance of P-fixation.

5 POTENTIAL IMPACTS OF PHYSICAL, CHEMICAL AND BIOLOGICAL PROCESSES

A cover system growth medium layer is typically designed with the assumption that it will remain intact and the basic physical dimensions and structure of the layer will not change. However, when long-term performance is considered, it becomes likely that the surrounding environment will alter the growth medium layer in some way. The initial performance of the growth medium layer, and cover system as a whole, will change as a result of physical, chemical and biological processes, and result in long-term performance, as shown in Figure 1.

INAP (2003) conducted an examination of the processes shown in Figure 1, and determined that their effects could be related to the change in three key cover performance properties; namely, the saturated hydraulic conductivity and moisture retention characteristics of the cover materials and the physical integrity of the cover system. The saturated hydraulic conductivity and SWCC are key hydraulic properties of a cover system layer. Tests can be completed to assess the likely changes in these properties (if any) over time; however, laboratory measurements more than likely illustrate a range of values for a certain material. INAP (2003) state that developing field-based measurements of the key hydraulic properties is essential for properly designing a cover system.

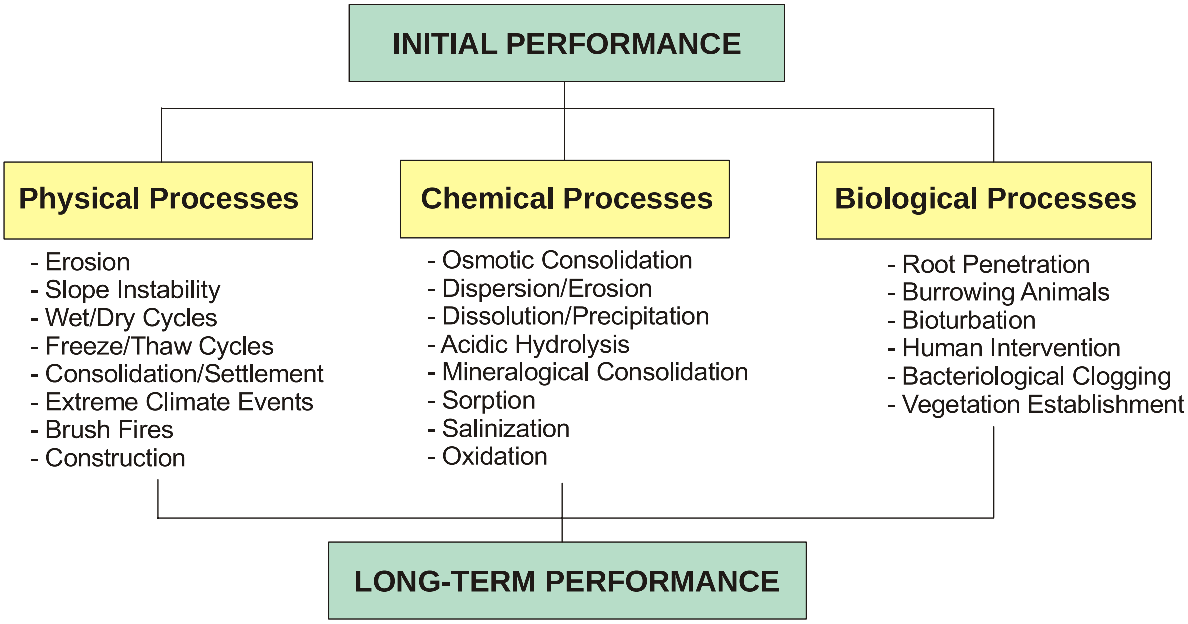

Figure 1. Processes that could impact the sustainable performance of mine waste cover systems (from INAP 2003).

6 WASTE FACILITY FINAL LANDFORM DESIGN

Several issues should be considered when designing the final landform for a waste storage facility in an effort to minimize the required thickness of a cover growth medium layer. The percentage of sloping surfaces on a reclaimed waste storage facility should be maximized from a water balance perspective. This will increase the percentage of runoff compared to infiltration for incident precipitation and therefore, the requirement for moisture storage and release through evapotranspiration is reduced. Saying this, however, depending on the local climate at the mine site, the growth medium layer still needs to be robust enough to minimize the impact of physical processes such as wet-dry and/or freeze-thaw cycling on sustainable cover system performance.

It is often desirable for the final landform of a waste storage facility, particularly for flatter surfaces, to incorporate a “crest and trough” pattern. This micro-topography is beneficial for revegetation efforts because precipitation accumulates in the troughs, thereby increasing soil moisture levels, and wind velocities are reduced across the ground surface, thus reducing potential erosion of topsoil and grass seeds. Rather than forming the “crest and trough” pattern with additional growth medium material, potential savings exist if the landform shape can be created during placement of the final lift of waste material.

7 SUMMARY AND CONCLUSIONS

Often in the design and construction of a barrier layer / growth medium cover system the focus of the design is on the barrier layer. Considerable attention is paid to the placement of the compacted layer, ensuring proper water content and compaction to produce a low hydraulic conductivity material. While the importance of the barrier should not be discounted, neither should the importance of the overlying growth medium. The growth medium layer serves as protection against physical processes, such as wet-dry cycling and freeze-thaw cycling, as well as chemical and biological processes, while providing the ability for the cover system to integrate into the ecosystem. An inadequate growth medium layer will not properly protect the compacted barrier layer, leading to possible changes in the barrier layer performance. Concurrent to these considerations is that the growth medium must possess sufficient available water holding capacity to ensure a sustainable vegetation cover, which would be a function of the underlying material as well as the moisture retention and thickness of the growth medium. In summary, the growth medium layer requires as much “design” attention as the barrier layer to ensure sustainable performance of the cover system.

In an effort to reduce the cost of a cover system that includes a barrier layer there is a general tendency to reduce the thickness of overlying growth medium. However, an inadequate growth medium (from the perspective of depth or compatibility with the ecosystem that is ultimately desired, and/or the final land use) is likely the most common reason for failure of a cover system that includes a barrier layer to meet design specifications. At the very least, provision of a growth medium with an adequate thickness to allow the climax vegetation to be sustainable will significantly reduce the risk of a cover system not meeting design specifications. Mature, sustainable, and diverse vegetation will provide a significant reduction in net percolation to the underlying waste through storage and release of moisture by evapotranspiration, while also providing a reduction in oxygen ingress as a result of biological activity that will inevitably be associated with the vegetation.

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