How do you Manage the Risks and Uncertainties Associated with Geomembranes in Mining Leachate Applications?

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1. Introduction

Managing the risks and uncertainties associated with geomembranes in mining leachate applications is essential to ensure the safety and reliability of mining operations. The performance of geomembranes is dependent on numerous factors, including design, installation, operation, maintenance, site conditions, soil properties, and environmental factors. Some of the common sources of risks and uncertainties include mechanical damage during handling or placement of the geomembranes, stress cracking due to point loads and uneven subgrade, degradation or deterioration due to ultraviolet radiation and/or oxidation, differential settlement or deformation of the soil or structure or chemical interactions of the stabilizer system with either acidic or alkaline liquors.

To effectively manage the risks and uncertainties associated with geomembranes, it is necessary to conduct a comprehensive and systematic assessment of critical performance properties. This assessment should include field and laboratory testing of the geomembrane as well as modelling and simulation of the interaction between mining liquors, temperature, and the retained stress-strain behaviour. Additionally, reliability analysis, probabilistic methods, sensitivity analysis, parametric studies, risk matrix, and risk ranking should be employed to quantify uncertainty, identify critical factors, prioritize risks, and allocate resources for mitigation.

ExcelPlas has pioneered testing of geomembranes in severe chemical environments such as anaerobic digestors, leach pads, and evaporation ponds using various techniques such as accelerated immersion testing followed by strain hardening modulus-stress cracking resistance (SHM-SCR) and HP-OIT, thin-film accelerated immersion (TFAI) testing, deformulation analysis of additive package, and pKa analysis of additives. These techniques help to reverse engineer the additive package of HDPE geomembranes and assess their durability and resistance to chemically aggressive solutions.

Selecting the appropriate type and quality of geomembrane materials that suit the project requirements and site conditions, following best practices and guidelines for design, installation, and operation, providing adequate protection, inspection, and maintenance of the system, applying contingency measures and corrective actions in case of unexpected events or problems, and monitoring and evaluating the performance over time are some of the strategies that can be employed to reduce the likelihood and impact of failure of the geomembrane.

Managing the risks and uncertainties associated with geomembranes offers several benefits, such as improving the efficiency and effectiveness of the barrier system, enhancing safety and reliability, reducing costs and delays of the project, minimizing environmental and social impacts, and increasing satisfaction and confidence of stakeholders.

The most commonly used geosynthetics in tailings dams and heap leach pads are HDPE geomembranes due to their excellent performance history in terms of durability and resistance to chemically aggressive solutions. However, the performance of the additive package in the HDPE geomembrane such as antioxidants and stabilizers may be severely altered by acidic, alkaline, or high ionic strength solutions, inhibiting their ability to protect the polymer from free-radical attack. Therefore, particular attention should be given to running immersion tests to screen potential interactions between the stabilizing additives and the chemical environment of the mining leachate.

2. HDPE Geomembranes

HDPE geomembranes contain proprietary blends of antioxidants and stabilisers (known as the additive package) to improve the service life of the polymer. The service lifetime of HDPE liners is mainly dependent on the level and permanence of the additive package. The problem is manufacturers do not disclose the mix of additives to the end-user, and they regularly engage in resin substitution, masterbatch substitution and additive substitution based on price and local availability of the raw materials.

This has led to a lot of uncertainty around the consistency and quality of HDPE geomembrane products available today. The way to overcome these issues is by reverse engineering the additive package through deformulation, and performing the newly developed rapid screening procedures such as TFAI.

Although conventional long-term immersion testing is now recognized as the preferred method to assess the durability of HDPE geomembranes in specific end-use media, the protracted amount of time required to develop meaningful ageing of the geomembrane is a disadvantage. Conventional accelerated ageing tests typically require a minimum of 3 to 6 months and sometimes years to complete, while the new rapid screening procedures can be completed within 2 to 4 weeks.

The additive de-formulation combined with the knowledge of the acid and alkali tolerance of each additive (known as pKa values) allows one to predict the performance of the geomembrane for a given service environment, while the rapid screening procedure can ameliorate the risk level associated with using HDPE geomembranes and provide a greater degree of comfort to designers and facility owners, particularly when project timelines are tight.

3. Managing Risks with HDPE Geomembranes

Geomembranes play an integral role in the design, construction, and application procedures of mining projects. However, deviations from standard procedures must be carefully considered to ensure successful implementation. The following factors should be taken into account:

- Firstly, high stresses are expected on geosynthetics in most mining projects, and hence they should be estimated realistically.

- Secondly, the thickness and material of the geomembrane liner should be selected based on its performance under anticipated loads, the coarseness/angularity of materials in contact, estimated foundation settlement, and material properties such as friction and tensile strength.

- The stability of the geomembrane should also be checked against its flexibility, chemical resistance, exposure to harsh climatic conditions, and cost. The theoretical analysis of geomembrane puncture may be carried out using the method proposed by Giroud et al. (1995). The final design should be based on suitable liner load tests and interface shear testing.

- Geosynthetics may be exposed to high intensities of solar radiation, UV exposure, extreme temperatures, high winds, and extreme ranges of leachate properties in mining projects located above 3 km elevation. Therefore, practical, robust, economical, acceptable to regulatory bodies, sustainable, and environmentally sound environmental protection measures should be taken into account.

- The design of mining facilities should meet both performance requirements and environmental demands. Most mitigation and control facilities for metal leaching (ML) and acid rock drainage (ARD) must be designed, constructed, and operated to perform indefinitely under normal and extreme climatic conditions. In Canada, ML/ARD sites are required to be kept under long-term care and maintenance for at least 100 years.

- The selection of the appropriate geomembrane material is critical, considering the potential for chemical and thermal degradations. The impact of mining solutions/liquors on geomembranes and their stabilization package must be assessed and addressed during the selection process.

- Finally, the foundation for the geomembrane liner should be firm to avoid large settlements that may strain the geomembrane liner, thus impacting its performance.

Conclusions

Managing the risks and uncertainties associated with geomembranes in mining leachate applications is crucial to ensure the safety, reliability, and sustainability of mining operations. Conducting comprehensive and systematic assessments of critical performance properties, employing various techniques for testing and analysis, selecting appropriate materials, following best practices and guidelines, and monitoring and evaluating the performance over time are some of the strategies that can be employed to reduce the likelihood and impact of failure of the geomembrane.