WATER RESEARCH COMMISSION

April 2008

The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

TECHNICAL BRIEF

INDUSTRIAL WASTE

Concern over the current regulatory and mining industry policies and practices governing solid mineral wastes prompted the WRC to fund a research project aimed at enhancing the capability of making reliable, quantitative predictions of water-related impacts associated with solid mineral wastes and demonstrating the effective integration of the resulting methodology into decision-making processes.

Solid Waste in the Minerals Extraction Industry

Background

The primary metals production sector, among others, is facing increasing pressure to improve environmental performance and contribute to development that is consistent with sustainability principles. A particular concern relates to the large tonnages of solid waste produced each year, most of which is consigned to land disposal.

Contaminated leachate from solid waste deposits results in degradation and pollution of the surrounding environment over the long term, with adverse consequences in terms of biodiversity conservation, quality and use of natural resources such as soil and water, and socio-economic and health impacts on local communities. **There is concern that current regulatory and mining industry policies and practices will be inadequate to prevent post-closure impacts or guarantee a risk-free, "walk-away" situation.**

For management to be effective, the potential impacts and risks associated with solid mineral wastes need to be quantitatively predicted and addressed during the early design stages of a project's life cycle, when the choice of appropriate technology could, in the long run, effect a reduction in both the amounts of waste generated and the environmental hazards associated with the waste.

A WRC funded research project was undertaken aimed at enhancing the capability of making reliable, quantitative predictions of water-related impacts associated with solid mineral wastes and demonstrating the effective integration of the resulting methodology into decision-making processes.

A Generic Methodology for Quantitative Assessment of Solid Mineral Waste Impacts

The main product of the research, a generic, systematic methodology for the quantitative prediction of impacts from solid mineral wastes, comprises six steps:

Step 1 – Problem formulation

Problem formulation, which entails the identification of assessment outcomes, requirements and constraints, is strongly coupled to data collection. A mineral waste inventory database has been developed to facilitate the collation of relevant data in a manner which supports and guides subsequent holistic assessment of waste character and environmental risks in a disposal scenario. It includes generalised process flow-sheets and spreadsheet templates for each mineral sub-sector in South Africa and also relevant information about the environmental impacts of solid wastes.

Step 2 - Qualitative waste characterisation

Qualitative waste characterisation is carried out in two consecutive stages. Firstly, solid waste characteristics are predicted from a consideration of ore type and composition, augmented by knowledge of the process route from ore to waste. The second stage entails the prediction of key characteristics of environmental significance i.e. hazard potential and mobility. Based on this qualitative understanding of the solid waste characteristics, it is possible to determine the likelihood and potential nature of adverse environmental effects arising from a particular solid mineral waste-stream.

Step 3 - Quantitative waste characterisation

Here, the overarching objective is to generate data that can be used to reliably forecast the potential generation and release of contaminated leachate in a given waste disposal scenario. The analytical framework developed for integrated and systematic characterisation of waste is comprised of a number of systematic and iterative stages, with progressive incorporation of accuracy and detail.

Step 4 – Leachate generation prediction

This step involves rigorous leachate generation modelling, which takes into account both hydrodynamic and chemical reaction processes in determining the time-dependent concentration profile of mobile contaminants at the interface between the waste deposit and the surrounding environment.

Step 5 – Fate and transport modelling

Modelling of the fate and transport of leached contaminants to obtain their spatial and temporal distribution in the subsurface environment can be achieved through the use of existing groundwater modelling tools. Such tools, which vary in complexity depending on the purpose for which they were developed, may also require site-specific data which are not readily available. A simple groundwater flow and mass transport model has therefore been developed for use in cases where full hydrogeological characterisation of the site is either unavailable or not warranted.

Step 6 – Impact quantification

The final step in the methodology is to calculate an appropriate impact indicator, based on the spatial and temporal contaminant concentration, for use in decision-making relating to policy, regulation, design, management and operations. In arriving at such an indicator, use has been made of water quality guidelines to develop risk profiles for the land area or land volume impacted by a waste deposit. The resulting indicator, the ***Impacted Land Footprint***, provides a useful measure in terms of which factors such as upstream mineral processing conditions, primary ores, waste management practices and disposal site location and design can be readily assessed. Extended use of this index to include assessment of resource-based impacts, such as degradation of soil and water quality, or its further adaptation to account for background contaminant levels or ecological sensitivity of the site or region, would also be possible.

Demonstration of the Approach

The application of the proposed methodology for the prediction of solid mineral waste impacts has been demonstrated in a case study on porphyry-type copper sulphide tailings, which are representative of broad classes of minerals tailings. The study was divided into three tasks:

(i) Review and analysis of the copper sulphide ore-to-tailings impoundment system

This revealed that currently available data were incomplete, with serious deficiencies relating to compositions of the waste output streams, characteristics of the copper ore deposits from which they are generated, and time-related emissions arising from their disposal. Despite these limitations, it was still possible to establish a qualitative understanding of the system and identify data gaps to be addressed during the qualitative waste-characterisation component of the subsequent task.

(ii) Qualitative and quantitative waste characterisation

A comprehensive list of element concentration ranges and forms in typical porphyry-type copper sulphide tailings was established on the basis of their origins, i.e. with reference to the characteristics of typical porphyry-type copper sulphide ores. Key constituents of potential environmental significance were identified on the basis of the hazardous properties and relative mobilities of the constituents in a typical disposal scenario. This generic qualitative characterisation was followed by the generation of quantitative data for a specific porphyry-type copper sulphide tailings sample, focusing on those characteristics of potential environmental significance.

(iii) Quantitative impact assessment

The impact indicator, the ***Impacted Land Footprint***, was shown to provide a useful assessment of the relative environmental impacts of tailings impoundments managed in different ways (covered and uncovered, saturated and unsaturated). The unsaturated and uncovered deposit result in the largest metals and salinity impacted land footprints, as a direct result of higher leachate concentrations and larger deposit area.

Conclusion

Although further refinement is possible and desirable, the capability of the generic methodology for quantitative assessment of solid mineral waste impacts has been demonstrated. The ***Impacted Land Footprint*** is a predictive tool, fully capable of supporting prospective decision making across a variety of contexts – planning, design and operation. Its credibility lies in the fact that it is based on a holistic consideration of the full material life cycle of minerals, from ore extraction through to refining. Its value is reinforced by the fact that it can be used in generic situations, or, with suitable data, made site-specific. The increased understanding afforded by this approach provides opportunities to influence and control behaviour, and eventually to optimise waste management and minimise environmental impacts across the entire life cycle of minerals' operations.

Further reading:

Waste Characterisation and Water-related Impact Predictions for Solid Mineral Wastes: A New Approach (**Report No: 1550/01/07**). To order this report contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565; E-mail: orders@wrc.org.za