European Waste Characterisation Standards for the prevention of acid/neutral rock drainage

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Abstract The importance of mining in most European countries has declined in recent decades, but mining has the potential to re-emerge as the backbone of the economy in many countries of central and Eastern Europe. Exploration for minerals is also active in Scandinavia, the Balkans and on the rim of Europe. In the aftermath of the Aznalcóllar (April 1998) and Baia Mare (January 2000) accidents, the European Commission published a "Communication on the Safe Operation of Mines" including two significant actions – the development of a "Best Available Techniques" document on the management of tailings and waste rock; and the development of European Directive 2006/21/EC on the management of waste from the extractive industry. When finalising the Directive, there were some open questions regarding waste characterisation methods. The Directive therefore calls for European-wide standards in waste characterisation, which are now being prepared by the European Committee for Standardisation (CEN) as mandated by the European Commission. Strong links between the CEN and the International Standards Organisation (ISO) are likely to be the vehicle by which new European requirements impact the industry globally. This paper will report on the preparation of the new standards, including the outcomes of two international workshops on acid generation behaviour; a comprehensive review of existing standards, the development of guidelines for kinetic testing, sampling and overall understanding of mine-waste characterisation processes; and the validation of a preliminary European Norm (prEN 15875) on Static testing for determination of acid potential and neutralisation potential of sulfidic waste.The CEN will work on the standards until early 2012. During this period the industry would be well advised to follow progress closely and to provide input where appropriate.

Key Words Europe, mine water, standards, policy, acid rock drainage

Introduction

There is a significant import dependency for most metallic minerals, as its domestic production is currently limited to about 3% of world production (Brown et al., 2010). Certain European countries are major mine producers of particular metals and minerals, such as brown coal in Germany (world's largest producer), chromium in Turkey (8.1% of the world total in 2008), titanium in Norway (7.1%) and silver (5.4%) and hard coal (1.4%) in Poland (Brown et al., 2010; WCI, 2010). The EU however uses 11% of global iron-ore production, while it produces more than 10% of the world's refined aluminium, copper, lead and zinc production (Brown et al., 2010; World Bureau of Metal Statistics, 2010). Industry as well as academia claim that the EU's apparent import dependency continues despite the presence of significant mineral potential within the EU.

Exploration for minerals is active in Scandinavia, the central part of Europe, the Balkans and surrounding countries. Many European mining projects have started up in the last five years and others are awaiting permits. The extractive industry has the potential to re-emerge as the development backbone of many regions in newer member states of the European Union (EU), as well as others in Eastern Europe and central Asia.

In 2000, the European Commission published a "Communication on the Safe Operation of Mines". The communication announced two significant new regulatory actions – the development of a reference document for Best Available Techniques (BAT) for management of tailings and waste rock (European Commission, 2009); and the development of a European Directive on the management of waste from the extractive industries (European Commission, 2006).

The aim of the Directive is to prevent major accidents and minimise the risks associated with tailings and waste rock disposal. It lays down requirements for the safe management of extractive waste including proper characterization of the waste and calls for the preparation of European-wide standards for that purpose. A working group of the European Committee for Standardization (CEN) was established in 2005 and the European Commission has granted it an official mandate to compile the necessary guidance for correct implementation of the Directive. The CEN hosted two international workshops on acid generation behaviour in Brussels on 4—5th May 2006 and 15—16th November 2007 and brought together the mining industry's experts on A/NRD to discuss their views on future standardisation.

Existing standards for the characterisation of waste

A number of CEN and ISO standards are potentially applicable to the characterisation of wastes from the mining industry. A variety of non standardized static tests methods exists for estimation of whether a waste material will generate A/NRD. Methods usually include the determination of sulfur/sulfide content of waste and, based on this, the calculation of acid potential (AP). Determination of neutralisation potential (NP) is usually done by digesting a finely ground sample with acid and measuring the acid consumed by the waste. The ratio of AP and NP or the subtraction NP-AP is then used in the assessment of potential risk for A/NRD (Kaartinen and Wahlstrom, 2009).

Static tests are designed for the purpose of measuring extractive waste's capacity for producing acidity and its acid neutralisation capacity. Static tests are used for screening purposes and to provide an answer to whether the mine waste material has a potential to be an acid producer or an acid neutralizer. These tests do not consider parameters such as the availability of acid-producing and acid-neutralising minerals and differences between the respective dissolution rates of acid-producing and acid-neutralising minerals (Kaartinen and Wahlstrom, 2009).

The potential of extractive waste to produce acid mainly originates from its sulfide content. However, no standard methods for the determination of sulfur species (sulfate-, sulfide-, disulfide- sulfur) are established for extractive waste (Kaartinen and Wahlstrom, 2009). Moreover, sulphides display differentiated reactivity (i.e. oxidation kinetics), spanning several orders of magnitude (Szczepanska and Twardowska, 2004).

Kinetic tests which allow determination of oxidation rates of sulfides and the release rates of acid-producing and neutralising minerals as well as metals are needed for deeper characterization of extractive waste (Kaartinen and Wahlstrom, 2009). Various comparisons of existing practices/standards have been carried out (Lapakko, 2002; Stenvall 2006) including Acid-Base Accounting (ABA); Modified ABA (Lawrence & Wang 1996); American Society for Testing and Materials (ASTM) standards and European pH dependence testing (CEN/TS 14997 and CEN/TS 14429).

Outcomes of two international workshops

Two workshops were held to provide a forum for CEN experts to exchange experiences with non-CEN experts on specific aspects of static and kinetic testing for prediction of acid/neutral drainage.

Experts agreed that the modified ABA method of Lawrence and Wang (1996) was an appropriate basis for a European standard because the method has been widely used in industry and research; it takes into consideration the slower reaction time of some buffering minerals; it does not contribute to overestimation of NP by using high temperatures or extremely low digestion-pH; and the method has good repeatability and reproducibility (Kaartinen and Wahlstrom, 2009; Wahlström et al., 2009). The modified acid-base accounting method by Lawrence and Wang (1996) uses the so called Fizz-test to determine the amount of acid to be added to the test suspension in the early stages of the test. According to internal CEN rules, the subjective nature of the fizz test makes it unsuitable for a CEN standard. Workshop delegates felt that changing to acid-additions based on carbonate content would not significantly change the efficiency of the modified-ABA method, but could increase the cost of testing and might generally over-estimate the NP.

On the subject of kinetic testing for the prediction of A/NRD potential, international practitioners advised that due to variations in mineralogy, climate, practicalities, and the different nature of waste rock and tailings, it would be very difficult to develop one single European Norm for kinetic testing. They pointed out that the kinetics of acid-producing and buffering reactions within waste rock and tailings are not truly intrinsic properties of the waste material. Therefore, the use of laboratory-scale parametric tests at the expense of common kinetic testing methods will lead to incorrect predictions of acid generation behaviour.

Finally, they stressed throughout the workshops that good mineralogical information about the waste is essential to be able to choose the best procedure and to interpret the results correctly.

A European guideline to the characterisation of waste rock and tailings

Failure of waste rock piles and tailings dams is commonly due to poor operation and maintenance, but could also be due to improper design or construction. A common element of such failures is insufficient control of the water balance and/or loadings relative to the design; where the dam pressures become too high, where overflow causes surface erosion or piping erosion occurs, failure of the dam wall can be the result.

Failure of tailings dams containing sulfide minerals results in further surface exposure and can increase the loading from acid rock drainage unless prompt and efficient clean-up is carried out (Walder and Drielsma, 2010).

To be able to manage and reduce the risk of A/NRD and alkaline drainage it is important to perform proper mineralogical, geochemical and hydrogological characterization of the ore, the waste, and the disposal site. It will also require management plans for the waste and verification of original characterization.

The CEN will develop a general guidance that is broad enough to describe the characterisation of both benign waste from aggregate quarries and potentially acid generating tailings with significant metal content. The general guidance document will recommend a general methodology for waste characterization covering both physical/geotechnical and chemical/geochemical aspects as well as other significant aspects from planning to interpretation and reporting. The document makes reference to relevant European standards where they exist (or are being developed) and, when needed, makes reference to publicly available documents/guidelines/standards from other jurisdictions.

prEN 15875 on determination of acid potential and neutralisation potential of sulfidic waste

Recognising that drawing conclusions from ABA data requires significant experience, prEN 15875 is based on the modified ABA method of Lawrence and Wang (1996). In summary, the new European Norm for static testing includes calculation of acid generation potential (AP) from Total and/or Sulfide-Sulfur content; determination of NP using a procedure based on Lawrence and Wang (1996) with analysis of total carbonate content to estimate the amount of acid required to reach pH 2.0—2.5; and calculation of NP Ratio (NPR = NP/AP) and Net NP (NNP = NP-AP).

It is known that carbonate minerals are the biggest source of neutralisation potential in extractive waste. Therefore it was considered feasible to replace the subjective Fizz-test with the determination of the carbonate content of the sample as a preliminary test to decide the amount of acid to be added at start and after two hours. The amount of acid to add corresponds to stoichiometric neutralisation potential in the carbonates, assuming all carbonates appear as calcium carbonate (Kaartinen and Wahlstrom, 2009). To have the digestion pH as uniform as possible throughout the test for samples with NP from different minerals, an upper limit for the volume of acid added at 22 hours has been set to be 50 % of the total volume (Kaartinen and Wahlstrom, 2009).

Calculation of AP as instructed by prEN 15875 assumes all sulfur to appear as pyrite. It is done by multiplying the total-S in mass fraction (%) by 0.625 to yield acid potential (AP) in mol H^+/kg based on 1 mole of sulfur in pyrite creating 2 moles of H^+.

An interesting, and perhaps the most important, finding from the robustness testing was the observation that combining the two acid addition steps at t=0 and at t=2 and adding acid only at t=0 h had no significant impact on the results. This amalgamation of acid addition steps was introduced to the draft standard in order to bring more flexibility to the execution time of the test within working hours and reduce possible sources of error in the procedure.

Kinetic testing guidance

The objective of this work task is to develop a guidance document for the planning, execution and interpretation of test results on acid generation kinetics, as well as including references to existing international and European guidelines and standards. A special focus is to provide guidance on the selection and use of kinetic tests on material that has been deemed potentially acid-producing (Wahlström et al., 2009).

The document will discuss both method selection and data interpretation. Kinetic tests allow determination of oxidation rates of sulfides and the release rates of other toxic elements from mine waste. A number of test methods have been developed. A distinction in kinetic testing can be made between tests designed to determine intrinsic properties of the material (parameter tests) versus tests designed to mimic a field scenario (simulation tests) and where the combined effect of various parameters on the weathering and release are measured.

Conclusions

The number of old mines/quarries and associated tailings storage facilities that need attention and rehabilitation, in addition to the number of mines/quarries in the process of being closed, is overwhelming. Mine waste and closure management has immediate impact on the industry's "license to operate", not just in terms of permitting, but also in terms of the social acceptability of the operation. Safety and environmental protection are key factors, but landscape change during and after operations, and post-closure land use are also of growing importance for planners and local communities. The prevention, mitigation and control of A/NRD is thought by many to be the single biggest issue facing the mining industry today. Following decades of work by industry and regulators to address the issue, the EU has taken another step forward in addressing waste characterisation practices for the purpose of preventing A/NRD from future waste facility closure projects. The impact of the new regulatory framework in the EU is already extending beyond its borders, due to Europe's ambition to demonstrate "global environmental leadership" and the financial community's willingness to adopt similar requirements themselves. Strong links between CEN and ISO are likely to be another vehicle by which the above new CEN standards impact the industry globally.

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