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A review of protocols and tests to characterise mine wastes for circular economy strategies

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Since the first scientific observations on mine wastes hundreds of years ago, we have gained some phenomenal knowledge of mine wastes based on a great diversity of characterisation protocols and tests. Traditionally, such mine waste characterisation provides information on current and future environmental conditions, because current mining operations manage mine wastes based on a linear economy thinking (“take-make-dispose”). By contrast in a circular economy ("make-use-return"), mining should produce little waste, any raw material losses to waste streams should be minimized, and any waste generated should be characterized for possible reuse, recycling or remining. In fact, mining can make substantive contributions to circular economy systems, by designing wastes out of entire value chains and looping mine wastes back into the material flows. As part of this new approach, historic mine waste piles of diverse mineral commodities have moved into focus as potential sources of metals and industrial minerals (e.g. phosphogypsum) as well as critical raw materials (CRM). The objective of this contribution is to review the various tools available to characterise mine wastes on a macro to micro scale for circular economy systems. Such a new approach requires protocols and test methods that support novel recovery technologies, innovative environmental advances and new by-product value chains. Yet, today’s waste characterisation protocols and test methods still focus on environmental risks, have serious limitations, are riddled with uncertainties that are hard to quantify, or only allow predictions of waste properties that represent best estimates. The time has come to drastically improve our scientific efforts to precisely characterise mine wastes on all scales for circular economy purposes (micro to macro scales). This route to greater confidence in the characterisation of mine wastes will come from new macro approaches (e.g. remote sensing, monitoring of waste dumps), meso tests (e.g. infield analyses, sensors), and micro laboratory analyses (e.g. computed tomography). There is reason for optimism that the required progress is possible. In future, researchers have to provide new tools that support innovative circular practices and novel approaches to resource recovery from mine wastes.