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Environmental assessment of sulfidic mine waste and its integration into green construction materials

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Proper management and storage of mine waste (e.g., tailings and waste rock) is one of the main issues that mining industries face. Additionally, there is already an uncountable amount of existent historical mine waste, which may, even centuries later, still be leaching contaminants into the environment. One solution to minimize the risks associated with the waste, with also potential economic benefits, is through the valorization of the waste. This can be done by first recovering valuable metals and removing hazardous contaminants. Then, the remaining residue can be valorized into green construction materials, such as geopolymers, ceramics or cement. For some mine waste materials, such as those with only trace levels of metals, that are not economically viable to extract, the "waste" can be reused directly without this additional cleaning step. In the present study, mine waste originating from 3 different sites, both operational and historical mines, was characterized and assessed in comparison with the cleaned mine waste (i.e., cleaned by bioleaching or ion flotation methods) and with different types of green construction materials containing (cleaned and uncleaned) mine waste. Particular emphasis was given to the study of the mobilization of metal(loid)s from the mine waste and green construction materials (i.e., ceramics, geopolymers and cement) under different conditions, through a series of leaching tests (i.e., EN 12457-2, US EPA's Toxicity Characteristic Leaching Procedure, and a pH-dependent leaching test). The standardized leaching tests were applied to either mimic neutral conditions in nature, conditions in a landfill (end of life), or a worst-case scenario (i.e., in extremely acidic or alkaline pH).

Mineralogical (X-ray diffraction) and chemical (X-ray fluorescence) characterizations of the original mine waste samples revealed high levels of Pb, Zn, and As in most samples. Additionally, the samples consisted mostly of quartz, micas, clay minerals and/or feldspars. Some samples also contained pyrite (FeS_2), a key mineral that generates acid mine drainage. Based on the leaching studies, some geopolymers, ceramics, and cement efficiently immobilized certain metals (such as Pb and Zn). Also, longer curing durations of the geopolymers in most cases improved the immobilization of metal(loid)s. Overall, the leaching studies revealed that the concentrations of mine waste incorporated in the construction materials, as well as the pH of those materials, were the main factors influencing the mobility of metal(loid)s. Additionally, for ceramics, the temperature at which the test pieces were fired, also played a major role. Through this detailed characterization, the environmental impacts were assessed from the mine waste to the downstream products, determining which valorization methods are the most viable to close the

circular economy loop.