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Leaching of trace metals (Pb, Zn) from contaminated tailings: a multicomponent reactive transport model of a pilot-scale experiment

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Unreclaimed mine tailings are a worldwide problem, these deposits presenting a source of contamination which can result in health and/or environmental issues. Metal and metalloid contaminants can be present in tailings in different geochemical forms and are likely to be transported under the action of leaching from surface to underlying groundwater. Unfortunately, water flow and mass balance related to leaching in the vadose zone are still difficult to measure at field scale, hence they are poorly known. To address this problem a recent pilot-scale experiment was set up, i.e a one m^3 column experiment ran over a period of 6 months. This experiment is suitable to control many parameters (water saturation, water flow, mass balance, etc.) while having a spatial and temporal scale closer to field conditions than standard laboratory experiments. A 70 cm high column was filled with highly Pb contaminated tailings, then regularly watered. The most reactive Pb-bearing phases are anglesite ($PbSO_4$) and plumbojarosite $Pb_{0.5}Fe_3(SO_4)_2(OH)_6$. The top half was unsaturated while the bottom half was kept saturated. Continuous measurements of water flows and water saturation have been done and geochemical properties of soil solutions were weekly monitored at different levels in the column. HPx software was used to build a 1D multicomponent reactive transport model to simulate fate and transport of Pb as well as other metal contaminants. Variably saturated water flow was simulated using the Richards equation and the van Genuchten analytic form was used to describe the unsaturated soil hydraulic properties. The main processes considered to simulate reactive transport were: advection-dispersion, thermodynamic equilibrium and kinetically-controlled dissolution/precipitation reactions. The simulations reproduced accurately the drop of two pH units measured in pore solution during the experiment. This trend resulted from the dissolution of plumbojarosite followed by ferrihydrite precipitation. The increase of Pb concentration in soil solution induced by dissolution of Pb-bearing phases was partially counterbalanced by Pb-sorption onto newly formed iron-oxide and precipitation of secondary mineral phases. The modelling results could be used to assess potential risk of groundwater contamination by mine tailings.