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Field-based accounting of CO_2 sequestration in ultramafic mine wastes using portable X-ray diffraction

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Abstract

Carbon mineralization, the sequestration of carbon within minerals, presents one method through which we could control rising levels of anthropogenic carbon dioxide (CO_2) emissions. The mineral wastes produced by some ultramafic-hosted mines have the ability to sequester atmospheric CO_2 via passive carbonation reactions. Carbon accounting in mine tailings is typically performed using laboratory-based quantitative X-ray diffraction (XRD) or thermogravimetric methods, which are used to measure the abundances of carbonate-bearing minerals such as hydromagnesite [$Mg_5(CO_3)_4(OH)_2{\cdot}4H_2O$] and pyroaurite [$Mg_6Fe^{3+}_2(CO_3)(OH)_{16}{\cdot}4H_2O$]. The recent development of portable XRD instruments now allows for the characterization and quantification of minerals in the field. Here we assess the feasibility of using a portable XRD instrument for field-based carbon accounting in tailings from the Woodsreef Chrysotile Mine, New South Wales, Australia. Modal mineralogy was obtained by Rietveld refinements of data collected with an inXitu Terra portable XRD. The Partial Or No Known Crystal Structures (PONKCS) method was used to account for turbostratic stacking disorder in serpentine minerals, which are the dominant phases in tailings from Woodsreef. Weighed mixtures of synthetic tailings were made to evaluate the precision and accuracy of quantitative phase analysis using the portable instrument. An average absolute deviation (bias) of 8.2 wt% from the actual composition of the synthetic tailings was found using the portable instrument. This is comparable to the bias obtained using a laboratory-based diffractometer (9.6 wt% absolute) and to the results from previous quantitative XRD studies involving serpentine minerals. The methodology developed using the synthetic tailings was then applied to natural tailings samples from Woodsreef. Surface crusts forming on the tailings pile were found to contain hydromagnesite (~5.8 wt%) and pyroaurite (~2.1 wt%). Comparable results were obtained using the laboratory-based instrument and these results are expected to have similar biases to the analyses of the synthetic tailings. These findings demonstrate that portable XRD instruments may be used for field-based measurement of carbon sequestration in minerals in engineered and natural environments.

Keywords: Carbon accounting, carbon sequestration, carbon mineralization, portable X-ray diffraction, PONKCS method, Rietveld refinement, chrysotile, hydromagnesite, pyroaurite