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Toxic Metal Release from Serpentine Soil in Simulated Environmental Conditions

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ABSTRACT

This study investigates the Cr, Ni and Mn release from serpentine soil in simulated environments in the presence of organic, inorganic acids and different ionic strength conditions. The fractionation and the bio-availability of these metals were also examined to identify their forms of release to the environment. Experiments were carried out over an acid concentration range of 0.05 to 10 mM using three organic (citric, acetic, oxalic) and inorganic (H_2SO_4, HNO_3, HCl) acids. The fractionation of metals in the soil samples was investigated using sequential leaching techniques, which identify the elements in different host fractions: exchangeable, carbonate bound, Fe-Mn oxide bound, organic matter bound, and residual. Bio-available fraction was observed using single extraction experiment with 0.01 M $CaCl_2$. Metal releasing rates increase in the order of nitric ≈ hydrochloric≈ acetic < sulfuric < citric < oxalic acid. The maximum rate of release of Ni and Mn was observed in the presence of oxalic acid which was recorded as 5.84×10^{-11} and 2.56×10^{-11} mol $m^{-2}s^{-1}$ respectively. However, Cr release is less compared to the other two metals. Nickel is released preferentially, relative to Mn and Cr in the presence of both organic and inorganic acids. Increase in ionic strength enhanced the quantity of heavy metal released from serpentine soil. However, there was no significant effect of the ionic strength on the metal release around pH range 8-9 which was in the region of the point of zero charge (8.57) of this soil. In the exchangeable fraction (readily available to plant uptake and groundwater), Ni (258 ± 9.20 mg/kg, 7.00%) was higher than Mn (49.4 ± 4.00 mg/kg, 7.87%) and Cr (<10 mg/kg, 1.00%). Nickel was the most bio-available metal compared to Mn and Cr, reported 168 ± 6.40 mg kg-1 in the 0.01M $CaCl_2$ phase. The results from the sequential extractions pointed out that Mn is mainly associated with the reducible fraction (Fe-Mn oxide bound fraction) whereas nickel is found mainly in the residual fraction. Large fractions of Cr are found in organic matter and Fe-Mn bound form indicating that the oxidation-reduction conditions in the soil may favor the release of Cr to the environment. This suggests that there is a potential toxic metal release from serpentine soils to the environment if such simulated conditions (organic, inorganic acids, oxidation-reduction conditions) persist in the natural environment.