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Solubility and mobility of thorium and uranium in soils: the effect of soil properties on Th and U concentrations in soil solution

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This study offers new insights into the dynamics of Th and U in a range of soils in the UK. A body of data has been obtained which demonstrates the wide range of concentrations of Th and U in pore waters in relation to soil physico-chemical characteristics, including pH and organic matter content. Soil solution composition is a key consideration when assessing thorium and uranium concentration and speciation in soil pore water. The data clearly demonstrate differential solubility of Th and U within and between different soils, influenced by pH and DOC, DIC and phosphate concentrations.

Thorium was most soluble (0.01 - 4 μg L-1) in acidic soils (pH 3.6 – 4.7) and the highest concentrations of dissolved Th and U were found close to the soil surface (0 - 20 cm). Thorium solubility was 5 - 14 times greater than U solubility (0.002 - 0.28 μg L-1). The greatest difference between Th and U solubility was found in the upper part of the soil profile whereas, with increasing soil depth, the ratio between Th and U solubility decreased. Both Th and U solubility decreased with soil depth and both were positively correlated with DOC, which seems to be the most important factor controlling Th and U solubility in acidic soils. The Th distribution coefficient ranged from 771 to 550,000 L kg-1 while the U distribution coefficient ranged from 3210 to 640,000 L kg-1.

In mildly acidic soils (pH = 5.8 – 7.0) U was significantly more soluble than Th. The formation of soluble uranyl carbonate complexes gave rise to a strong positive correlation between U concentration and DIC in soil solutions, especially under anaerobic conditions at high CO_2 partial pressures. There was a large variation in U distribution coefficients (7240 – 303,000 L kg-1) in alkaline soil which related primarily to the variation in organic matter content (5 - 29 %). Thorium and U distribution coefficients were both positively correlated with soil organic matter and soluble phosphate concentrations. Generally it seems that soil pH, organic matter content, sesquioxides and DOC strongly affect U and Th solubility under aerobic acid-neutral soil conditions whereas DIC can be the primary determinant of solubility of U in alkaline soils.
These preliminary findings increase our understanding of Th and U dynamics in diverse soil types and can be used to improve predictions of the environmental and health impacts of these radioelements.