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# Bioaccessibility of U, Th and Pb in particulate matter from an abandoned uranium mine

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Currently, there are approximately 150 uranium mines in Europe at various stages of either operation, development, decommissioning, restoration or abandonment (wise-uranium.com). The particulate matter comprising the mounds of waste rock and mill tailings poses a risk to human health through the inadvertent ingestion of particles contaminated with uranium and thorium, and their decay products, which exposes recipients to the dual toxicity of heavy elements and their radioactive emissions.

We investigated the bioaccessibility of $^{238}$U, $^{232}$Th and $^{206,214,210}$Pb in particulate samples taken from a contaminated, abandoned uranium mine in South West England. Sampling included a mine shaft, dressing floor and waste heap, as well as soils from a field used for grazing. The contaminants were extracted using the *in-vitro* Unified Bioaccessibility Research Group of Europe Method (UBM) in order to mimic the digestion processes in the human stomach (STOM) and the combined stomach and gastrointestinal tract (STOM+INT). Analyses of concentrations of U, Th and Pb in the extracts were by ICP-MS and the activity concentrations of radionuclides were determined on the same particles, before and after extraction, using gamma spectroscopy.

'Total' concentrations of U, Th and Pb for all samples were in the range 57 to 16,200, 0.28 to 3.8 and 69 to 4750 mg kg$^{-1}$, respectively. For U and Pb the concentrations in the STOM fraction were lower than the total and STOM+INT fractions were even lower. However, for Th the STOM+INT fractions were higher than the STOM due to the presence of Th carbonate species within the gastrointestinal fluid. Activity concentrations for $^{214}$Pb and $^{210}$Pb, including total, STOM and STOM+INT, were in the range 180 to $<$1 Bq g$^{-1}$ for the dressing floor and waste heap and 18 to $<$1 Bq g$^{-1}$ for the grazing land.

Estimates of the bioaccessible fractions (BAFs) of $^{238}$U in the most contaminated samples were 39% and 8% in the STOM and STOM+INT, respectively, whereas the respective BAFs for $^{232}$Th were 3% and 9%. For stable $^{206}$Pb the STOM and STOM+INT BAFs were 16% and 3% for the most contaminated samples, whereas those from the field had 44% in the STOM fraction and 17% in the STOM+INT fraction. The BAFs for $^{214}$Pb and $^{210}$Pb were the same as $^{206}$Pb. Dose estimates were made for the contaminants together with radioactive doses in order to assess potential risk to human health.