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Using radium isotopes as tracers of transfers in the soil - water- –plant system

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Because soils form at the critical interface between the lithosphere and the atmosphere, characterization of the dynamics occurring through this compartment represents an important goal for several scientific fields and/or human activities. However, this issue remains a challenge because soils are complex systems, where a continuous evolution of minerals and organic soil constituents occurs in response to interactions with waters and vegetation. This study aims to investigate the relevance of short-lived nuclides of U- and Th-series to quantify the transfer times and scheme of radionuclides through a soil – water – plant ecosystem. Activities of (226Ra), (228Ra) as well as (228Th) were measured by TIMS and gamma-spectrometry in the major compartments of a forested soil section: solid soil fractions (exchangeable fraction, secondary phases and inherited primary minerals), waters (seepage soil waters and a spring further down the watershed) and vegetation (fine and coarse roots of beech trees, young and mature leaves). The matching of these nuclides half-live to bio-geochemical processes time-scale and the relatively good chemical analogy of radium with calcium make these isotopes especially suitable to investigate either time or mechanism of transfers within a soil-water-plant system. Indeed, the (228Ra/226Ra) isotopic ratios strongly differ in the range of samples, allowing quantifying the source and duration transfers. Analyses of the various solid soil fractions demonstrate a full redistribution of Ra isotopes between the inherited minerals and secondary soil phases. Moreover, the transfer of these isotopes to the seepage water or to the tree roots does not follow a simple and obvious scheme. The radium isotopic ratio in the trees roots does not match the soil exchangeable fraction, suggesting a mixed pool of radium for roots uptake. Decay of 228Ra within the various parts of the trees allows calculating a vegetation cycling duration of about 12 years for this nuclide. Finally an unexpected large amount of unsupported 228Th in the tree leaves can only be explained by a preferential migration of the 228Ac (228Th precursor). The very short life of this nuclide allows therefore assessing that such transport from roots and deposition within stem and leaves take place within 30 hours at the most.