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Modelling soil and soil to plant transfer processes of radionuclides and toxic chemicals at long time scales for performance assessment of Radwaste disposal

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Performance assessments for surface nuclear waste disposal facilities require simulation of transfer processes from the waste canisters to a reference group living near-by. Such simulations need to be extended over several hundred to hundred thousand years, depending on waste type, restraining possibilities to represent short term system complexity and variability. Related modelling can be simplified as long as processes are represented conservatively with assessment endpoints estimated larger compared to more realistic modelling approaches. The indicators are doses for radionuclides (RN) and risk factors for toxic chemicals (TC, i.e. heavy metals, nitrate).
We discuss a new simulation tool (SCM-Andra-multilayer-model, SAMM) that, among others, allows to model situations where RN/TC move through a soil profile characterised by temporal undersaturation and root growth (soil-plant subsystem of the biosphere model compared to the adjacent saturated geosphere). SAMM describes all relevant transfer and reaction processes (advection, diffusion, root transport, radioactive decay, chemical reactions incl. sorption - desorption) using well known differential equations solved numerically within MATLAB with scenario description and parameterisation defined in Excel sheets.
With this conservative approach in mind, we apply global parameters for which the solid-solution (Kd) or soil-to-plant (TF) distribution coefficients are the most relevant. Empirical data are available for homogeneous situations, such as one compartment pot experiments, but rare for entire soil profiles. Similarly soil hydrology, in particular upward and downward advective fluxes are modelled using an empirical approach solely based on key soil hydrological parameters (precipitation, evapotranspiration, irrigation, water table level) and the soil porosity. Variability of soil hydrology in space and time, likely to change drastically even on hourly bases (i.e. intense precipitation event) or within a single column (i.e. preferential flow and capillary rise) is nonetheless represented by annual averages. Changing water saturation and associated variability in redox conditions, RN/TC speciation and mobility, represents an example, where the simulation abilities with SAMM are beyond our capacity of in situ observation and measurement, restricting of course our efforts of validation. The latter is thus limited to simpler cases with parameter values stable within the soil column or throughout time. The study of more complex situations is possible with the SAMM simulation tool.
For illustration, we give at least two examples, one for a RN and one for a TC; we evaluate the species initially present as well as the daughter RN and the product of reactivity of the TC. Focus is given to situations where RN/TC are present at the base of a soil column; simulation end points are concentrations at the soil surface and for specified agricultural plant species.
Dose and risk calculations based on these data are carried out in classical food chain assessment tools. These illustrations are for generic sites and situations for which at least a minor component of upward advective movement is considered, keeping in mind the conservative approach mentioned above.