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HP1: A variably-saturated water flow, solute transport and biogeochemistry code for soil and sediment systems

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To model multi-component transport during transient variably-saturated flow in the vadose zone, complex models are needed that integrate a broad range of mixed equilibrium and kinetic reactions. The recently developed HP1 code integrates HYDRUS-1D (solving water flow and solute transport for unsaturated transient flow conditions) with PHREEQC (a generic biogeochemical model) allowing simulation of interactions between physical, chemical and biological processes in soil and sediments. The code is verified using an alternative code for a NTA (nitrylotriacetate) and cobalt transport problem involving kinetic degradation, cell growth and sorption for steady-state flow conditions. Similar verification examples are available for cation exchange, surface complexation and reduction/oxidation processes. A simulation of the long term leaching of uranium-238 and its daughter nuclides (applied as a naturally occurring radioactive material in mineral P-fertilizers) through the soil to shallow ground water for natural boundary conditions illustrates the capabilities of the HP1 code as a tool for analyzing and assessing complex environmental soil quality problems.