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Radon diffusion coefficients in soils of varying moisture content

C. Papachristodoulou (1), K. Ioannides (1), and S. Pavlides (2)

(1) Department of Physics, University of Ioannina, Ioannina, Greece (xpapaxri@cc.uoi.gr; kioannid@cc.uoi.gr), (2) Department of Geology, Aristotle University of Thessaloniki, Thessaloniki, Greece (pavlides@geo.auth.gr)

Radon is a naturally occurring radioactive gas that is generated in the Earth's crust and is free to migrate through soil and be released to the atmosphere. Due to its unique properties, soil gas radon has been established as a powerful tracer used for a variety of purposes, such as exploring uranium ores, locating geothermal resources and hydrocarbon deposits, mapping geological faults, predicting seismic activity or volcanic eruptions and testing atmospheric transport models. Much attention has also been given to the radiological health hazard posed by increased radon concentrations in the living and working environment.

In order to exploit radon profiles for geophysical purposes and also to predict its entry indoors, it is necessary to study its transport through soils. Among other factors, the importance of soil moisture in such studies has been largely highlighted and it is widely accepted that any measurement of radon transport parameters should be accompanied by a measurement of the soil moisture content. In principle, validation of transport models in the field is encountered by a large number of uncontrollable and varying parameters; laboratory methods are therefore preferred, allowing for experiments to be conducted under well-specified and uniform conditions.

In this work, a laboratory technique has been applied for studying the effect of soil moisture content on radon diffusion. A vertical diffusion chamber was employed, in which radon was produced from a ^{226}Ra source, was allowed to diffuse through a soil column and was finally monitored using a silicon surface barrier detector. By solving the steady-state radon diffusion equation, diffusion coefficients (D) were determined for soil samples of varying moisture content (m), from null (m=0) to saturation (m=1). For dry soil, a D value of 4.1×10^{-7} m^{2}s^{-1} was determined, which increased moderately by a factor of $\sim$3 for soil with low moisture content, i.e. up to $m \sim$0.2. At higher water fractions, a decrease in D was initiated and became particularly pronounced approaching complete saturation; at $m =$0.9, D was as low as 2×10^{-9} m^{2}s^{-1}.

A series of field experiments has also been conducted using alpha-track CR-39 detectors to follow the moisture-dependence of radon diffusion through soil under natural conditions. Diffusion coefficients were determined as a function of surface soil moisture assuming a one-dimensional diffusive radon transport model. Comparison between results obtained by the two methods showed that laboratory studies may provide a good indication of radon diffusion coefficients to be expected in the field. However, values determined in the field were systematically lower than those assessed in the laboratory. This finding could be attributed to soil-dependent parameters, such as differences in pore space geometry between the soil used in laboratory experiments and the undisturbed soil. In the latter case, the higher degree of compaction imposes a more tortuous pathway to soil gas, while at the same time the diffusive gas flux is hindered by local-scale zones of higher bulk density or water content.