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Interactive Comment

Interactive comment on "Predicting terrestrial ^{222}Rn flux using gamma dose rate as a proxy" *by* T. Szegvary et al.

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Thank you for your comments reflecting a more cautious view on our approach. In principle, we agree that each of the points you made is valid. The factors you mention can be of major importance at small scales, such as relevant for predicting the radon potential at a building site. Yet, the scale we are interested in, is much larger. We would like to be able to predict average radon flux for a country or at best for a particular region, such as Central France or Northern Germany. At these scales, the effects of the factors you mention largely even out.

As a first example, we may take the contribution of the 238U decay series to the total gamma dose rate, relating to your point (1). We are aware that 238U and 226Ra may not always be in secular equilibrium but data on 238U is more widely reported and allowing us to discuss your concern. Proportions of the contribution of the 238U series to total gamma dose rate are reported in our manuscript for Switzerland, for North-West Italy in Chiozzi et al. (Rad.Meas., 35:147-165, 2002) , for Spain in Quindos et al. (Environ.Int., 29: 1091-1096, 2004) and for Cyprus in Tzortzis et al. (Rad.Meas., 37: 221-229, 2003). Contributions of the 238U series for individual types of rocks reported in these four studies range from 12 % to 90 %. However, the average for each country or region ranges from 27 % (Spain), 29 % (North-West Italy) to 30 % (Cyprus, Switzerland). Thus, in the context of our objective to predict larger scale averages for radon flux, it seems justified to assume a constant contribution of the 238U series to the total gamma dose rate.

A second example relates to your point (2). Indeed, the emanation coefficient for radon can vary by a factor of 10. Again the magnitude of this variation is a question of scale. Greenman and Rose (Chem. Geol. 129:1-14, 1996) determined emanation coefficients for each horizon in 12 contrasting soil profiles in the North-East of the United States. Emanation coefficients ranged from 5.5 % to 33 % for individual horizons. However, average emanation coefficients for entire soil profiles only ranged from 13 % to 29 % and two-thirds of the soil profiles were in the narrow range between 18 % and 22 %.

Regarding your point (3), there might be a misunderstanding. You write that dose rate is a measure for the radon (and thoron) that could not escape to the atmosphere and a high emanation from the soil thus results in a decrease in the dose rate and not in an increase. This would be correct, if we related radon flux to the dose rate component of radon and its daughters only. This is not the case. We relate radon flux to the total terrestrial gamma dose rate, including the 238U series, 232Th series and 40K. Robert L. Grasty (Geophysics 62: 1379-1385, 1997) once made a theoretical study of the effect you may have related to. He predicted an increase in the gamma dose rate originating from the 238U series of about 6 % when moisture saturation increases from 0.70 to 0.95 (assuming an emanation coefficient of 25 %). However, the increase in the contribution of the 238U series is more than compensated by a concurrent decrease in the contributions of the 232Th series an 40K. Thus, the overall result of increasing soil moisture is a decrease in total gamma dose rate. This decrease coincides with a decrease in radon flux resulting from increased tortuosity and diffusion resistance of the moister soil and is in line with our findings. Extremely low rates of emanation are also possible in very dry soils with water contents $< 5\%$ (Peter Bossew, Applied Radiation and Isotopes 59: 389-392, 2003). In these soils the probability is high that radon atoms are captured by neighbouring grains due to their high recoil energy not being partly absorbed in a water film covering the grain of origin. Thus, these atoms can not escape respectively are no longer available for exhalation. But as these observations were made in the laboratory and water contents smaller than 5% are very unusual in nature, so we consider this effect to be negligible. In point (4) you make the case that soils are frequently less permeable close to the surface due to fine grained weathering products, reducing radon flux but not dose rate. We consider exchange of radon between natural soils and the atmosphere to be largely driven by diffusion, not by mass flow. Thus soil diffusivity rather than permeability will determine radon flux. In general, soil bulk density increases with depth and so does soil moisture, resulting in reduced air filled porosity and diffusivity with increasing depth. The importance of this effect is probably minor because the contribution to the surface flux of radon decreases rapidly with the depth of any particular soil horizon.

We were inspired by your comments to look again at our approach and underlying assumptions. Our conclusion is that our assumptions may not always be valid on a small scale but that they hold at the larger scale at which we try to predict radon flux. This conclusion is supported also by the close correspondence between predicted and measured regional radon flux shown in Table 1 of our manuscript.

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