



Radon-222 measurements in groundwaters and rocks from fractured aquifer (Ploemeur, Brittany)

T. Le Druilennec (1), C. Tarits (1), G. Ielsch (2), L. Aquilina (3), G. Tymen (4), V. Ayraud (3), O. Bour (3)

(1) Université de Bretagne Occidentale, IUEM, UMR-CNRS 6538 “Domaines Océaniques”, place Nicolas Copernic, 29280 Plouzané, France, (2) Institut de Radioprotection et de Sureté Nucléaire, Laboratoire d’Etude sur le Radon et d’Analyse des Risques, B.P. 17 - 92262 Fontenay-aux-Roses cedex, France, (3) Université de Rennes 1, UMR CNRS 6118 “Géosciences Rennes”, Campus de Beaulieu, Rennes cedex, France, (4) Université de Bretagne Occidentale, UFR “Sciences et Techniques”, ERCS “Laboratoire de Recherches Appliquées Atmosphère-Hydrosphère”, Avenue Le Gorgeu, 29285 Brest, France (thomas.ledruilennec@univ-brest.fr)

This paper deals with Radon-222 (^{222}Rn) and Radium-226 (^{226}Ra) contents of groundwater in Brittany (France) during the exploitation within a fractured aquifer in a nitrate-rich agricultural environment (Ploemeur site).

In the last years, many studies have been focused on the different parameters and physical phenomena that influence radon-emanation and -transport in soils, particularly for radon-mapping and -risk management (Ielsch et al. (2002), Weltner et al. (2002)) Radon can help in the understanding of the transport and exchange mechanisms in the lithosphere, the atmosphere (Renoux et al., 1980) and the hydrosphere. Radon-222, a radioactive inert noble gas with a half-life time of 3.8 days, is produced from ^{226}Ra in the radioactive decay chain of ^{238}U . This very mobile and practically inert element is affected by physical phenomena, e.g. adsorption, dissolution, but not by chemical ones. It emanates from mineral grains by alpha recoil or diffusion, and the rate depends on the microstructure of rocks and environmental conditions. Studies in hydrogeology often rely on the assessment of differences in ^{222}Rn concentrations between deep and shallow waters. Indeed, in fractured aquifers ^{222}Rn concentrations in deep water are strongly dependent upon the hydrological settings and ^{226}Ra concentrations in rocks. On the other hand, in shallow waters ^{222}Rn concentrations fall

within the concentration value in groundwater and that of rainwater in equilibrium with the atmosphere. Groundwater-dissolved ^{222}Rn can, thus, be used as a tracer to investigate and estimate flow-rates, get insight into shallow and deep water mixing (Hoehn and von Gunten (1989), Hamada (2000)) or calculate flow velocities in homogeneous aquifers (Kafri, 2001).

The Ploemeur fractured aquifer is located within a granite/schist shear zone, at a depth of 40-100 m. The 21 boreholes of the site allow the sampling of different surroundings (e.g. shallow and deep waters). During a 10-year period, production rate and chemical parameters were continuously measured in the tap water from a deep-water plant. A $\text{SO}_4\text{-NO}_3$ evolution was observed over the time after pumping initiation. This evolution has been attributed to an equilibrium between the physical parameters of the flow and the chemical kinetics of an autotrophic denitrification process which occurs in the pyrite bearing-fractures. The chemical characteristics of the groundwater collected in 18 wells located around the site allowed us to identify three different groups: (i) Group I is directly related to the main pumped well and characterized by reduced NO_3^- levels combined with an increased SO_4^{2-} production resulting from the denitrification process occurring in pyrite bearing fractures; (ii) Group II, weakly influenced by pumping is characterized by high NO_3^- concentrations and a short residence time; (iii) Group III, poorly related to pumping, presents very stable concentrations through time and a short residence time.

During 1-week field seasons held in March, June and December 2004, 54 water samples were collected in 21 boreholes. The ^{222}Rn volume activity was measured by using an ionization chamber coupled with a degassing unit (whole system closed). The ^{222}Rn dissolved in water sample was extracted from the liquid phase using a pump. The ^{222}Rn volume activity is then measured in the air of the system by using the ionization chamber. The measurement uncertainty is 10-20 %. The ^{226}Ra volume activity was indirectly measured in 15 water samples by measuring the ^{222}Rn volume activity in air after degassing at the equilibrium state. This measurement is realized by using scintillation flasks and a counting chamber. The measurement uncertainty is 10-15 %. The ^{226}Ra concentration in rocks was also measured in 10 samples (granites and micaschists) by gamma spectrometry (HP Germanium detector). The measurement uncertainty is 10 %.

These first results allow us to highlight: (i) the spatial distribution of ^{222}Rn activity in groundwater, (ii) a relationship between variations in ^{222}Rn concentrations and hydrogeological settings, (iii) a relation ^{222}Rn vs NO_3/SO_4 in groundwater and (iiii) the variability of ^{226}Ra contents in rocks and in groundwaters.

References:

Hamada H. (2000), Estimation of groundwater flow rate using the decay of ^{222}Rn in a well, *J. Environ. Radioactivity* 47 (2000), 1-13.

Hoehn E., and von Gunten H.R. (1989), Radon in groundwater: a tool to assess infiltration from surface waters to aquifers, *Water Resour. Res.*, 25, 1795-1803.

Ielsch G., Ferry C., Tymen G. and Robé M.C. (2002). Study of a predictive methodology for quantification and mapping of the radon-222 exhalation rate, *Journal of Environmental Radioactivity*, Volume 63, Issue 1, 15-33.

Kafri U. (2001), Radon in groundwater as a tracer to assess flow velocities: two test cases from Israel, *Environ. Geol.*, vol. 40, Issue 3, 392-398.

Renoux A., Tymen G., Le Gac J., Madelaine G. (1980), Study of the ^{222}Rn short-lived daughters disequilibrium in a mixte maritime and continental atmosphere near granitic soils, *Health Phys.*, vol 39, 291-298.

Weltner A., Mäkeläinen I. and Arvela H. (2002), Radon mapping strategy in Finland *International Congress Series*, vol 1225, 63-69.