IRSN
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Can radon gas measurements be used to predict earthquakes?

After the tragic earthquake of April 6th 2009 in Aquila (Abruzzo), a debate has begun in Italy regarding the alleged prediction of this earthquake by a scientist working in the Gran Sasso National Laboratory, based on radon content measurements. Radon is a radioactive gas originating from the decay of natural radioactive elements present in the soil.

IRSN specialists are actively involved in ongoing research projects on the impact of mechanical stresses on radon emissions from underground structures[1], and some of their results dating from several years ago are being brought up in this debate[2]. These specialists are therefore currently presenting their perspective on the relationships between radon emissions and seismic activity, based on publications on the subject.

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The first observation of a radon content anomaly considered, *a posteriori*, as an earthquake precursor signal, dates from over 40 years ago. Indeed, since the Tashkent earthquake of 1966 (Uzbekistan), a large number of recordings have revealed unusual variations in the radon content of soil gas or groundwater samples, before or during the occurrence of earthquakes in most seismic regions throughout the world. These preseismic or coseismic signals (depending on the case) are also sometimes recorded after seismic tremors, or correlated with aftershocks. The form and duration of these anomalies are extremely variable and continue to elude all duly validated theory.

Radon is a radioactive gas formed continuously in the earth's interior, from deep crustal layers to surface soil layers, due to the natural presence of uranium or radium (even in trace quantities) in all rock formations. Due to its half-life of only 3.8 days, it mostly disappears through radioactive decay in subsurface layers near the place where it was formed. However, a very small fraction of the radon formed in the earth's crust manages to escape to the atmosphere.

The variations in radon content recorded in seismic regions clearly indicate that the stresses and deformations that precede or accompany an earthquake have an impact on gaseous or liquid underground fluids, and on the radon transported therein. However, in order to transform such observations into genuine predictions, we first need to be able to associate a radon anomaly signal with the focal depth, epicentre and magnitude of the earthquake possibly predicted, all this within a time frame sufficiently narrow to allow public authorities to take appropriate population protection measures in the region under threat (e.g. preventive evacuation). Unfortunately, none of this is yet feasible for the scientists currently working on the identification of usable correlations between radon content and seismic activity in Asia, Europe and America. The physical mechanisms underlying unusual radon contents are still only partially known, and the same is true for the characteristics that make a measurement site sensitive to disturbances induced by an approaching earthquake, while a neighbouring site is not.

Natural or man-made underground cavities clearly fall into the category of theoretically sensitive sites and therefore make good candidates for the analysis of seismic precursors. For example, this is the case with the old underground gallery dug in the Beaufortain massif (Savoie, France) and instrumented by the French Atomic Energy Commission (CEA) since 1995, where researchers from

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[1] Richon, P., Perrier, F., Pili, E. and Sabroux, J.C., 2008. Detectability and significance of 12 hr barometric tide in radon-222 signal, dripwater flow rate, air temperature and carbon dioxide concentration in an underground tunnel. *International Geophysical Journal*, 176/3: pages 683-694.
[2] Richon, P., Sabroux, J.C., Halbwachs, M., Vandemeulebrouck, J., Poussielgue, N., Tabbagh, J. and Punongbayan, R., 2003. Radon content anomaly in the soil of the Taal volcano (Philippines): A likely precursor of the M 7.1 Mindoro Earthquake (1994). *Geophysical Research Letters*, 30/9: 1481 (4 pages).

the CEA, IRSN and Paris Earth Physics Institute are currently testing, with a certain degree of success, the hypothesis according to which the mechanical stresses induced by the seasonal filling of the nearby Roselend artificial lake are responsible for radon content variations in the atmosphere of the gallery[3].

Another example is the underground laboratory in the Gran Sasso tunnel (Gran Sasso National Laboratory), near the town of Aquila where a magnitude 6.3 occurred on April 6th, giving rise to the aforementioned controversial prediction. In such a laboratory, dedicated to research on elementary particles and shielded for this purpose against cosmic radiation by a thick mountain, radon is a hindrance (interference with detectors). Like its French counterpart in the Fréjus tunnel (Modane Underground Laboratory), the Gran Sasso National Laboratory is equipped with extremely sensitive radon measurement instruments. Located in a highly seismic region near an active fault, the Gran Sasso National Laboratory is also well suited for detecting possible variations in radon content associated with the regional seismic cycle, as during the earthquake in Assis[4] in September 1997.

Such observations contribute to enhancing scientific knowledge, thereby providing hope for researchers and for the populations concerned. However, in the absence of a sufficient number of concordant observations and of a proper understanding of the mechanisms causing the observed anomaly signals, it would be premature to transform such observations into operational predictions. In addition, none of the data used to predict the terrible earthquake in Aquila has yet been distributed to the scientific community.

In the case of Aquila, as in the case of Kobe (Japan) in 1995 or Tashkent in 1966, radon is probably only one indicator among others. Nevertheless, it clearly suggests that the prediction of earthquake catastrophes is a scientific objective worth pursuing.

[3] Trique, M., Richon, P., Perrier, F., Avouac, J.P. and Sabroux, J.C., 1999. Radon emanation and electric potential variations associated with transient deformation near reservoir lakes. *Nature*, 399: pages 137-141.

[4] Plastino, W., Bella, F., Catalano, P.G. and Di Giovambattista, R., 2002. Radon groundwater anomalies associated with the Umbria-Marche earthquakes (September 26, 1997). *Geofisica Internacional*, 41/4: pages 369-375.