The Use of Radon as Tracer in Environmental Sciences

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Abstract
Radon can be used as a naturally occurring tracer for environmental processes. By means of grab-sampling or continuous monitoring of radon concentration, it is possible to assess several types of dynamic phenomena in air and water. We present a review of the use of radon and its progeny at the University of Cantabria. Radon can be an atmospheric dynamics indicator related with air mass interchange near land-sea discontinuities as well as for the study of vertical variations of air parameters (average values of different types of stability: 131-580 Bq m⁻³). Concerning indoor gas, we present some results obtained at Altamira Cave (Spain): from 222 to 6549 Bq m⁻³ (Hall) and from 999 to 6697 Bq m⁻³ (Paintings Room). Finally, variations of radon concentration in soil (0.3 to 9.1 kBq m⁻³) and underground water (values up to 500 Bq l⁻¹) provide relevant information about different geophysical phenomena.

Key words: radon, seismicity, ventilation, tracer.

1. INTRODUCTION
Radon is element 86 in the periodic table. ²²²Rn originates in the ²³⁸U decay series and has a half-life of 3.82 days, ²²⁰Rn (thoron) is in the ²³²Th chain with a half-life of 55.6 seconds, and ²¹⁹Rn (actinon) is in the ²³⁵U series with its half-life of 4 seconds. All are alpha particle emitters. Radon is a colour-
less gas with a density of 9.73 kg/m³ under standard conditions, making it the heaviest gas in nature. When cooled below its freezing point, radon has brilliant phosphorescence which becomes yellow at lower temperatures and orange-red at the temperature of liquid air. It was this property that led radon to be called niton (the shining one) at the time of its discovery by Dorn. In 1900, while studying radium salts, he observed an additional ionizing gas diffusing from thicker layers of the radium compounds (Dorn 1901).

The radon atom possesses a stable closed shell electronic configuration which gives it the chemical properties of a noble gas element. The electronic structure of radon suggests very limited chemical activity however the relatively low first ionization potential of 10.7 eV suggests that some interactions might be possible. Radon is sometimes referred to as a metalloid element which lies on a diagonal between the true metals and non-metals in the periodic table. It has some of the characteristics of both groups, behaving similarly to boron, germanium, antimony and polonium (Stein 1987). The fact that it is mildly radioactive and does not combine with other gases makes it unique as a tracer for studying a number of processes in the indoor and outdoor atmospheres (Wilkening 1990). A brief description of the work developed during the last thirty years by the Radon Group of the University of Cantabria using radon as a tracer for different aspects is given in this paper.

2. RADON AS AN ATMOSPHERIC TRACER

The occurrence of radon in the atmosphere has been known soon after it was discovered in 1900. However, its distribution in space and time, its physical state as an atmospheric component, and its mode of participation in the dynamics of the atmosphere are not yet fully understood. Recently, an increase of interest has been shown in this field (IAEA Proceedings Series 2012).

The determination of the concentration in the air of short-life radon daughter products is important in the solution of problems relating to the environment in order to evaluate the origin and trajectory of air masses or the washing of atmospheric aerosols by rainfall (IAEA Proceedings Series 2012). In this way, in 1982 we developed a campaign of measurements of these elements close to land-sea discontinuities, by gamma spectrometry analysis of filters collected 1.5 m above ground level, taken in the early morning by a filtration time of 30 min with a suction pump that produces a flow of 100 m³/h. To calculate the activity in the air of radon daughter products we worked on the hypotheses of the radioactive equilibrium between the first, ²¹⁸Po, Ra A, and the second, ²¹⁴Pb or Ra B daughter products. This hypothesis, a reasonable one by virtue of the different half-lives of the two elements, adds a condition to the three well known equations that ex-