

Radon Retention in High Humidity Places

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Abstract. With the aim of determining radon content in high humidity zones a two-step radon measuring device has been designed. The first step contains a certain amount of silica-gel as a desiccant agent, and the second one contains an activated charcoal specially adapted for radon adsorption. Both stages are modular, so that an analysis of both humidity and radon distribution can be made. For its design, the connective-diffusive transport equation has been solved for the sampling device using data obtained by the charcoal manufacturer, mainly the distribution coefficient for radon. This guarantees that the sampling device retains radon with an efficiency of 100%. Experimental measurements have been made with it and satisfactory results are obtained.

KEYWORDS: *Radon concentration; Nuclear metrology; Radiological protection.*

1. Introduction

The use of activated charcoal for radon sampling in air is widespread due to the simplicity of its handling. This kind of systems can be passive or active. The first one has the drawback of the radon exchange between atmosphere and charcoal. With the use of active devices which sample radon by means of the circulation of air through a bed of activated charcoal this problem is minimized.

However, in these active systems, the radon retention efficiency is a parameter that depends not only on the air flow velocity and its specific design: activated carbon type, cartridge diameter and length, but also on the moisture content of the air, which depends on temperature and pressure. In this situation, determination of the radon content in air in very humid places is a difficult task for this type of systems because the absorption of moisture by the charcoal distorts its retention efficiency in a not easily foreseeable way.

Nowadays, activated charcoal especially adapted for the retention of noble gases is commercially available, and radon more specifically. An analysis of their performances for radon retention has been previously done [1]. The variability of the radon retention efficiency as a function of humidity can be avoided by drying the air before it penetrates into the activated charcoal. Being the charcoal retention efficiency for dry air, a constant value provided by some charcoal manufacturers.

With these data in mind, a two stages radon sampling device has been designed. The first one contains a certain amount of silica-gel as a desiccant agent while the second contains an activated charcoal specially adapted for radon adsorption. Both stages are modular, so that an analysis of both humidity and radon distribution can be made.

The characteristics of the cartridge that contains the activated charcoal can be obtained from the connective-diffusive radon transport equation for a flow rate, a type of activated charcoal and a type of desiccant agent.

Although the model used is a general model it has been applied and tested with an air sampler whose flow rate is 20 litres/min, which has permitted to collect radon in short times while obtaining high counting rates.

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2. Method

The sampling device is a cylinder which contains a desiccant agent bed, like silica gel, and after it another bed with the activated charcoal will retain the radon. For its complete design, it was necessary to elaborate a model that could let us know the distribution of radon in the activated charcoal, so that the design guarantees the complete retention of all the radon contained in the air that has entered the charcoal bed.

In the model it is considered a dry air flow, which has a certain concentration of radon, crossing the charcoal bed. The radon concentration in air would follow a convective-diffusive model [2] [3]:

$$A \frac{\partial q}{\partial t} = D \frac{\partial^2 q}{\partial x^2} - V \frac{\partial q}{\partial x} - \lambda A q \quad (1)$$

being:

$$A = 1 + \frac{K_d \rho}{\theta} \quad (2)$$

with:

λ , the radon decay constant (s^{-1})

K_d , the distribution coefficient for radon in the selected charcoal (m^3/kg);

ρ , charcoal density (kg/m^3);

θ , the bed porosity (dimensionless);

q , the radon activity concentration in air (Bq/m^3);

D , the radon diffusion coefficient (m^2/s);

V , the air velocity in the pores (m/s)

To solve this equation it has been considered that there is no contribution from diffusion given the slowness of diffusion as compared to convection and so the radon concentration in air will be:

$$q = q_0 e^{-\beta x} \delta \quad (3)$$

with:

$$\delta = 1 \quad (t \geq \alpha x)$$

$$0 \quad (t \leq \alpha x)$$

and

$$\alpha = \frac{A}{V}$$

$$\beta = \frac{\lambda A}{V}$$

The radon will reach a depth x in a time t in the charcoal bed, so provided α is known the maximum distance (L) that radon will migrate through is as follows:

$$L = t/\alpha = t V/A$$

For this work the activated charcoal used was Nusorb G30, 6x12, because it showed an excellent performance in radon retention [1] and its technical parameters are well known [4].

Considering now that the charcoal bed has a porosity of 0.4, K_d is valued $2.5 m^3/kg$ for an air velocity of $0.04 m/s$ at sampler window, and that the sampler is connected to a pump with a flow rate of $20 l/min$, then $A = 3125$, $\alpha = 31250 s m^{-1}$ and $L = 3.2 \cdot 10^{-5} x t m$ with t in seconds.

For a sampling time, which is guessed on the basis of expected radon concentrations, of 30 minutes $L = 0.058 m$.

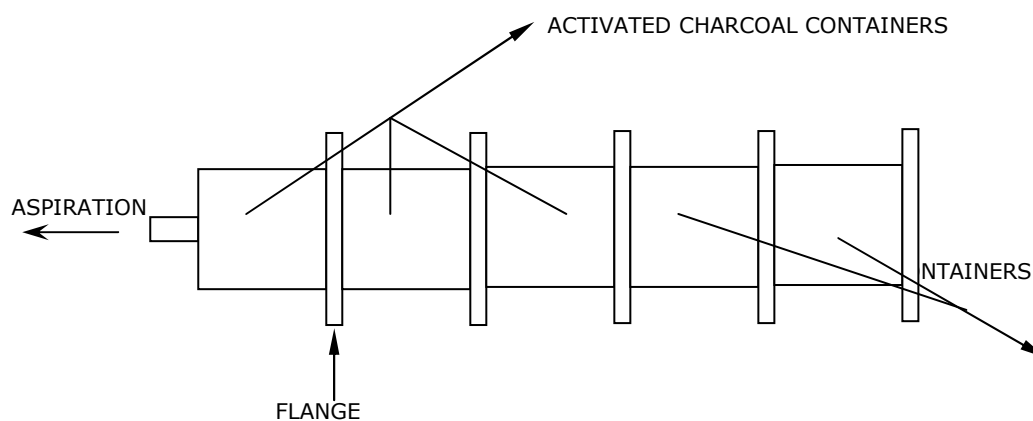
2.1 Sampling device design

The sampling device is made with an initial section containing silica gel which devoted to dry the sampled air; this section is constituted by two sections in order to check whether all the water contained in the air is completely absorbed and so that the air entering the activated charcoal is dry. The silica gel chosen is that from Panreac with a grain size larger than 2 mm.

After the drying section there is another one constituted by at least three sections, each one 12 cm long, of activated charcoal that should remove the radon from the dry air. The second and the third sections are supplementary sections installed to check the performance of the system. Their dimensions were derived from the resolution of the above equations for these two sampling conditions: 20 litres/minute for the aspiration flow and 30 minutes for the sampling time.

A sketch of the sampling device is shown in figure 1, being its diameter of 10 cm. Each silica gel container contains approximately 750 g. while each activated charcoal container has approximately 530 g.

Figure 1: The radon sampling device



3. Results

3.1 Humidity measurements

To control the effectiveness of the sections of silica gel for drying the air 28 tests have been made in the sampling conditions stated before and in caves with extreme air humidity conditions. According to the temperature, the atmospheric pressure and the 100% relative humidity of the cave, and using a psychrometric chart, the air has a water content of about 11.5 g/m^3 . Considering the sampling conditions, each time the volume circulated through the sampler has been 0.6 m^3 , so that the amount of water in the volume has been 6.9 g.

The silica gel from each test has been controlled by weighing it when the device is prepared and when it is returned to the laboratory for analysis.

The expected mass of water, 6.9 g has been the mean value of the weight of water gained by the first silica gel section in the set of tests, having taken into account the weight of water adsorbed by the silica gel during the preparation and transport processes. In all cases, the second silica gel section has gained no weight.

So, it can be concluded that the air entering the activated charcoal section is completely dry. Moreover, it is also verified that the activated charcoal has gained no weight after each test in the cave. It is also concluded that it is only necessary one section of silica gel for the desiccation stage.

3.2 Radon measurements

In those 28 tests, radon measurements have also been made. The measuring device has been tightly wrapped after preparation. Each radon measurement at the cave has been initiated by removing the cover to allow air to enter firstly into the silica-gel bed, and secondly into the charcoal bed where the radon is adsorbed. At the end of each measurement period, the device has been resealed securely and returned to the laboratory for gamma-ray spectrometric analysis.

After each sampling, the activated charcoal of each cylinder has been put in a marinelli beaker and preserved it in cold condition for three hours after the sampling in order to reach the radioactive equilibrium between ^{214}Pb and ^{222}Rn .

Those marinelli beakers have been measured by gamma-ray spectrometry using HPGe detector, with 60% relative efficiency, collecting at least 3000 net counts under the 352 keV peak of ^{214}Pb in order to achieve counting uncertainties below 4%. The detector works coupled to an electronic chain, including a multichannel analyser. The detector is calibrated in energies and in efficiency by using a calibration source prepared with a marinelli beaker filled with activated charcoal spiked with a reference certified material, which contains twelve different lines for gamma-ray spectrometry: from 59 keV to 1836 keV.

All tests reveal that radon is only in the first cylinder. The amount of radon found in the second and third container is only about a 2% of the radon retained by the first one.

Supplementary tests were made. One of them was done with up to five cylinders of activated charcoal and the same conclusion is obtained. Another one was made with the sampler in the cave but not connected to the air flow sampler, just to see how much radon would absorb the charcoal only by staying in the cave, as a background measurement. The amount of radon found in each cylinder is the same found in the rest of the test for the second and the third cylinders. After sampling, the silica-gel was measured for its radon content and the result was negligible.

All these tests confirm that all the Rn is sorbed in the first activated charcoal section as the developed model had predicted.

3.3 Equipment application

Once having validated the sampling device it has been used to test the radon concentration in the air of the Pozalagua cave situated in the karstic area of Carranza, north of Spain.

A total of 28 samples were collected in different times during last year. Using the gamma ray spectrometry measurement system described above, the radon activity concentration in the air of the cave is calculated with an uncertainty of about 10%.

Results lie in the range [210, 804] Bq/m³, and they are in good agreement with other values found in caves. [5-6].

4. Conclusions

The proposed model to evaluate the amount of charcoal needed in an active sampling system to retain the Rn contents in dry air, for specific sampling conditions, works properly.

For the sampling conditions considered in this work and given the results obtained, a Rn sampler with just one 10 cm cylinder filled with silica gel and another one with activated charcoal is enough to retain the Rn in 100% relative humidity air.

Results obtained for Rn are in good agreement with other values found in caves.

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