A practical setup for routine measurement of exhalation rates of radon from building materials

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1. Introduction

Measurements of radon exhalation rates from soil or/and building materials mostly employ accumulation chambers in association with a variety of radiation detectors, e.g. scintillation cell or Lucas cell (Sundar et al, 2003), ionization chamber (Al-Jarallah et al, 2001), electret (Kotrappa and Stieff, 2008), solid state alpha detectors (Keller et al 1982; Tuccimei et al, 2006), nuclear track detectors (Maged and Ashral, 2005), etc. But experience has shown (Sundar et al, 2003; Tuccimei et al, 2006) that presence of the accumulator itself perturbs the ambient exhalation, leading to back-diffusion which may ultimately invalidate the results unless subjected to further analyses. Designing experiments to measure the free (or ambient) radon exhalation rates therefore presents a practical challenge. One of the goals of the present study is to setup a standard procedure for routine determination of the free exhalation rates of radon from building materials.

A practical procedure and the necessary setup for routine measurement of the free exhalation rate of ^{222}Rn from building materials are described. The setup includes an ionization chamber-based continuous radon monitor and a relatively large-volume radon accumulation chamber. The procedure accounts for the effects of leakage and back diffusion. It also enables the experimentalist to interact with the setup in real time via a PC, e.g. to determine the optimum accumulation time before the effects of back-diffusion and radon decay set in. The free exhalation rates of selected building materials used in Kuwait are 1.63, 2.29, 3.99 and 5.39 Bqm^{-2}h^{-1} for gypsum, marble, ceramic, and granite, respectively.

2. Materials and Methods

The apparatus used for the measurement includes a radon accumulation chamber (about 101 X 10^{-3} m^3 cylindrical stainless steel container), a 30 X 10^{-3} m^3 stainless steel drum containing activated charcoal, a continuous radon monitor "AlphaGuard" (model PQ2000PRO, Genitron, Germany), PC, and samples of building materials (10 cm x 10 cm x 1 cm) comprising tiles of granites, ceramics, and marble (Figure 1).

At time *t,* the relation between the radon concentration $C(t)$ ($Bq\ m^{-3}$) inside the chamber and J ($Bq\ m^{-2}s^{-1}$) is the time independent radon flux or area exhalation rate of the exhaling material of surface area A (m^2) enclosed in the container, V is the volume of air in the container (m^3), λ_V is the rate of radon exchange (s^{-1}) between the container and the outside air, and λ is the decay constant of radon (7.56 x 10^{-3} h^{-1}) :

$$C(t) = \frac{JA}{V(\lambda+\lambda_V)}(1-e^{-(\lambda+\lambda_V)t}) \qquad (1)$$

Equation 1 assumes that the concentration of radon outside the chamber is negligibly small compared to $C(t)$, and $C(t = 0) = 0$. Considering times t for which $(\lambda + \lambda_V).t << 1$, equation 1 reduces to a linear relationship between $C(t)$ and t, i.e.

$$C(t) = JA/V \qquad (2)$$

A plot of $C(t)$ versus t for times that satisfy equation 1 will yield a slope , from which the value of J was estimated.

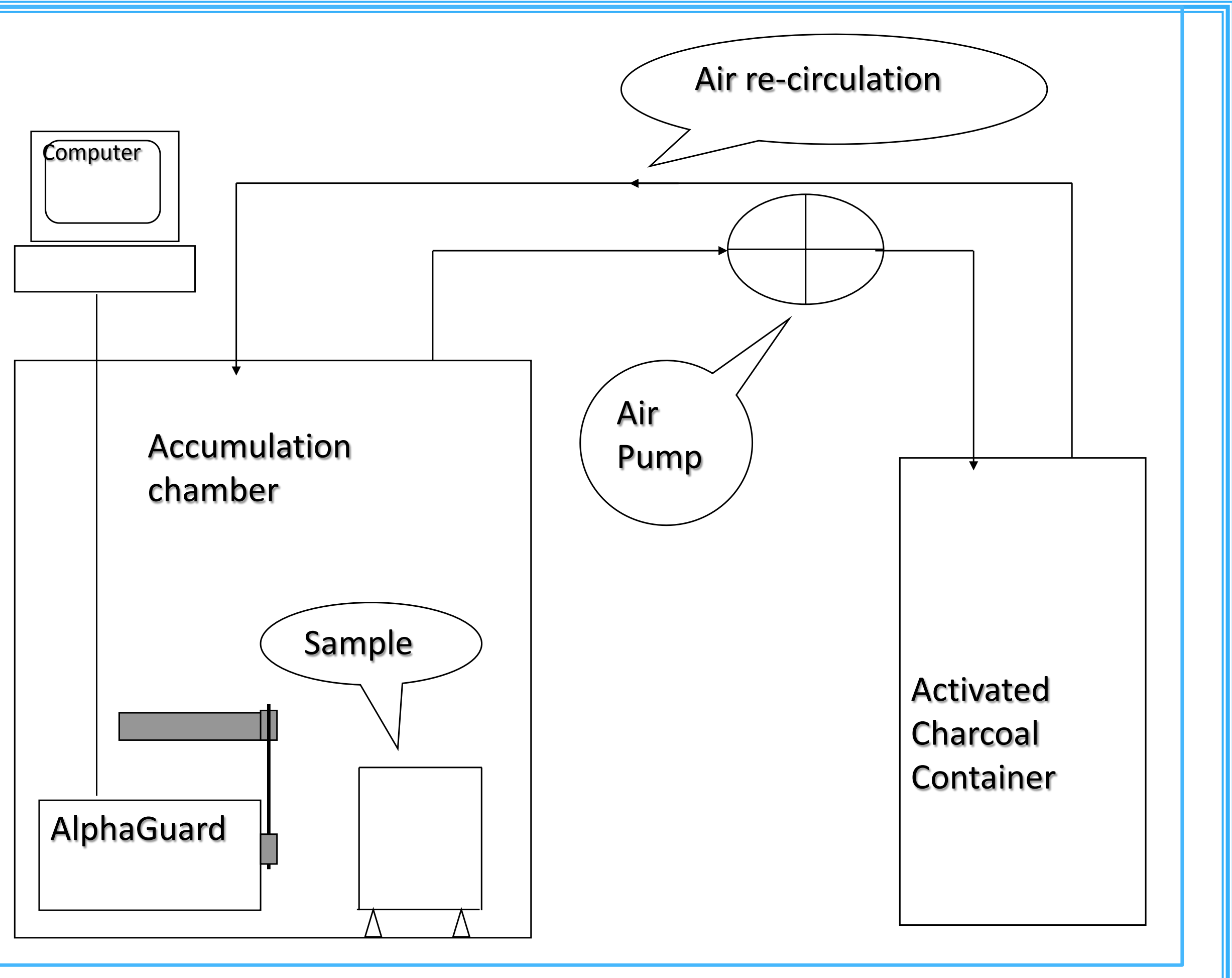


Figure 1. Setup for Rn exhalation measurement , comprising accumulation and filtration chambers, alphaguard and PC

3. Results

Figure 2 is a typical plot of the radon concentration in the accumulation chamber as a function of time. The linear or free exhalation portion is seen before the losses through radioactive decay and back diffusion set-in. The maximum (optimum) time (T_{opt}) for which equation (3) remains valid, i.e. before back diffusion and decay set-in, depends on many parameters, including; the volume of the measuring chamber, exhalation rate of the enclosed material, the concentration of ^{222}Rn in the air pores of the materials, e.t.c. According to Stranden (1983) T_{opt} should be less than 30 hours whereas Keller et al (1982) suggest that a generally valid upper limit cannot be given 'a priori'. In the present study, T_{opt} was determined for each sample in the course of the measurement. The values vary from one sample material to another, see table 2.

Figure 2 Radon concentration in the chamber during accumulation

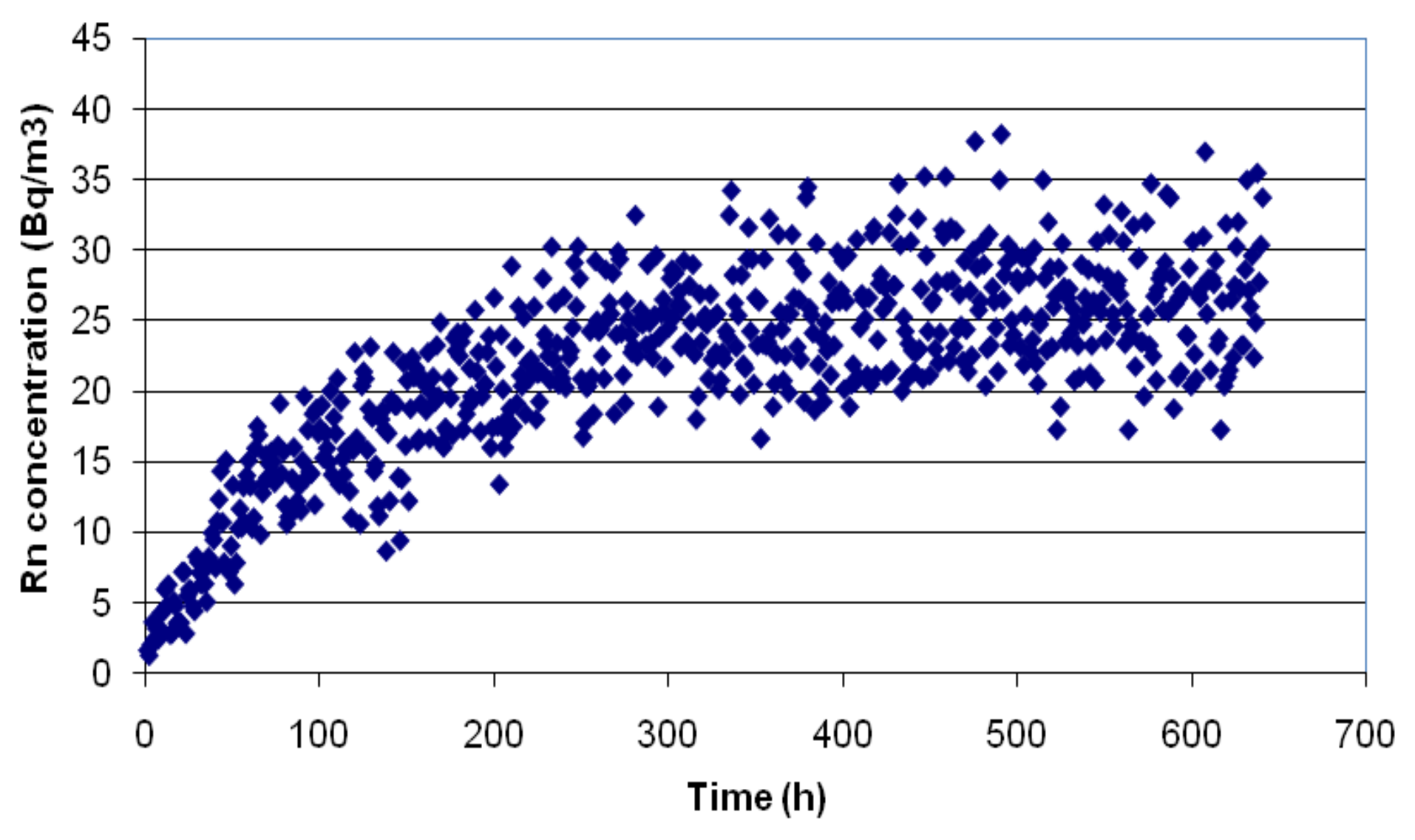
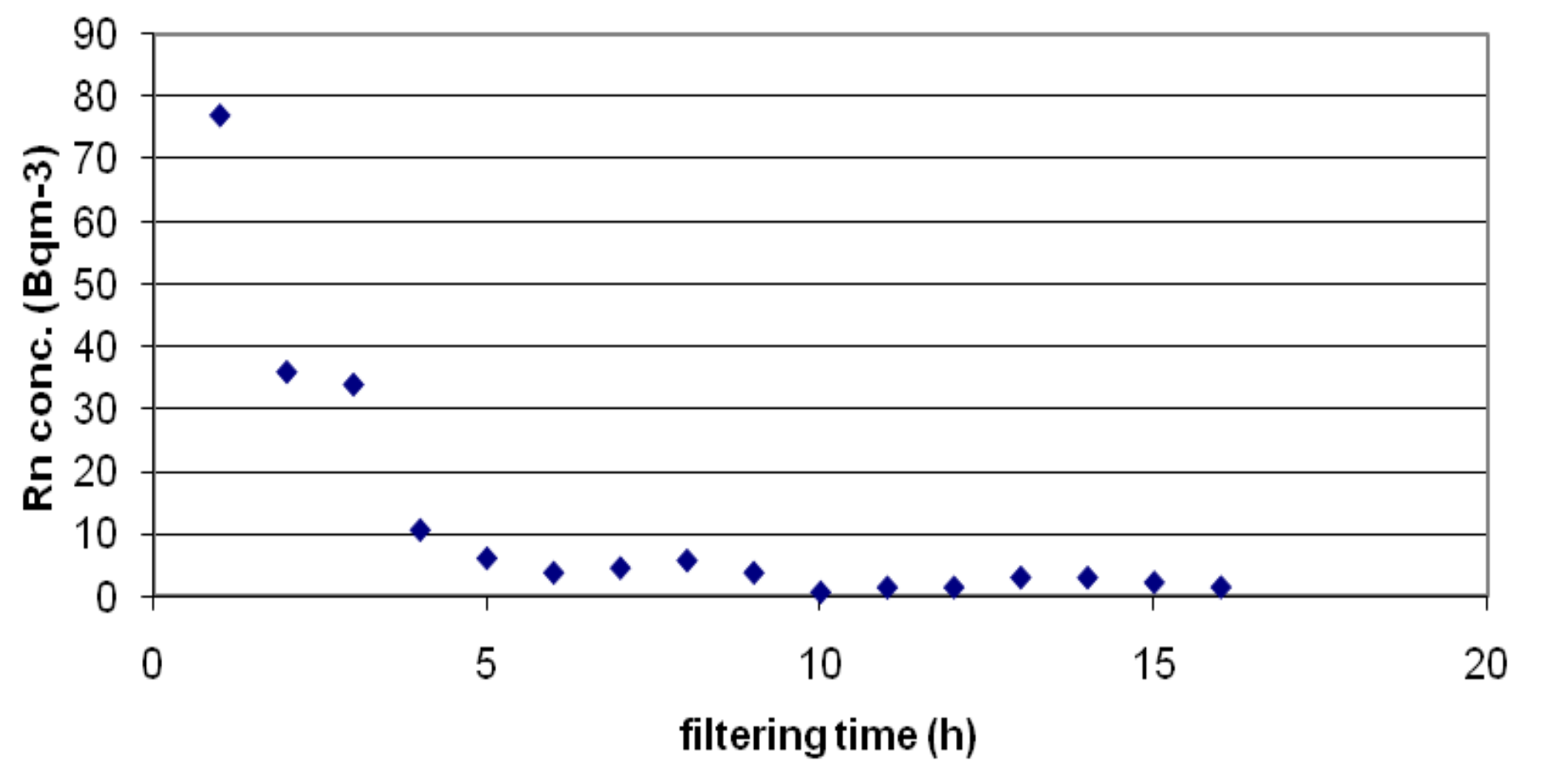


Figure 3 Radon concentrationlin the chamber during filteration through charcoal



Prior to commencement of exhalation measurement, radon in the chamber was evacuated by circulating air in the chamber through charcoal. Figure 3 shows that radon concentrations were reduced to as close to zero as possible. This is important so as not to invalidate the initial concentration values, which are normally low especially for materials with low exhalation rates. It is also noted that the exhalation rates were calculated from these initial data points, i.e., before the T_{opt}.

The optimum times for the samples analyzed in this study range from 4 – 14 hours, and they are many orders lower than the usual accumulation times used in radon exhalation experiments. The setup can therefore be adopted/adapted for routine radon exhalation measurement.

Table 1. Free exhalation rate of radon from some building tiles

Material	**Mean Temperature (°C)**	**Mean air pressure (mBar)**	**Mean Rel. Humidity (%)**	**Slope *S* (Bqm^{-3}h^{-1})**	**Optimum Accumulation time T_{opt} (h)**	**Exhalation rates *J* (Bqm^{-2}h^{-1})**
Granite	**23.4**	**1008.6**	**39.4**	**1.30**	**9**	**5.38**
Ceramic	**23.5**	**1012.9**	**40.2**	**0.96**	**4**	**3.99**
Marble	**23.2**	**1016.6**	**41.6**	**0.55**	**5**	**2.29**
Gypsum	**23.3**	**996.7**	**40.0**	**0.39**	**14**	**1.63**

4. Conclusions

A practical procedure and the necessary setup for routine determination of the free exhalation rate of radon from building materials have been described. The procedure has also been used to measure the exhalation rate from selected building materials used in Kuwait. It should therefore be possible to classify building materials using a "radiation performance index" that takes contributions from both gamma radiation and radon exhalation into consideration.

5. Acknowledgmen

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