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EFFECT OF VARIATION IN THE AMBIENT TEMPERATURE ON THE NIST ENCAPSULATED ²²²Rn EMANATION STANDARD SOURCE

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ABSTRACT- The effect of ambient temperature variation on radon emanation fraction from NIST standard source was studied using a newly constructed chamber. The results indicate that, the effect of decreasing the temperature rather than the certified value (at 21 ± 3 °C) has a considerable effect on decreasing the radon emanated from the source. On the other hand, the radon emanation fraction factor of the source is tendentious to the unity when the temperature was increased to more than 30 °C. The effect of the accumulation time on the radon emanation is very exhibiting whatever the temperature decrease.

1. INTRODUCTION

The NIST (National Institute of Standards and Technology, U.S.A.) radon emanation standard source consists of a polyethylene-encapsulated ²²⁶Ra solution that is sufficiently accurate and efficacious for calibrating instruments used in a variety of measurement applications (Colle et. al., 1995; Kotrappa and Stieff, 1994). The standard source is certified in terms of two parameters; the total ²²⁶Ra activity A_{Ra} at reference time t_r (408.7 Bq with uncertainty of 0.93 %) and the ²²²Rn emanation fraction *f* (0.890 at 21°C with uncertainty 4.0%), which is defined as, the fraction of the total ²²²Rn generated by decay of ²²⁶Ra that is released from the capsule and contained within the volume of an accumulation chamber.

For the case of a typical accumulation application, the ²²²Rn activity (A_{Rn}) at the end of an accumulation period from t = 0 to t = T_A may be given in an approximate form as:

$$A_{Rn} = f A_{Ra} e^{-\lambda_{Ra} T_D} (1 - e^{-\lambda_{Rn} T_A}) \tag{1}$$

where λ_{Ra} is the ²²⁶Ra decay constant, T_D is the time interval from the certified ²²⁶Ra activity reference time t_r (9 Sept. 1991) to the start time t = 0 of the accumulation period ($T_D = t_0 - t_r$), λ_{Rn} is the ²²²Rn decay constant, and T_A is the time interval for the total duration of accumulation (NIST, 1994). This work is a new approach for monitoring the ²²²Rn emanation fraction from this source in different ambient temperatures which could be a source of error in the calibration processes.

2. EXPERIMENTAL WORK

Measurements of the effect of temperature variation on the emanation fraction f of standard source were presumed in a newly constructed calibration chamber and a NIST traceable Alpha Guard radon monitor (Mansy et. al., 2000). The radon was accumulated for 8 days in different controlled temperatures (0- 40 °C). with temperature fluctuation of \pm 0.3 °C.

The determination of emanation fraction f at different ambient temperature is simply calculated using the following equation:

$$f = \frac{I_{exp}}{I_{the}}$$
(2)

where I_{exp} is the experimental integrated radon concentration inside the calibration chamber that measured by the Alpha Guard and corrected for the standard pressure and temperature (1013.25 mbar; 273.15) by using alpha expert software correction factor for pressure and temperature (Genetron 1995). I_{the} is the theoretical integrated radon concentration that calculated for the ²²²Rn emanation standard source:

$$I_{the} = A_{Ra}^{0} [T_{A} - (\frac{1}{\lambda_{Rn}})(1 - e^{-\lambda_{Rn}T_{A}})]/V$$
(3)

 A_{Ra}^{0} is the ²²⁶Ra activity at the start of accumulation interval and assuming the value of *f* is equal unity. *V* is the air volume inside the chamber that corrected for volume V_{stp} at standard pressure and temperature:

$$V_{stp} = \frac{V \times p \times 273.15}{1013.25 \times T} \tag{4}$$

where p is the pressure in mbar and T is temperature in Kelvin for the air volume inside the accumulation chamber.

3. RESULTS AND DISCUSSION

Figure (1) shows the build-up curves for the NIST radon standard source inside the calibration chamber at different controlled temperatures. It is clear that, the build-up of radon concentrations, accumulated from the NIST standard source, were varied with changing temperature. As the temperature changes, the diffusion of radon out of the polyethylene capsule affects.



Fig. (1) Radon build up for the NIST standard source at different temperatures.

The values of the emanation fractions f at each temperature were calculated using equations 2, 3 and tabulated in table (1).

Table (1) The calculated emanation fraction f at different ambient temperatures

T °C	f
0	0.321
8	0.603
14	0.772
21	0.89*
28	0.937
35	0.985
40	0.973

* From the standard source certificate (NIST, 1994)

Decreasing the temperature to zero °C exhibited a decrease in f to approximately 36 % of its certified value at 21 °C. The variation rate of f with temperature was approximately 3.4% °C⁻¹ in the temperature range less than 21 °C. When the temperature was increasing 21°C to about 30 °C, the rate of increasing in f was approximately equal to 0.8% °C⁻¹. Table (1) represents also a slight decrease in the obtained value of f over 35°C. This decrease may be due to a little diffusion of the radon gas from the calibration chamber. Increasing the temperature over 35 °C may affect the permeability properties of the rubber material sealing the chamber.

The more likely variables that may affect f are the age of the ²²⁶Ra capsule and the accumulation time (Colle and Kishore, 1997). Figure (2) shows the dependence of the obtained f values on the accumulation time. The effect of the accumulation time on the radon emanation from the source varied considerably at the lower temperatures accumulation. The growth rate in f decreased by increasing the temperature. After a certain accumulation time, f becomes constant even with increasing the accumulation time. For instance, at zero °C the growth rate in f is 0.26 % per hour for accumulation time. Moreover, after 170 h of accumulation at zero °C, f becomes constant even with increasing the accumulation time. While it needs only 90 h to become constant at 14 °C. The dependence of emanation fraction f on the accumulation time was not remarked in the temperatures equal to or over 21 °C.



Fig. (2) The dependent of the emanation fraction of the NIST standard source on the accumulation time at low temperatures conditions.

4. UNCERTAINTY ANALYSIS

The uncertainty in the evaluation of f at different ambient temperatures was calculated using the law of propagation of uncertainty for the specific mathematical function given by the model of the measurement procedure(Taylor and Kuyatt, 1994). The standard uncertainty in the calculation of integrated activity of the NIST standard source u_{I_4} (0.68%) is given as follows:

$$u_{I_{A}}^{2} = [T_{A} - \frac{1}{\lambda_{Rn}} (1 - e^{-\lambda_{Rn}T_{A}})]^{2} u_{A_{Ra}}^{2} + [\frac{A_{Ra}}{\lambda_{Rn}^{2}} - A_{Ra}e^{-\lambda_{Rn}T_{A}} \\ (\frac{T_{A}\lambda_{Rn} + 1}{\lambda_{Rn}^{2}})]^{2} u_{\lambda_{Rn}}^{2} + [A_{Ra}(1 - e^{-\lambda_{Rn}T_{A}})]^{2} u_{T_{A}}^{2}$$
(5)

 $u_{A_{Ra}}$ is standard uncertainty in ²²⁶Ra activity of the NIST standard source (0.465%), $u_{\lambda_{Rn}}$ The standard uncertainty in measuring λ_{Rn} inside the accumulation chamber (0.88%), $u_{T_{4}}$ is the standard uncertainty for the exposure time which is negligible.

The standard uncertainty $u_{I_{the}}$ (0.88%) of the theoretical calculation of the integrated radon concentration inside the accumulation chamber is calculated by the propagation of uncertainty in u_{I_A} and the standard uncertainty in measuring the air volume inside the chamber u_V which depends on:

- •1 The standard uncertainty in measuring the net air volume inside the chamber (0.46%).
- •2 The maximum standard uncertainty due to repeatability in measuring temperature inside the accumulation chamber (0.3%),
- •3 The maximum standard uncertainty due to repeatability in measuring pressure inside the accumulation chamber (0.1%).

Consequently, the standard combined uncertainty u_f can be calculated as :

$$u_{f}^{2} = (\frac{1}{I_{the}})^{2} u_{I_{exp}}^{2} + (\frac{I_{exp}}{I_{the}})^{2} u_{I_{the}}^{2}$$
(6)

 $u(I_{exp})$ is the standard uncertainty in the measuring of I_{exp} (2.94%) which depends on:

The maximum standard uncertainty due to the monitor readings (1.04%),

The standard uncertainty in Alpha Guard radon monitor calibration factor (2.75%) (Mansy et al., 2000), The expanded uncertainty in the evaluation of f at different temperatures was 6.14 % at a confidence level of approximately 95% and the coverage factor is 2.

5. CONCULOSION

The effect of decreasing temperature rather than the certified value of the NIST standard source has a considerable effect on decreasing of the radon emanated from the source. On the other hand, the radon emanation fraction factor of the source is tendentious to the unity when the temperature was increased to more than 30 °C. The effect of the accumulation time on the radon emanation from the NIST standard source is very considerable at lower temperatures accumulation. The growth rate in the emanation fraction f decreases by increasing the temperature. After a certain accumulation time, it becomes constant even with increasing the accumulation time.

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