Assessing Radon Exposures from Materials Containing Naturally Occurring Radioactive Material (NORM)

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1. Abstract

The requirements of the European Basic Safety Standards Directive (1) for work with NORM were implemented in the UK by the Ionising Radiations Regulations 1999 (2). These regulations apply to work activities involving NORM (other than work with NORM, which is being processed for its radioactive, fissile or fertile properties), where effective doses to workers or other persons are likely to exceed 1 mSv per year. Where the work is subject to regulatory control, employers must comply with similar requirements to those applied to practices involving artificial radionuclides.

To assess the radiation exposures to employees working with NORM the UK regulations require a risk assessment to be carried out. A previous paper (3) has discussed the methodology of how this is done in practice in the UK. One of the main difficulties highlighted is in the assessment of the contribution to the total exposure caused by radon emanating from the NORM itself. To date, most assessments have relied on generic exposure models to derive broad estimates of doses from radon. Data on actual radon levels and how they vary with time is usually not available. In addition radon doses are normally calculated from the radon daughter concentration so assumptions have to be made on the equilibrium factor to be used. Due to the necessarily pessimistic nature of such assessments, actual doses may be lower than those estimated. This paper considers if this radon contribution may be more accurately assessed allowing the risk assessment to be refined and help, therefore, determine whether regulatory controls are required.

2. Previous work

To refine the risk assessment process it would be advantageous if the likely radon levels in a particular workplace could be estimated more precisely. A review of published literature (4,5,6) indicates that it is possible to measure the quantity of radon emanating from samples of NORM material in the laboratory. A number of methods have been used to attempt to measure this for typical NORM materials with a low thorium-232 and uranium-238 content (few Bq/g). A summary of the main findings to date is given below:

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Experiments typically measure radon emanation rate (in $Bq/m^2/s$) and it has been demonstrated that samples of different materials with a similar radionuclide composition can show a wide range of values. Radon emanation has been found to vary with the radium content in the sample as would be expected, but also with the distribution of the radium within the sample.

In a perfectly sealed system the radon gas will reach a plateau value but again the time taken for this to be achieved can vary significantly for apparently similar samples. The rate at which the radon builds up can also vary significantly with some experiments indicating that a significant proportion of the final value can be obtained in the first 24 hours.

The above findings suggest that it is necessary to make actual radon emanation measurements for the particular materials of interest rather than relying on previously published data. The laboratory experiments will also give an indication of how quickly radon levels build up. This is important as the results may show that over the period of a weekend or even overnight radon levels could build up significantly such that personnel entering the workplace following these periods may be initially exposed to higher radon levels.

It has also been reported (7) that the final airborne concentration that the radon can build up to in a real situation, say a mineral store, is dependent on a number of factors other than the emanation rate measured above and can be calculated as below:

$$X_{rn} = (3.6\ N_{rn}\ B) / VK \quad (a)$$

Where:

X_{rn} is the final radon-222 activity concentration (Bq/m^3)

N_{rn} is the radon emanation rate ($Bq/m^2/s$)

B is the surface area of the source (m^2)

V is the volume of the storage space (m^3)

K is the ventilation rate (h^{-1})

It should be possible, by looking at a particular workplace, to estimate the final radon levels as long as the emanation rate for the particular material has been measured in the laboratory experiments.

3. Proposed work

It is clear from the above that there are many parameters that will influence the build up of radon levels inside a workplace where NORM is being stored or used. The following methodology is proposed to investigate if these parameters can be measured and then used to estimate doses to employees for use in the risk assessment process:

- carry out laboratory experiments to measure the radon emanation rate, final radon level and rate of radon build up for typical UK NORM materials (mineral sands) and investigate any parameters that may affect this such as radium content, moisture content, packing density or depth of material. It is proposed to investigate three mineral sands processed in the UK namely ilmanite, synthetic rutile and bastnasite. Iimanite and synthetic rutile are used in significant quantities for the manufacture of titanium dioxide used as a whitener in many products. Bastnasite is processed in much smaller quantities and is used to manufacture optical lens polishing materials. Typical radionuclide analyses of these materials are given in the table below. The reproducibility of any measurements made will also be established this being seen as key to the whole process.

- By use of equation (a) given above, the maximum theoretical radon gas concentration can then be calculated for a particular workplace. This number plus the information gained on the rate of radon build up above can be used to produce a more refined risk assessment to determine if doses can exceed 1 mSv per annum.

Actual radon measurements will then be made in the workplace to see if the patterns of radon build up mirror those found in the laboratory situation and if the final values compare with calculated values. These measurements will then be used to more accurately assess true radon doses. The rate at which radon levels reduce, when for example the doors are opened increasing the ventilation, will also be important.

Table 1. Radionuclide analysis of mineral sands.

Material	Thorium-232 decay series (Bq/g)	Uranium–238 decay series (Bq/g)
Synthetic Rutile	0.7	0.2
Ilmanite	0.5	0.2
Bastnasite	5.0	0.1

4. Methods of measurement

4.1 Laboratory work

Previous work (6) has identified suitable equipment and methods for making these measurements and these will be repeated here. The measurements will be made using a steel exhalation chamber with a perspex lid in which the samples being analysed are placed. The chamber is connected to a Lucas Alpha-Scintillation Flask by a closed loop of rubber hoses. At intervals the air in the Lucas Flask is replaced with that from the exhalation chamber by means of a pump. The Flask can then be removed from the closed system and placed inside a Pylon AB-5 counter and the counts obtained used to establish the radon gas concentration inside the flask at the time of sampling. The layout of the apparatus is shown in Figure 1 below.

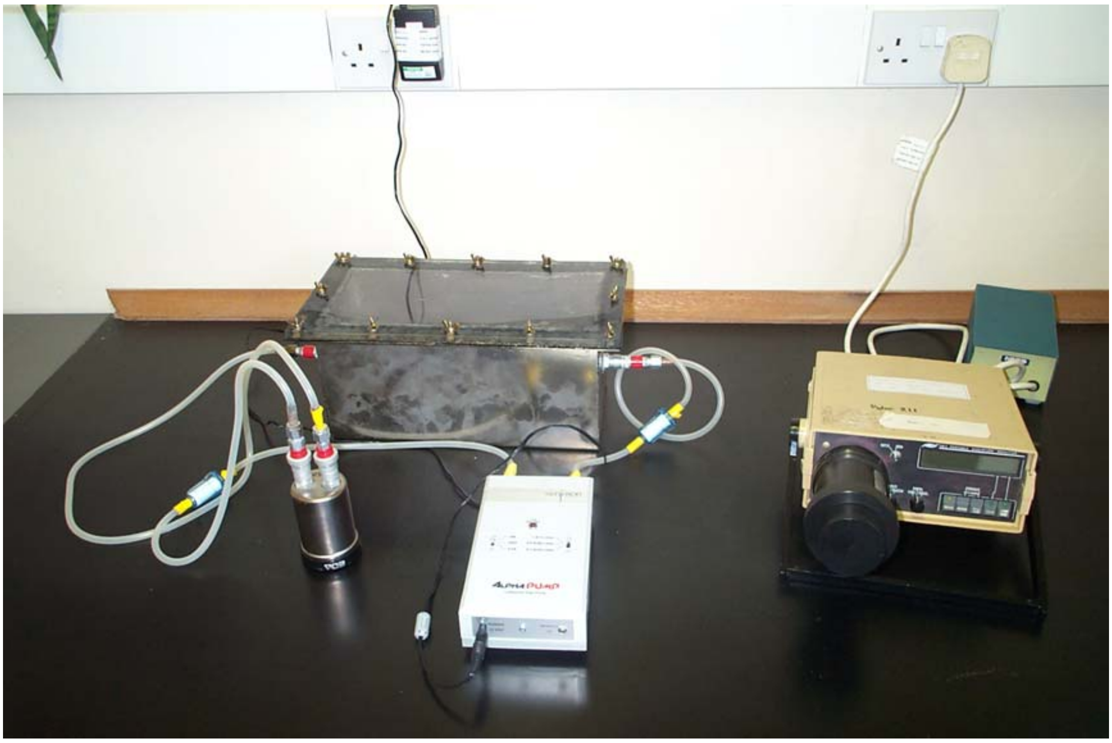

Figure 1. Layout of apparatus used for radon emanation experiments.

4.2 Field work

There are several methods available to measure average radon levels over time. Most measurements are made using passive track etch type detectors, which have to be left in situ for a period of three months and as such cannot track the variations in the radon levels in the workplace. In addition they only measure radon gas concentrations and not radon daughter concentration as required to accurately calculate radon doses. The sensitivity of the measurements is also poor in this context (of the order of 1 mSv).

To measure radon gas concentrations it is proposed that “grab” samples will be taken in a workplace using Lucas Flasks attached to sampling pumps. In addition measurements of the radon daughter concentration will be measured using an Industrial Working Level Meter. The measurements should allow the build up of radon gas and daughter concentration to be plotted with time. Making both measurements will also allow the equilibrium factor to be measured. These results can then be used to calculate radon doses. To try and make an assessment of the radon gas coming from the ground, radon measurements will be made in similar type buildings in the area or in the workplace itself when empty of NORM materials.

5. Proposed outcomes

It is hoped that the work carried out will:

Allow more accurate dose assessments to be carried out to better identify those workplaces that may be subject to regulatory control

Identify simple radiation protection control measures from a knowledge of the factors affecting the build up of radon gas in a workplace and help ensure that doses are being kept ALARA.

Lead to the publication of some generic guidance to assist organisations working with NORM materials.

6. References

[1] European basic Safety Standards Directive 96/29/EURATOM (EC, 1996)

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[3] Shaw, PV, Regulation of work with NORM: Practical experience from the UK.

[4] Quindos LS, Fernandez PL, Soto J, A Method for the Measurement of the Emanation Factor for Rn-222 in Small Samples of Porous Materials

[5] Morawska, L, Jeffries C, Distribution of Radium in Mineral Sand Grains and its Potential Effect on Radon Emanation.

[6] Cliffe, KD, Miles JCH, Brown K, The Incidence and Origin of Radon and its Decay Products in Buildings

[7] Dixon, DW, Hazard Assessment of work with ores containing elevated levels of natural radioactivity NRPB-R143, Chilton, (1984).