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A PASSIVE RADON GAS DETECTOR FOR USE IN HOMES

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Abstract

A passive integrating radon gas dosemeter has been developed using electro-chemically etched tracks in CR-39. The detectors will be used in a survey of 2000 or more homes in the UK. The response of the dosemeters is shown to be linear with respect to exposure. It is shown that snap-on polyethylene lids allow ^{222}Rn to diffuse into the detector cup while excluding radon daughters, dust and ^{220}Rn. Initial results from a trial survey are presented.

Keywords

Radon; alpha-particles; CR-39; SSNTD; pre-etching; electrochemical etching.

Introduction

NRPB are planning to carry out a survey of the UK to determine average exposures of people to gamma rays and ^{222}Rn daughters in their homes, and to identify areas where high exposures may occur (Brown, Cliff and Wrixon, 1981; Miles and Driscoll, 1981). It is expected that 2000 or more homes will be surveyed, and for this purpose passive dosemeters that can be issued by post have been developed. Radon daughter exposures will be estimated by using a passive detector to measure the integrated exposure to radon gas and assuming an appropriate equilibrium factor. Approximately 400 homes are currently being monitored as a trial survey, and the initial results have been compared with active measurements of radon and its daughters. The detectors are left in homes for successive periods of three or six months to cover a whole year. In each dwelling one detector is exposed in the main living area and one in a bedroom.

Methods

The dosemeter consists of two pieces of CR-39 fixed in the base of a mass-produced polystyrene cup (Fig.1). A piece of cloth is fitted to the top of the cup to allow radon to diffuse in while preventing radon daughters or dust from entering. The radon in the cup decays through its chain of daughters and some of the alpha particles emitted in this process will enter the detector, leaving invisible trails of damage. The number of trails is proportional to the integrated exposure of the detector to radon gas (Frank and Benton, 1973).

After the exposure of dosemeters in homes, the CR-39 detector elements are removed,

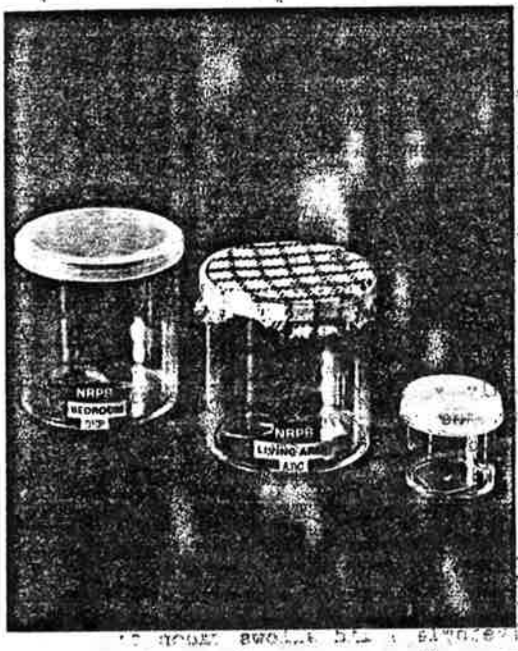

Fig. 1. Passive radon dosemeters.

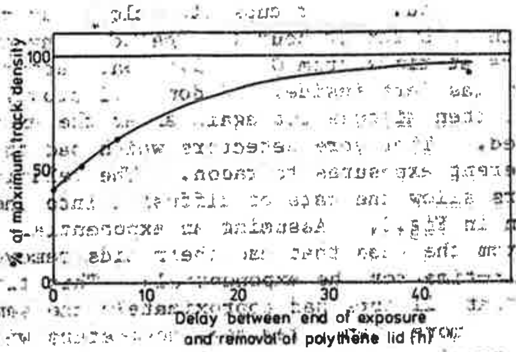

Fig. 2. Diffusion of radon into detectors with polyethylene lids. The maximum track density is that given by cups with cloth covers.

— Calculated exposure of dosemeters assuming $\lambda = 0.0693\ h^{-1}$ for diffusion and ignoring the decay of radon.

⊙ Experimental points.

one element from each cup is reserved for possible future examination and the other element is etched. There is a pre-etching stage of one hour in 20% NaOH at 80^0C followed by electrochemical etching in 30% KOH at 2 kHz, 18.3 kV cm^{-1} rms, 30^0C for 6 hours. The strengths of the etchant solutions are checked by titration. A constant 30^0C is maintained by etching on a thermostatically controlled heated tray. The detectors are etched on the exposed side only, to reduce background, while the unexposed side is in contact with an earthed plate. A drop of saline is used to ensure good electrical contact between the CR-39 and the earthed plate. Each detector is connected separately to the power source through a 10 mA fuse so that if a hole etches through one detector, this does not affect the etching of the rest. Up to ten detectors are etched together at the same voltage, provided they are they the same thickness within ±5%. It has been found that a ±5% variation in electric field strength results in a ±10% variation in sensitivity, but this can be corrected for. Two power sources are used, each connected to ten etching cells. Using a timer switch for overnight etching, 40 detectors can be etched in 24 hours.

If the first detector element reveals a very high track density, the second is electrochemically etched without a pre-etch. This reduces the sensitivity by a factor of six. Each sheet of CR-39 (obtained from Pershore Mouldings Ltd) provides 130 dosemeter elements. As sheets vary in sensitivity, samples from each sheet are calibrated by exposing them in dosemeter cups in a Fast Radon Exposure Device (FRED). This consists of an oil drum containing a radium source which maintains a concentration of about 7.5×10^4 Bq m^{-3}. The radon concentration can be measured during exposure by sampling with Lucas flasks. For calibration purposes, dosemeters are exposed to about 10^8 Bq m^{-3} h.

During the present trials, cups have been used with a cloth cover to exclude radon daughters and dust. However, experiments have shown the cloth to be unnecessary, as radon still diffuses into the cup when it is fitted with its original snap-on polyethylene lid. Four cups with cloth covers and ten with polyethylene lids were exposed in FRED for 17 hours. The polyethylene lids were removed from the dosemeters at times from 0 to 45.5 hours after the end of the exposure to release any radon gas left inside. Radon will slowly diffuse into each cup during exposure, then diffuse out again after the exposure at the same rate until the lid is removed. Therefore detectors which had their lids removed at different times had different exposures to radon. The relative track densities on the different dosemeters allow the rate of diffusion into the cup to be calculated. The results are shown in Fig.2. Assuming an exponential build up of radon in the cups, the result from the cups that had their lids removed immediately after exposure imply a 10 hr half-time for the exponential. This fits the other data points very well, showing that all cups had approximately the same radon diffusion rate. For exposure of more than a few days dosemeters with polyethylene lids will give almost the same results as ones with cloth covers, with only ~10% loss of track density due to decay of radon during its delayed entry into the detector. Use of the polyethylene lid saves time and excludes moisture and ^{220}Rn from the cup. If a small package of desiccant is included in a cup with a polyethylene lid, the dosemeter should also be suitable for measurements of ^{222}Rn in soil.

Smaller cups are also available (Fig.1) which would be suitable for personal dosemeters. Two 22 mm diameter discs of CR-39 can be fitted at the top and bottom of the cup, separated by a short piece of plastic tubing which just fits inside the cup. As with the larger cups, the polyethylene lid allows radon to diffuse in while excluding dust and radon daughters. The response of detectors exposed in 10 ml cups has been found to be ~50% of the response in the 100 ml cups used in houses.

Results and Discussion

Different sheets of CR-39 vary in sensitivity from 1.9×10^{-5} to 4.3×10^{-5} tracks mm^{-2} for an exposure of 1 Bq m^{-3} h (0.14 to 0.32 tracks mm^{-2} WLH^{-1} for an

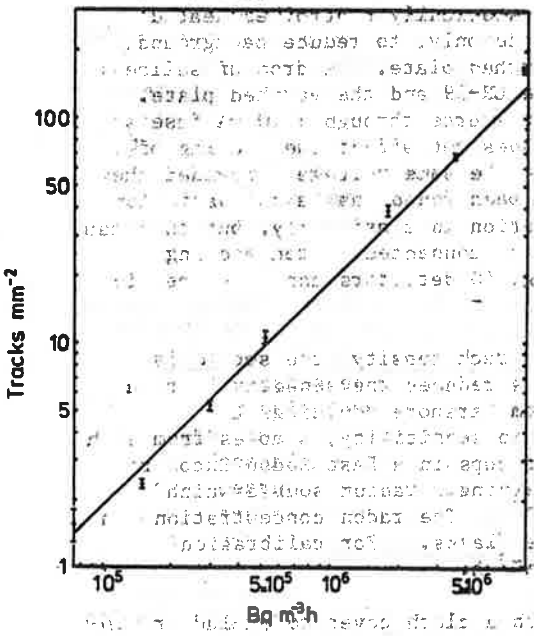

Fig. 3. Dose response of the passive radon dosemeter.

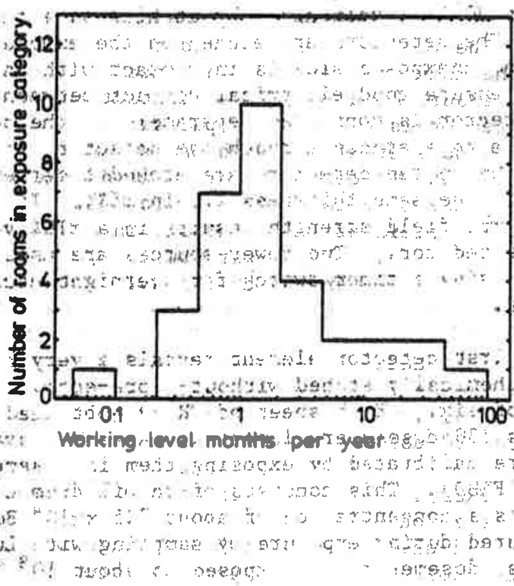

Fig. 4. Initial results of a survey of living rooms in an igneous region of the UK. Equilibrium factor 0.5 and 100% occupancy assumed.

equilibrium factor of 0.5), presumably due to variation in the conditions in which the plasic is cured. The background track density varies from 0.15 to 0.40 tracks mm^{-2}, usually corresponding to about 1 WLH. A trial has been carried out exposing a set of dosemeters made from the same sheet of CR-39 to different lengths of time in FRED. The results are shown in Fig.3, and display linearity between exposure and track density up to 7×10^{-5} Bq m^{-3} h. The dosemeters have also been exposed in dwellings where active mesurements of radon have been carried out, so that the results of active and passive measurements can be compared. NRPB are currently carrying out a survey of homes in an igneous region of the UK where the average exposure of the population to radon daughters is expected to be higher than for the rest of the UK. Both active and passive mesurements are carried out. Initial results from these exposures are shown in Fig.4. It is not to be expected that active and passive measurements will agree closely since householders can change the radon concentration by an order of magnitude simply by opening a window. However, there was broad agreement between active and passive measurements.

The interpretation of the results of either active or passive radon measurements is difficult, as neither technique measures directly the exposoure of individuals to radon daughters. Active measurements lasting a few hours cannot be used to give an accurate estimate of the exposure of an individual, as the concentration of radon changes from day to day depending on the ventilation rate. Passive detectors avoid this problem as they give a result in terms of the average ^{222}Rn gas concentration for the duration of exposure. However, passive detectors have other difficulties. The radiation dose to the lungs is mainly due to radon daughters not radon gas. An equilibrium ratio has to be assumed, introducing some uncertainty into the result. Another problem is that the radon concentration in a room during the day will be different from that at night. Although the measurement of interest is the average concentration during the period of occupancy, the passive detector measures the average over day and night. Overall, the radon exposure of an individual probably cannot be estimated to better than a factor of two by either technique, though the accuracy of the estimate of average population exposure is probably more accurate. Ideally, a passive integrating radon daughter working level dosemeter which is small enough to be carried as a personal dosemeter is desired. However, Urban and Piesch (1981) have shown that passive detectors exposed to the air in an attempt to measure WL give results varying by up to a factor of three in the same environment. Active integrating WL meters are available (Duport and others, 1980), but these require batteries and pumps. The best passive method of measuring WLH appears to be to use a radon gas dosemeter and assume an equilibrium factor.

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