THE ASSESSMENT OF RADON AND ITS DAUGHTERS IN NORTH SEA GAS USED IN THE UNITED KINGDOM

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There has been considerable interest in the radon content of natural gas in North America for some years, and activity concentrations of up to 1450 pCi l^{-1} at STP have been measured at wellheads(1). In contrast, reported measurements of radioactivity in North Sea natural gas streams have only appeared relatively recently(2). The National Radiological Protection Board began the project described in the present paper in 1977 at the request of the British Gas Corporation. The objectives were to measure the activity concentrations of radon-222, lead-210 and polonium-210 in those gas streams coming ashore in the UK, and to assess the possible exposure of the public that might result from the use of the gas in the home.

MEASUREMENTS

Natural gas is routinely filtered soon after coming ashore to remove particulate material of greater than 1μm aerodynamic diameter before being distributed on the national grid system. The maximum activity concentrations that could reach domestic appliances were therefore assessed by measurements made by sampling after filtration, but before distribution. The radon-222 content was measured directly using 3 litre chambers designed within NRPB(3). The rate of decay was followed and found to be consistent with the 3.8 day half-life of radon-222. The lead-210 and polonium-210 activity concentrations were determined by passing a known amount of gas through concentrated nitric acid, an effective scrubbing agent for metals. A high pressure bubbling system was employed, which had been developed by the British Gas Corporation. This permitted a representative sample of $1m^3$ of the gas at STP to be scrubbed in a reasonable time. Four samples of gas from each stream were separately scrubbed so that duplicate analyses could be performed for each radionuclide. Lead was selectively stripped from the acid solution by a two-stage solvent extraction, the chemical recovery being estimated gravimetrically. After a suitable ingrowth period, the more energetic beta particles from the bismuth-210 daughter were counted using a coincidence-shielded gas-flow proportional counter; the lead-210 content of the sample was inferred from the results. Polonium-210 was determined by electrodeposition and alpha spectrometry using polonium-208 as a tracer. The results available at the time of writing for all the gas lines currently on stream are shown in Table 1.

TABLE 1. Radon-222, polonium-210 and lead-210 activity concentrations of North Sea Gas streams supplying the U.K.

Stream	Radon-222, Bqm^{-3}	Polonium-210, $mBq\ m^{-3}$	Lead-210, $mBq\ m^{-3}$
A	31	2.5	< 17.4
		2.1	< 15.5
B	35	14.1	21.5
		17.0	< 8.1
C	33	4.1	22.2
		3.3	< 7.0
D	27	< 1.5	21.5
		< 1.9	< 7.4
E	36	< 5.6	< 12.2
		< 2.2	< 8.9
F	39	< 2.6	< 7.8
		< 2.2	< 7.0
G	11	9.3	19.6
		10.0	11.5

Note that since 1Bq corresponds approximately to 27 pCi, an activity concentration of 37 Bq m^{-3} is equivalent to about 1 pCi l^{-1}.

The limits of detection are determined both by the sensitivity of instrumentation and by the chemical recovery. Consequently, the limit of detection is particular to each sample. Typical relative standard deviations for these results are 20% for radon and 25% for polonium and lead, based on counting statistics alone.

ASSESSMENT

If the cautious assumption is made that these activity concentrations persist until the gas is combusted in the home, then the maximum possible exposure of individual members of the public may be calculated using a simple model. As a result of filtration, any particulate matter remaining in the gas stream is well within the so-called respirable range.

If there is a steady input rate of activity A into a room which has a ventilation rate of λ air changes per hour, then the total activity present at time t is given by the equation

$$N_t = \frac{A}{\lambda} (1 - e^{-\lambda t}) \qquad \ldots\ldots(1)$$

As t increases, N_t tends towards an equilibrium value N_e where

$$N_e = \frac{A}{\lambda} \qquad \ldots\ldots(2)$$

A typical room might have a volume of some $30m^3$ and a ventilation rate of 1 air change per hour. A typical gas burner used continuously would consume approximately $0.3m^3$ of gas per hour. Under these

circumstances the equilibrium activity concentration C_e in Bq m^{-3} is given by

$$C_e = \frac{N_e}{30} = \frac{0.3\ a}{30} = a.10^{-2} \quad \ldots\ldots(3)$$

Here a is the activity concentration in the gas in Bq m^{-3}.

RESULTS

Using the highest measured activity concentrations in the gas, the highest concentrations in air for polonium-210 and lead-210 for the conditions assumed are those shown in Table 2. These may be compared to the Derived Air Concentrations for these nuclides appropriate to members of the public which are taken to be one tenth of those for occupationally exposed workers (4).

TABLE 2. Comparison of maximum possible air concentrations with appropriate derived limits

Nuclide	Air concentration, Bq m^{-3}	Derived air concentration, Bqm^{-3}
Pb-210	$2.2\ 10^{-4}$	3.10^{-1}
Po-210	$1.7\ 10^{-4}$	9.10^{-1}

In the case of exposure to radon-222, its short-lived daughters contribute significantly to the dose and calculations are made in terms of the Working Level (WL). The highest calculated exposure will be obtained if it is assumed that the radon daughters are in full equilibrium in the gas at the time of supply to the house. By definition, an activity concentration of 3.7 kBq m^{-3} (100 pCi l^{-1}) of radon-222 in equilibrium with its daughters corresponds to 1 WL. Applying equation (3), the highest radon concentration measured in the gas then corresponds to $1.05.10^{-4}$ WL in the room. The unit of radon daughter exposure is the Working Level Month (WLM), which corresponds to an exposure to 1 WL for one working month (170h). One year of continuous exposure (8760h) to $1.05.10^{-4}$ WL will therefore correspond to $5.4\ 10^{-3}$ WLM in a year. This can be compared to what might be regarded as the maximum permissible exposure for a member of the public, namely 0.4 WLM in a year, (i.e. one tenth of that for occupationally exposed workers) and to an annual exposure of 0.16 WLM from natural background radiation in the U.K. (5).

In summary, the activity concentrations in the home have been calculated using cautious assumptions. No allowances have been made for dilution with gas from other sources (which is presently not significant) deposition of lead or polonium in pipework and, in the case of radon, the time lapse between coming ashore and combustion. It is also known that ventilation rates are usually increased during cooking perhaps by as much as an order of magnitude. Nevertheless the activity concentrations in the house calculated here are two to three orders of magnitude lower than the appropriate limits for members of the public.

It is therefore concluded that no significant radiation exposure of the public results from the distribution of natural gas from the fields in the North Sea that supply the United Kingdom. Nonetheless the activity concentrations of these radionuclides are being periodically monitored, and measurements will be carried out on any new fields that come on stream.

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