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Assessment of dose from indoor pollutants

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During the past twenty years there has been growing concern over pollution of the general environment. For the purpose of monitoring airborne pollutants out of doors, it has generally been adequate to sample the outdoor environment. One example is the use of permanent outdoor dust samplers to determine the levels of airborne effluents from nuclear installations. It is difficult to imagine how levels of such pollutants would not be appreciably lower indoors; continuous indoor monitoring of them has, therefore, not been deemed necessary.

It was inevitable, of course, that attention would eventually turn towards pollution indoors since this is where persons spend most of their time. Indoor pollution is now a topic in its own right and is being considered by such bodies as the Royal Commission on Environmental Pollution and the International Commission on Radiological Protection. A number of international conferences are also planned which will be devoted entirely to this topic.

Concern has been increased by a more general awareness that pollutants produced indoors tend to linger indoors. Some of the commonly-mentioned pollutants are formaldehyde from chipboard, oxides of nitrogen and carbon from cooking, smoke from cigarettes, and radon. The "Save it" campaign of the 1970s emphasised the financial benefits of conserving energy, and this has led to reduced ventilation rates in many homes and offices with consequent enhancement of levels of indoor pollutants.

It is simply not adequate just to take grab samples of airborne pollutants indoors to estimate the integrated exposure from them: exposure depends on the levels that exist during the period of occupancy. The ideal arrangement would be to determine personal exposures with some form of personal monitor but such arrangements are generally impracticable or unworkable.

Assessment of exposure to indoor pollutants must therefore involve measurements of the environment, but additional data will then be needed to relate the measured results in some way to human dose. The assessment of one such pollutant, radon, is being undertaken in this manner.

In the national survey of natural radiation indoors in the home,[1] the long-term average concentrations of radon are being measured by passive detectors in two rooms in the home, the living area and bedroom. The concentration of the radon gas is largely determined by the ventilation rate, which in turn is determined by the values of a number of parameters peculiar to each house and room and the preferences of the occupants with regard to window and door-opening, and the use of open fires. It is also determined by the outdoor radon concentration and, since this varies diurnally, by the period of day when the room is occupied. At any given time, it is further influenced by the prevailing atmospheric conditions. The concentration of the decay products of radon, which is the parameter of real interest, is, of course, dependent on the state of equilibrium of the decay products that prevails during occupancy. This is affected by all the factors mentioned above as well as the proportion of decay products that plate out on the room surfaces.

The actual radiation dose received by the occupants is determined by their breathing rates during occupancy and the characteristics of the radon decay product aerosol. The breathing rate is determined by the activities of the occupants, and the characteristics of the aerosol are once again influenced by the ventilation rate. Since the ventilation rate and occupancy

habits seem to be such important factors in assessing exposure to any indoor pollutant, and not only radon, they are discussed in the remainder of this paper.

Ventilation rate

Some information on window-opening habits is available from the work of Brundrett[2]. The number of open windows is strongly influenced by the weather, with external moisture being the strongest influence in winter, and mean temperature in summer. It was found that the room in the home most likely to have an open window is the bedroom, that dwellings where the housewife is at home are more likely to have at least one open window, and that houses with larger families are also more likely to have a window open.

Relatively little data are available on personal habits with respect to the opening of internal doors. A pilot study by the Building Research Establishment[3] revealed that about 34% of the persons in the sample usually kept their living room, bathroom and second and third bedroom doors open. Some 50% usually kept their main bedroom doors open. Answers by members of Board staff to questions on this topic are summarised in Table 1. The values given are averages for summer and winter. There is a noticeable decrease in the percentage of open windows and internal doors during the night.

It is very difficult to discover what persons' habits are with regard to the opening and closing of windows and internal doors. Respondents tend to relate their answers either to their actions on the day of the inquiry (termed the availability heuristic by social researchers) or to their actions in hot or cold weather, leaving the researcher to decide which is the norm. An attempt has been made to overcome this difficulty in the questionnaire now being used in the Board's national survey of indoor natural radiation[1]. Participants are being asked to describe their habits during the 24 hours immediately prior to completing the questionnaire. The 24 hours have been

Table 1 Window and internal door opening habits in 130 dwellings

Room	Percentage open			
	Windows		Internal doors	
	Day	Night	Day	Night
Living area	35	6	48	37
Bedroom	52	44	63	42

sub-divided into three categories: yesterday morning and afternoon, yesterday evening, last night. This breakdown is also used to discover the type of heating used in the home during the same period. Since the issue of the questionnaire to 2000 households is extended over more than twelve months, this method should produce a good indication of national habits and enable an estimate to be made of the prevailing ventilation rate and of the radon decay product concentrations.

Occupancy habits

To date, a value of 90% indoor occupancy has been used in various calculations of radiation exposure in the United Kingdom; this figure derives from the work on weapons fallout in the 1950s[4]. The United Nations Scientific Committee on the Effects of Atomic Radiation[5] uses a value of 80% for the worldwide average percentage of time spent indoors. Neither source breaks down its overall value into the time spent indoors in the home and the time spent in other indoor places such as offices, factories, shops and schools. Such a distinction would be necessary if the indoor pollution levels were substantially different between such places.

A study of available survey data was undertaken to derive more detailed occupancy factors and this is being published elsewhere[6]. Information was obtained for the whole population and for certain groups in the population, such as housewives and retired persons, who spend more time than usual in the home. On average, the inhabitants of the United Kingdom spend 75% of their time indoors at home with a further 15% spent in other indoor locations, thus confirming the earlier overall estimate. Total occupancy of the home varies more between weekdays and weekends than between winter and summer.

Individual patterns of occupancy within the home and the related activities are, of course, dependent on factors such as sex, age and family composition. On average, however, persons spend 41% of their time indoors sleeping or resting, 19% on leisure activities, and 15% on other activities. It is, of course, reasonable to assume that the time spent sleeping or resting mainly occurs in the bedroom. Leisure activities (watching television and reading) are likely to take place in the living area, and the remaining time indoors is spent in various locations throughout the house. Occupancy of each room also varies with the time of day. The living area and bedroom are no doubt intermittently occupied throughout the day but they are likely to become the main occupied rooms during the evening and night.

Conclusions

These refined estimates of occupancy, with subsequent data on variables affecting the ventilation rate, will be used to refine the present estimate of exposure to radon decay products[7] when the complete results from the national survey of indoor exposure become available[1]. Such information should have wider applicability in radiation protection, for instance, in

assessing the potential impact of accidental releases to the atmosphere in the nuclear power industry. It may also have wider applicability to indoor pollutants in general.

References

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