Lung Dose Modelling From Realistic Measurements Of Occupancy Exposure To Radon Progeny

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Abstract

The risk of lung cancer resulting from exposure to radon, is directly related to the progeny concentration and the actual period of occupancy. Current exposure studies and dose models to date use the widely accepted protocol that the occupancy factor is 80%(1,2). Our experimental studies on real time simultaneous monitoring of both radon progeny and occupancy periods have shown that much greater accuracy in risk assessment can be achieved when occupancy periods are measured rather than assumed to be a constant 80%.

Introduction

The risk of lung cancer arising from exposure to radon progeny is directly related to the total cumulative exposure, expressed as the product of Working Level x Occupancy Factor. In order to improve the accuracy of estimation of the health risk associated with exposure to radon progeny, accurate measurements of personal occupancy are necessary. Customarily, an occupancy factor of 80% is assumed, in the absence of more appropriate data. A recent study undertaken by N.H Harley and B.R. Litt(3,4) utilized a passive radon gas monitor(CR39 alpha track) worn by the participants. Additionally, subjects were required to keep an activity log of where they had been and what they had done. An alternative approach undertaken by Thomson & Nielsen, is based on the simultaneous measurement of both the real time continuous radon progeny variations and the actual occupancy periods within that environment. All measurements were recorded automatically, without the need for any personal activity diaries. The data gathered from this study is later used for calculating WLM exposure levels based on direct measurements.

Experimental Measurements

The chosen study environment was the basement area of a typical family residence of four occupants. For this experiment, no attempt was made to distinguish individual family members. A continuous working level radon monitoring system(TN-WL-02) manufactured by Thomson & Nielsen, was configured to record hourly radon progeny concentration levels automatically. This system is based on the principle of active sampling of the ambient air onto a filter with subsequent determination of the gross alpha counts by a solid-state detector. Data from this system, collected over

a period of several months, was later analyzed on a standard PC computer to produce continuous hourly plots of the radon progeny. In addition, monitoring and recording of the occupancy periods were made using a customized surveillance system. Each time a family member entered the basement area, the system was activated to subsequently record the occupancy duration. The data from this system was also later analyzed on a PC and the two plots combined to form the composite exposure profiles, as seen in Figure 1.

Results

A summary of the results covering four consecutive days are shown below in Table 1. Random variations in both WL and occupancy patterns can result in a wide range of WLM values. Over a four day period, as seen in Figure 1, the working level concentration varies by a factor of 5:1. Occupancy patterns reflect typically the habits of two working adults and two school age children. Activity is greatest at times in the afternoon when the children return from school and also on Saturdays. During the hours of sleep there is obviously no activity in the basement and radon progeny levels then are less of an exposure risk.

Table 1

	Thursday	Friday	Saturday	Sunday
Rd Average	0.038WL	0.032WL	0.017WL	0.027WL
Rd std dev	0.012WL	0.010WL	0.005WL	0.005WL
Occupancy	13%	17%	30%	8%
WLM/yr	0.25	0.28	0.26	0.11

Based on these values a comparison can be made between calculations of exposure from actual and assumed occupancy factors. It is seen that under realistic conditions, the occupancy factor is not necessarily 80%.
Previous studies in this basement area have determined the average annual value to be 0.04WL. Using the usual occupancy factor of 80%, the estimated exposure is given as:

$$\text{WLM/yr} = 0.04 \times 0.8 \times 730 \times 12 / 173 = 1.62$$

Using the measured values from table 1, the calculated exposure is given as:

$$\text{WLM/yr} = 0.028 \times 0.17 \times 730 \times 12 / 173 = 0.24$$

In terms of the effective dose equivalent, the conversion factor between dose absorbed in the bronchial region and exposure to radon progeny is: 10mSv/WLM, as adopted by the ICRP(8).

Conclusions

Commonly employed lung dose models i.e. Jacobi-Eisfeld(5), Harley-Pasternak(6) and James-Birchall(7), include a simple proportionality constant for the occupancy factor. We have seen however that the actual value can vary significantly and is not a constant. When estimating radon health risks therefore, it is preferable that both progeny and occupancy be measured continuously. This is entirely feasible using monitoring equipment from Thomson & Nielsen, additionally removing the encumbrance of having participants keep activity diaries. By going to a higher level of system sophistication, individuals within a monitored zone can also be analyzed separately.

References

1. U.S. Environmental Protection Agency and U.S. Department of Health and Human Services. A citizen's guide to radon. U.S. EPA Pamphlet No. OPA-86-004, 1986.

2. New Jersey Department of Health. A case-control study of radon and lung cancer among New Jersey women. New Jersey Department of Health, 1989.

3. Harley N.H. et al. Personal and home Rn222 and gamma-ray exposure measured in 52 dwellings. Health Physics, Vol.61, No.6, pp.737-744, 1991.

4. Litt B.R. et al. Validation of a personal radon monitor for use in residential Rn222 exposure studies. Health Physics, Vol.61, No.6, pp.727-735, 1991.

5. Jacobi W. et al. Dose to tissues and effective dose equivalent by inhalation of radon 222, radon 220 and their short lived daughters. Report Gesellachaft fur Strachlen- und Umweltforschung GSF-S-626, Munich, Germany, 1980.

6. Harley N.H. et al. Environmental radon daughter alpha dose factors in a five-lobed human lung. Health Physics, Vol.42, pp.789, 1982.

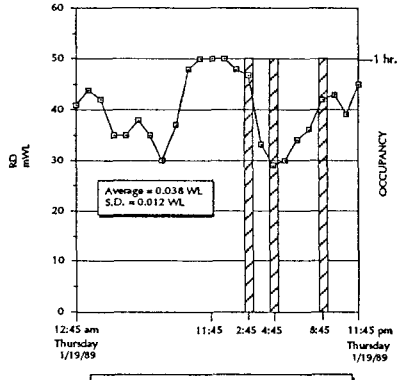
7. James A.C. et al: A dosimetric model for tissues of the human respiratory tract at risk from inhaled radon and thoron daughters. Proceedings of the 5th Congress of the International Radiation Protection Association, Jerusalem, March 1980.

8. International Commission on Radiological Protection. Limits for inhalation of radon daughters by workers, ICRP publication 32, Ann. of ICRP, 6(1), 1981.

WLM EXPOSURE CALCULATIONS

Using Measured Radon Daughter Values
and Measured Occupancy Values

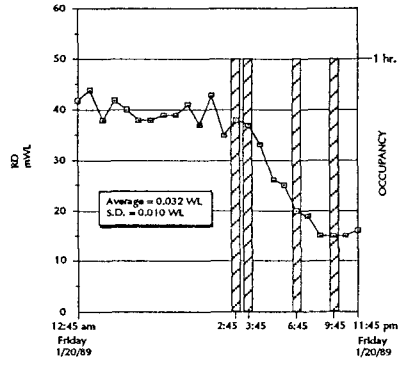
Equipment: TN Proprietory Systems



Percentage Occupancy = 3/24 hr = 13%

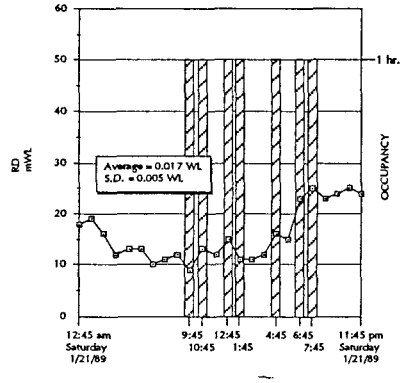
$WLM = \frac{0.038 \times .13 \times 730}{173} = 0.02$

$WLM/yr = 0.02 \times 12 = 0.25$



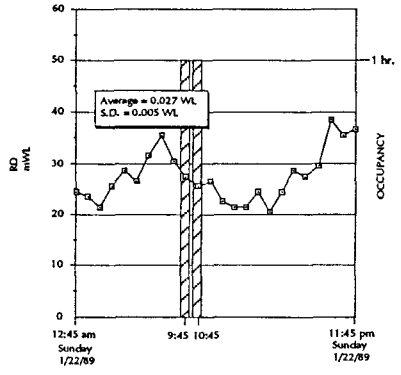
Percentage Occupancy = 4/24 hr = 17%

$WLM/yr = \frac{0.032 \times .17 \times 730 \times 12}{173} = 0.28$



Percentage Occupancy = 7/24 hr = 30%

$WLM/yr = \frac{0.017 \times 0.3 \times 730 \times 12}{173} = 0.26$



Percentage Occupancy = 2/24 hr = 8%

$WLM/yr = \frac{0.027 \times .08 \times 730 \times 12}{173} = 0.11$

FIGURE 1