Health Physics Vol. 61, No. 4 (October), pp. 539–542, 1991
Printed in the U.S.A.

0017-9078/91 $3.00 + .00

Pergamon Press plc

● *Note*

SHORT- VS. LONG-TERM INDOOR RADON MEASUREMENTS

L. S. Quindos,* P. L. Fernandez and J. Soto
Department of Medical and Applied Physics, Faculty of Medicine of Santander,
University of Cantabria, c/Cardenal Herrera Oria. 39011, Santander, Spain

***Abstract*—The major advantage of short-term vs. long-term indoor Rn measurements is that the information is available rapidly. A study of the results obtained for Rn measurements developed in Spain, employing grab samples and 3-mo α-track measurements, is discussed.**

INTRODUCTION

THE DESIGN of national or regional survey programs frequently involves trade-offs between the quantity and quality of data obtained as a function of the objectives of the study. Because of this, the choice of an appropriate method of measuring Rn concentration is very important.

Integrated measurements employing passive etched-track detectors give long-term exposures for people living in houses. The data are related directly to health risks. Nevertheless, the expensive devices and the longer time required to obtain the results are disadvantages of this method.

On the other hand, grab samples are less expensive and offer the advantage of prompt availability of data, but it is more difficult to calculate average concentrations over a period longer than for the instant of measurement. Previous works have shown differences between the results derived from several types of short-term and long-term Rn concentration measurements (Ronca-Battista et al. 1988; Steck 1990).

In this note, we compare the results of short-term and long-term national surveys conducted in a specific area of Spain with high Rn levels in houses.

METHODS

During 1988 we carried out a national survey on indoor Rn in Spain. In this survey, Rn in houses was determined using α-scintillation cells developed in our laboratory as a modified design of the original Lucas cell (Lucas 1957). The inside walls of the cell were lined with ZnS(Ag)-coated Mylar, but the main difference with the traditional one was the ability to open the cell after use by removing the bottom. This modification enabled cleaning of the cell by replacing the ZnS(Ag) sheet, if necessary, without flushing the cell with clean air or nitrogen, and made the cell reusable many times. We checked the cell for leaks by pressurization and by comparing the decay of Rn in the cell to the expected theoretical behavior of Rn. In both cases, no leakage was detected.

During our participation in the Third Commission of the European Communities (CEC) intercomparison of active detectors for the measurement of indoor Rn held at the National Radiological Protection Board (NRPB), Chilton, United Kingdom, in October 1987, we tested several options for different cell volumes and positions of the ZnS(Ag) sheets (Miles and Sinnaeve 1988). For practical reasons, we chose standard cells of 1 L capacity and a sensitivity of 81 cpm per Bq (3 cpm per pCi). The background of this kind of cell ranged from 0.7 to 1.3 cpm, counting times were 20–30 min, and the resulting low limit of detection was around 10 Bq m^{-3}.

Considering the seasonal and diurnal variation of the indoor Rn concentration (Wilkening and Wicke 1986; Wrixon et al. 1988), and in order to approach our instantaneous measurements with the cells to time-averaged values, we conducted our survey during the winter period and collected the samples in the first hours of the morning. With these two basic conditions, we joined others in applying this technique as recommended by the U.S. Environmental Protection Agency (1987).

As a result of this study, we found areas in the country with high Rn levels in houses, especially west and north-

(*Manuscript received* 5 *November* 1990; *revised manuscript received* 17 *April* 1991, *accepted* 30 *April* 1991)
* Author to whom correspondence should be addressed.

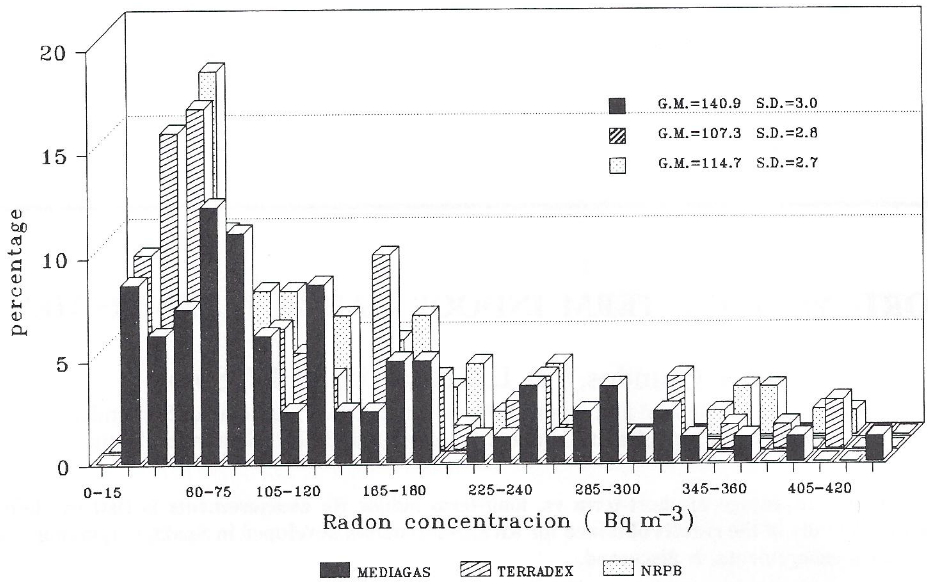

Fig. 1. Distribution of indoor Rn concentrations for the three measurement methods.

west of Spain. In a second phase during the winter of 1989, the average values of indoor Rn concentrations were evaluated by placing two types of passive integrating Rn detectors in 94 houses of these areas. One was from Terradex† and another from the NRPB. After an exposure period of 3–4 mo, the detectors were recovered and shipped to the manufacturer for analysis. At the time of deployment and removal of the detectors, we took grab samples using the technique described above. From these last measurements we derived the median of the two values which was then compared with the results obtained from the integrating Rn detectors.

During the same time period and in the same area, Terradex detectors were placed in 94 other houses so that, together with our own measurements, a total of 188 data sets were available for comparison.

† Terradex, Tech/Ops Landauer, Inc., United States.

RESULTS AND DISCUSSION

The three distributions of indoor Rn concentrations (94) obtained by using the grab sampling method and the two types of passive integrating Rn detectors mentioned above are shown in Fig. 1. Because the data are more lognormal than usual, the geometric means and standard deviations will be used to compare surveys. Although the geometric mean concentrations derived from the grab-sampling measurements are slightly higher than the integrated values, the results of the Student's *t*-test and correlation of the data for the three distributions indicate no significant differences among them ($p < 0.05$). A complete statistical summary of the Rn levels measured in the houses by different intervals of concentration is given in Table 1.

Table 2 represents the percentages of houses for different intervals of indoor Rn concentration for the three distributions. We have determined the limit of each interval considering the recommended action levels pub-

Table 1. Results from indoor Rn measurements for different ranges of concentration and techniques of measurement.

Range concentration (Bq m^{-3})	Cells (Spain) G.M. (Bq m^{-3})	S.D.	Number of measurements	Terradex (U.S.) G.M. (Bq m^{-3})	S.D.	Number of measurements	NRPB (United Kindom) G.M. (Bq m^{-3})	S.D.	Number of measurements
<37	26.3	1.3	11	29.6	1.2	15	29.6	1.2	12
37–75	44.4	1.1	17	44.4	1.5	44	44.4	1.4	26
75–150	107.3	1.2	25	103.6	1.2	15	103.6	1.2	19
150–200	173.9	1.1	10	166.5	1.1	12	170.2	1.1	12
200–400	281.2	1.2	16	281.2	1.2	12	270.1	1.2	14
>400	869.5	1.9	15	806.6	1.7	11	782.9	1.7	11
Total	140.9	3.0	94	107.3	2.8	94	114.7	2.7	94

Table 2. Percentages of houses for the three measurement techniques referred to different indoor Rn concentrations.

Range concentration (Bq m^{-3})	Percentages of houses Cells (Spain)	Terradex (U.S.)	NRPB (United Kingdom)
0–150	61	62	59
150–200	12	12	13
200–400	16	14	16
>400	11	12	12

lished by several countries and institutions shown in Table 3. In Table 2, the percentages of houses in which remedial action is necessary are almost the same, emphasizing the coincidence of the results from the three techniques. Nevertheless, if we study the percentages of houses for a lower interval (0–55 Bq m^{-3}), the indoor Rn concentrations obtained by using the grab sampling method are appreciably smaller than the passive integrating detectors. This fact, of course, is related to the greater sensitivity in the Rn detection of these last detectors compared with the instantaneous measurements from the cells.

Finally, the two distributions of indoor Rn concentrations (188) relating results from passive and active methods have been analyzed. From a statistical point of view, as found in the results described above, no significant differences were detected between these two distributions. Also, the conclusions are basically the same in the evaluation of percentages of houses for different indoor Rn intervals.

According to the regression analysis in Fig. 2, the correlation coefficient is 0.86 and the slope of the regression line is 1.2 with a statistical error of 5%. This good correlation, of course, is very important in strategy planning for regional or national surveys in order to minimize the cost of the program and to focus research effort, as soon as possible, in areas where the presence of Rn is a hazard for people.

Table 3. Recommendations for Rn limitation in existing and future houses given as the annual average of the gas concentration.

Authority	Existing homes (Bq m^{-3})	Future homes (Bq m^{-3})
ICRP	400	200
CEC	400	200
WHO	200	200
Sweden	800	140
Finland	800	200
Federal Republic of Germany	250	250
Norway	800	200
Nordic	200	200
U.S.	150	150

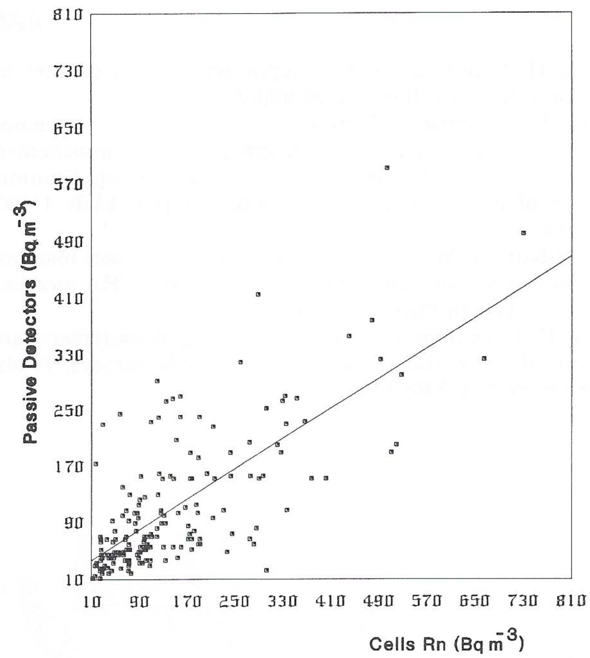

Fig. 2. Correlation between indoor Rn concentrations measured by passive etched-track detectors and modified Lucas cells.

CONCLUSIONS

If the number of randomly selected houses is appropriate, short-term and long-term measurements give rise to similar distributions for indoor Rn concentrations using restrictions in the sampling procedure. This means that if enough "instantaneous" measurements are made, regardless of their individual variability, their average value is still a reasonable representation of the "true" average concentrations over an extended time period. Moreover, in developing a regional survey giving percentages of houses exceeding the thresholds recommended by the EPA and the CEC, 150 Bq m^{-3} and 400 Bq m^{-3}, respectively, are approximately the same for both techniques, although when a large number of houses are involved, even these small percentage differences could be significant.

Finally, it is interesting to note that while the average of the grab sample provides an accurate indication of the probability for high Rn concentrations in a group of houses, the technique does not let us predict the specific Rn concentration for an individual house to be used in evaluating the exposure for people.

Acknowledgments—This research was performed under CEC Contract B16-0314-E(TT), DGICYT contract CEE88-0009, FISss contract 89/0575, and CSN contract 89/0010. The authors are indebted to Dr. Wilkening for his careful review of this paper. Technical assistance and suggestions from our colleagues are also appreciated.

REFERENCES

Lucas, H. Improved low level alpha scintillation counter for radon. Rev. Sci. Instrum. 28:680–683; 1957.

Miles, J. C.; Sinnaeve, J. Results of the third CEC intercomparison of active and passive dosemeters for the measurement of radon and radon decay products. Luxembourg: Commission of the European Communities; Report EUR 11882; 1988.

Ronca-Battista, M.; Magno, P.; Nyberg, P. Standard measurement techniques and strategies for indoor ^{222}Rn measurements. Health Phys. 55:67–69; 1988.

Steck, D. J. A comparison of EPA screening measurements and annual ^{222}Rn concentrations in statewide surveys. Health Phys. 58:523–530; 1990.

U.S. Environmental Protection Agency. Interim protocols for screening and follow-up radon and radon decay product measurements. Springfield, VA: National Technical Information Service; EPA 520/1-86-014; 1987.

Wilkening, M.; Wicke, A. Seasonal variation of indoor radon at location in the southwestern United States. Health Phys. 51:427–436; 1986.

Wrixon, A. D.; Green, B. M. R.; Lomas, P. R.; Miles, J. C.; Cliff, K. D.; Francis, E. A.; Driscoll, C. M. H.; James, A. C.; O'Riordan, M. C. Natural radiation exposure in UK dwellings. Oxford: National Radiological Protection Board; NRPB-R-190; 1988.