INDOOR RADON CONCENTRATIONS IN SOUTH AFRICAN HOMES

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ABSTRACT

Radon concentrations have been measured in about 2 000 South African houses during a phased study. The winter-month average was 63 Bq/m^3 and the geoemetric mean 45 Bq/m^3. Parameters correlating with high indoor radon concentrations were floor type and uranium content of geological formation.

INTRODUCTION

The radiation dose from inhaled decay products of radon seems to be the dominant component of radiation exposure of the world population. Although much can be learnt from overseas experience, local differences warrant an investigation of the South African situtation. On the one hand the South African climate may favour better ventilation conditions which may result in lower indoor radon concentrations. On the other hand the cold Highveld winters and lack of central heating may promote stagnant indoor conditions for certain months of the year. Furthermore, the densely populated areas on the Witwatersrand are surrounded by waste dumps from gold/uranium mines. These contain enhanced ^{226}Rn concentrations. The Department of National Health and Population Development and various town and city councils provided financial and logistic support for this study.

OBJECTIVES AND PHASES OF THE STUDY

The main objective was to assess the magnitude of the public exposure to indoor radon concentrations through nationwide surveys as extensive as possible, in accordance with requirements and resources available.

The study was conducted in three phases. The first phase was conducted in 1988 in a few areas to obtain initial logistic and sampling experience and to evaluate the techniques. The second phase during the winter of 1989 evaluated randomly selected houses of AEC employees and areas selected from an airborne radiometric survey, granitic areas, and an area that showed a geological fault and high indoor radon concentrations. In the third phase the study was expanded to other areas, including an area where indoor burning of coal might contribute to high indoor radon levels.

METHOD AND PROCEDURES

In order to obtain representative concentrations for average conditions, it is necessary to perform integrated measurements over days or preferably even months. No consideration is given to diurnal patterns or the equilibrium factor of the radon. These factors should be the subject matter of later studies.

SAMPLING TECHNIQUES

All the studies were performed primarily during the winter months. Time-integrating passive samplers were used. Charcoal canisters (Cohen *et al,* 1986) were used in some early investigations but this method of sampling was discontinued. Nuclear-track (or track-etch) detectors (Urban *et al,* 1981) were used for sampling. These monitors were normally exposed for three months. After electrochemical etching of the films the tracks were counted using a computer-automated technique.

DATA COLLECTION

Together with each measurement a one-page questionnaire was administered to obtain information about the house. This information was finally combined with that of the area characteristics and the radon concentrations in a computer data base.

DATA ANALYSIS

Data analysis was aimed at determining the relationship between indoor radon concentrations and house characteristics and the area characteristics. Analyses of variance (ANOVA) were determined for four effects, namely ventilation, sub-floor type, floor type and geographical type.

Poor ventilation is represented by a level 0 and high ventilation by level 5. Sub-floor level of 0 indicated normal soil, level 1 filling with rubble with large pores, level 2 a basement or crawl space and level 3 filling with mine tailings. Floor type level 0 indicated wooden floor or no floor covering and 1 concrete slab. Geographical types were assigned level 0, 1 or 2, where 0 indicated geological type with relatively low uranium concentrations, 1 indicated uncertain or variable uranium concentrations and 2 relatively high uranium concentrations. This evaluation indicated that the areas selected were not significantly biased towards high-uranium geological types.

RESULTS

The sample size was 1 801 houses, the total averaging was 63 Bq/m^3, the median 52 Bq/m^3, the mode 39 Bq/m^3 and the geometric mean 45 Bq/m^3.

The measured indoor radon concentrations are shown in Figure 1.

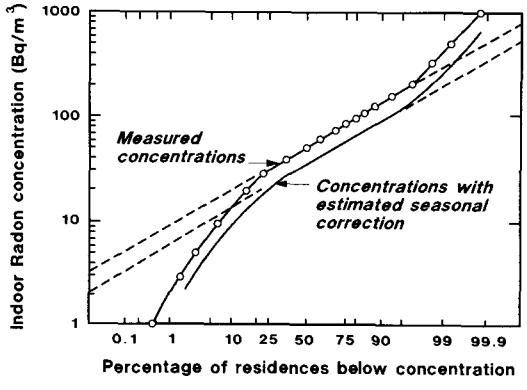

Figure 1: Log-normal distribution of Indoor Radon Concentrations in South Africa

It should, however, be noted that the measured values do not represent seasonally-, construction- and locality-averaged values. Outdoor measurements indicated a winter- to annually-averaged ratio of 1,5. (This approximates ratios reported for the USA [Borak, *et al*, 1989].) Dividing the winter-measured values by 1,5 gives the lower curve in Fig. 1.

Table 1 gives the indoor radon concentrations for the various areas.

Table 1: Median and Range (Bq/m³) for each Town in Compounded Data Set

Town	Sample Size	Median	Geometric Mean	Average	Maximum
Cape Town	134	10	9	13	52
Bedfordview	16	23	4	20	72
Malmesbury	59	25	24	42	150
Richards Bay	76	33	26	38	120
Rustenburg	10	34	31	33	48
Parys	44	37	41	66	595
Brits	30	38	35	42	119
Paarl	60	39	45	85	842
Johannesburg	284	45	37	49	197
Stilfontein	72	45	50	62	131
Sandton	16	46	46	50	106
Roodepoort	6	50	49	61	130
Akasia	7	52	51	57	97
Soweto	150	54	53	56	131
Hartbeespoort	28	56	49	59	145
Boksburg	116	56	59	66	212
Verwoerdburg	29	57	55	61	136
George	91	60	55	64	143
Pretoria	148	61	54	66	197
Phalaborwa	8	62	60	61	79
Krugersdorp	53	65	67	77	273
Springbok	67	70	60	78	340
Beaufort-West	62	74	61	79	184
Nababeep	88	78	79	87	393
Randfontein	45	80	84	92	185
Randburg	13	87	92	122	440
Germiston	143	93	89	116	297

The results of the multifactor analysis of variance are given in Table 2.

Table 2: Results of multifactor ANOVA

Source of variation	Sum of Squares	d.f.	Mean Square	F-ratio	Sig. Level
Main characteristics	1 758 425	11	159 846	4,405	,0000
Uranium deposits	603 667	2	301 833	8,318	,0003
Floor type	378 796	1	378 796	10,439	,0013
Sub-floor	330 050	3	110 017	3,032	,0284
Ventilation	446 524	5	89 305	2,461	,0314
2-factor interactions	1 508 942	30	50 298	1,386	,0809
Floor-type/uranium	435 650	2	217 825	6,003	,0025
Floor-type/subfloor	99 916	2	49 958	1,377	,2528
Floor-type/ventilation	239 179	5	47 836	1,318	,2536
Ventilation/uranium	420 480	10	42 048	1,159	,3147
Sub-floor/ventilation	234 736	9	26 082	,719	,6921
Sub-floor/uranium	5 472	3	1 824	,050	,9851

935 missing values have been excluded.

DISCUSSION

Measurements in about 2 000 residential homes in South Africa indicate an approximate log-normal distribution of indoor radon concentrations. An average concentration of about 63 Bq/m^3 was measured during the winter months of three consecutive years. If corrected for seasonal variations an average closer to 42 Bq/m^3 is expected.

Table 2 shows that geological type (containing uranium) and floor type played significant roles as well as the combination of these factors.

The results from Table 1 show that coal burning (Soweto) did not result in higher radon concentrations in the typical residences where coal is burnt.

Detailed discussions are given in a separate report (AEK-0036/90).

CONCLUSIONS

The average indoor radon concentration found in about 2 000 South African residences averaged about 63 Bq/m^3. The seasonally-averaged value is estimated to be closer to 42 Bq/m^3. Although the former value ranges high among international values, the percentage of houses with concentrations above 200 Bq/m^3 coincide closer with the international average. In less than 1 % of the houses monitored, concentrations about 400 Bq/m^3 were recorded while between 3 and 4 % recorded values above 200 Bq/m^3. With the seaonal correction these percentages decrease to 0,5 % and between 1 and 2 % respectively.

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