NATIONWIDE DISTRIBUTION OF INDOOR RADON MEASUREMENTS

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ABSTRACT

A rapidly growing United States data base consisting of over 90,000 indoor radon concentrations measured with passive integrating Track Etch detectors is described. The data base is subdivided by region and state, and a variety of statistical parameters summarizing the contents of the data base are presented for each geographical area.

The primary conclusions that can be drawn are that there are some homes with unacceptably high radon levels in nearly every state, and that there exist regions where a significant fraction of homes have unacceptably high radon levels. Initial attempts to make the data base more representative of the United States as a whole indicate an arithmetic mean for the country of between 3 and 4 pCi/l.

INTRODUCTION

The measurement of radon with Track Etch (Alpha Track Detectors (ATD's)) devices has been employed for a variety of applications since the early 1970's. The application to the environmental area was started in 1979 and the ATD method has been described previously (1-4).

Measurements of indoor air using ATD's were made in Sweden in 1980-1982 (5) and applications in the United States started about the same time (6). Other early ATD results have also been described (7-13).

From the outset of the environmental ATD measurements, we felt that some record of the indoor measurements should be kept, and the initial results on 60,000 indoor radon measurements using ATD's have been described (14).

The present data base, consisting of 91,000 long-term ATD results, is the subject of this paper. The publication of these results is intended to accomplish the following objectives:

1. Determine the geographic distribution of indoor radon in the United States.

2. Provide an initial indication of the magnitude of the indoor radon problem in the U.S.

3. Serve as an aid to state and federal officials and laboratories in planning public health and research programs.

We feel these objectives have been largely met.

The paper will discuss the nature of the data base, state and regional data, historical trends in the data and the data base as a whole.

DATA BASE CHARACTERISTICS

Each record of the data base contains zip code (when available), average radon level in pCi/l, ATD serial number, state, room (when available), dates of exposure and days exposed. Records have been placed in the data base which have the following qualifications:

a. Indoor living space measurement (measurements in crawl spaces, sumps, drains, soils, water and outdoor air have been carefully eliminated.)

b. Exposure time greater than 15 days (this eliminates most "blind" chamber exposures).

c. Radon level greater than 0.1 pCi/l (this eliminates most "blind" blanks).

d. No replicate records having same zip code, exposure dates and room.

e. Single family homes comprise most of the data base.

Despite the above precautions, the data base remains an unplanned record of results from large and small clients, individuals, states, federal agencies and research laboratories. It is not designed to be representative of the United States and we have little knowledge of the objectives of agencies conducting ATD surveys. A large fraction of the records cover locations known to have either high or low radon potential.

In an effort to make the data more representative, statistics (to be described) have been population-weighted by state to reduce the overwhelming statistical influence of large numbers of measurements in a single state (e.g. PA or WA). The populations used are taken from 1980 Bureau of the Census results on "Total Number of Housing Units, by States".

RESULTS

STATES

For each state, statistics are available for numbers of measurements, median, geometric mean, geometric standard deviation, arithmetic mean, percent of readings exceeding 4, 8 and 20 pCi/l and the maximum reading.

Results for all states have been given previously (14) for a smaller data base. For this paper we present in Table I results for those states having more than 900 measurements. The data should be representative of each state and show the wide variability in statistics from state to state across the country.

Arithmetic means for 23 states exceed the 4 pCi/l guideline (16) and in 38 states 15% or more of the measurements exceed the guideline.

Results from this study were compared with screening results (largely short-term measurements) for a number of states involved in cooperative surveys with the Environmental Protection Agency. Data for the percent of homes exceeding 4 pCi/l are shown in Table II and Figure 1.

REGIONS

To provide a larger number of records for statistics, we have combined the states into seven arbitrary regions. The statistics for each region are population-weighted by state and the results are given in Table III. The data are ranked by geometric mean. The Mountain States region has high values for all statistics closely followed by the Mid-Atlantic region. The Northwest region is characterized by very low values.

TRENDS WITH TIME

Since data have been collected since 1980, we have developed the significant statistics of the entire data base as a function of year. The objective is to find if there are trends in statistics as a function of time.

The year in the starting date for each record was used to create files with all exposures started in the same year. The records for each year were added to those for the previous years to give a cumulative set for each year. The statistics were then developed for each year on a state population-weighted basis as described earlier. The trend data are shown in Table IV, together with the number of states encompassed by the data base as it grew. It was not until 1984 that sufficient states were represented to indicate statistics on a countrywide scale.

NATIONAL STATISTICS

The 1987 data in Table IV comprises, in fact, the entire 91061 records of the current data base, giving population-weighted values of 1.91 for the geometric mean with 21.7 percent of the readings exceeding 4 pCi/l.

GENERAL OBSERVATIONS

We have reported previously on specific room statistics and zip-coded records (14). For the present data base, we estimate about 15% of the records are basement exposures.

Exposure times showed 3% in the 15-40 day period, 77% in the 40-160 day period and 20% with greater than 160 day exposure periods.

A comparison of MEDIAN and GEOMETRIC MEAN in Tables I, III and IV show a close correspondence. This indicates a strong log-normal distribution with a slight positive skewness on the high side.

CONCLUSIONS

DISTRIBUTION OF INDOOR RADON LEVELS

The selected state statistics in Table I show a range of about a factor of 10 in all statistics. (The data are ranked by geometric mean.) The wide differences from state to state may be largely explained by geology. With the exception of Illinois, all of the high states are associated with either the granites of the Appalachians or the Rocky Mountains. Washington and Oregon are believed to be low because of the predominantly volcanic terrain of the Northwest. California, a large state, is inadequately sampled, but the generally low statistics may imply home construction predominately without basements and moderate climate in the most populated areas.

The regional statistics in Table III show the strong correlation with regional geology observed with selected states. The relatively high Midwest values may reflect the zone of glaciation covering the northwest tier of states augmented by basement type construction with low air interchange.

COUNTRY-WIDE STATISTICS

The historical data in Table IV show the population-weighted statistics leveling off in 1983-84 with the values in 1987 representing the entire current data base. We would have expected a significant increase in radon levels from 1986 onward because of the recommended (15,16) follow-up measurements with ATD's on short term basement levels between 4 and 20 pCi/l; this has not been observed.

Table II and Figure 1 show a good correlation between data from this study and short-term screen results even though this study had less than 200 measurements in five states of the EPA/State set. We believe that this correlation enhances the credibility of our entire data base.

The overall statistics continue to imply a higher arithmetic mean for the country than that reported by other published work (13,17). The carefully designed "National Survey" now being planned by the Environmental Protection Agency is needed to resolve such issues.

Also surprising is the roughly 2 percent of the measurements (population weighted) which exceed the "occupational standard" of 20 pCi/l (6 WLM/yr) (17). This implies that about one million homes in the U.S. may have radon levels in excess of those permitted in uranium mines.

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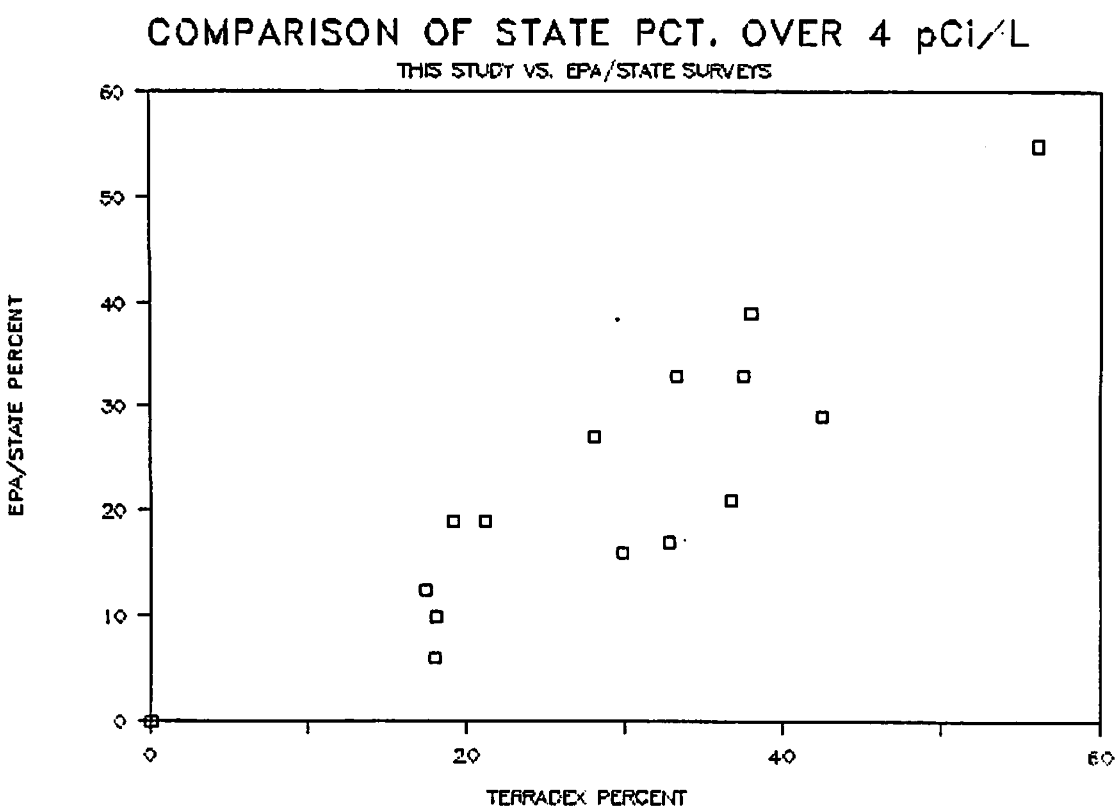

Figure 1. Percent of measurements exceeding 4 pCi/l. EPA/State survey results compared with this study.

TABLE I. SELECTED STATE STATISTICS WITH GREATER THAN 900 RECORDS

STATE	NUMBER RECORDS	------AVERAGE pCi/L------ MEDIAN	GEOM. MEAN	ARITH. MEAN	---PERCENT GREATER THAN--- 4 pCi/L	8 pCi/L	20 pCi/L	MAXIMUM pCi/L
WA	12818	0.60	0.67	1.39	5.8	2.5	0.6	144.3
OR	7150	0.86	0.91	1.50	6.2	1.7	0.2	187.7
CA	1267	1.10	1.14	2.17	12.5	4.7	0.8	67.9
NY	9879	1.10	1.22	2.72	13.9	6.2	1.7	394.7
ME	1608	1.72	1.87	4.83	23.3	9.6	2.9	1212.5
VA	2521	2.30	2.17	3.33	24.4	5.8	1.0	114.0
NJ	6806	2.07	2.27	6.18	28.2	13.2	4.3	1234.6
IL	2718	2.20	2.28	4.79	26.2	8.1	2.0	396.9
MD	1424	2.30	2.39	4.81	30.1	14.0	3.3	171.5
CO	913	3.10	3.22	7.81	38.1	15.3	4.2	691.3
PA	31105	4.70	5.04	12.39	56.1	31.7	11.0	3125.4

TABLE II. COMPARISON OF STATE SURVEY RESULTS

STATE	THIS STUDY NUMBER OF TESTS	PERCENT OVER 4 pCi/L	EPA/STATE SURVEYS NUMBER OF TESTS	PERCENT OVER 4 pCi/L
AL	572	18	1200	6
AZ	105	18	272	10
CO	913	38	900	39
CT	546	19	1500	19
IN	521	38	1500	33
KS	19	37	1000	21
KY	155	33	879	17
MI	285	18	489	13
MN	562	33	1000	33
PA	31105	56	42489	55
RI	85	21	190	19
TN	805	30	1800	16
WI	352	28	1200	27
WY	193	43	800	29

TABLE III. REGION POPULATION-WEIGHTED STATISTICS

REGION •	NUMBER RECORDS	AVERAGE pCi/L MEDIAN	GEOM. MEAN	ARITH. MEAN	PERCENT GREATER THAN 4 pCi/L	8 pCi/L	20 pCi/L
NORTH WEST	20871	0.70	0.76	1.43	6.0	2.1	0.5
PAC. STATES	1769	1.13	1.19	2.33	13.2	5.3	1.0
SOUTH EAST	3145	1.20	1.33	2.46	13.6	5.6	1.4
NEW ENGLAND	3304	1.71	1.78	3.57	19.6	7.6	2.1
MID-WEST	6377	2.33	2.41	4.26	28.8	10.8	2.2
MID-ATLANTIC	52159	2.38	2.53	5.91	29.1	14.4	4.5
MTN. STATES	3260	2.79	2.92	6.14	34.7	15.8	4.7

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NORTH WEST	OR,WA
PAC. STATES	AZ,CA,NV
SOUTH EAST	AL,AR,FL,GA,KY,LA,MS,NC,OK,SC,TN,TX
NEW ENGLAND	CT,ME,MA,NH,RI,VT
MID-WEST	IL,IN,IA,KS,MI,MN,MO,NB,ND,OH,SD,WI
MID-ATLANTIC	DC,DE,MD,NJ,NY,PA,VA,WV
MTN. STATES	CO,ID,MT,NM,UT,WY

TABLE IV. POPULATION-WEIGHTED STATISTICS BY YEAR

CUMULATIVE * YEAR **	NUMBER STATES	AVERAGE pCi/L MEDIAN	GEOM. MEAN	ARITH. MEAN	PERCENT GREATER THAN 4 pCi/L	8 pCi/L	20 pCi/L
1980	3	0.62	0.61	0.93	1.8	0.7	0.3
1981	5	0.58	0.58	0.85	2.5	1.0	0.2
1982	17	1.46	1.59	2.38	13.6	6.3	1.5
1983	44	1.34	1.43	2.40	12.0	4.1	0.9
1984	46	1.45	1.58	3.45	15.5	6.1	1.9
1985	49	1.62	1.73	3.53	18.0	7.4	2.2
1986	50	1.79	1.88	3.83	21.4	8.8	2.3
1987	50	1.81	1.91	3.81	21.7	9.2	2.3

*
e.g. "1982" is 1980,1981 and 1982

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Year of Exposure Starting Date