1988_41



# PRELIMINARY RESULTS OF A NATIONWIDE WATERBORNE RADON SURVEY

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## ABSTRACT

Levels of radon in private groundwater supplies in several states, along with preliminary descriptive statistics, are presented. Geometric means for states range from a few hundred to a few thousand picoCuries per liter (1 pCi/L = .037 Bq/dm$^3$), while levels range from below the lower limit of detection (about 100 pCi/L) to over 100,000 pCi/L in four states.

## INTRODUCTION

The Kutztown University Waterborne Radon Survey has disseminated nearly 6000 waterborne radon test kits by mail to locations in several states. Preliminary results on over 2200 measurements of private well water will be presented here. We have attempted to exclude measurements of spring water, municipal water supplies, and supplies whose location is uncertain. We will present only very simple descriptive statistics: Maximum and minimum measurements for each state, arithmetic and geometric means and arithmetic and geometric standard deviations for each state. We have not yet attempted to prove that these data are lognormally distributed, but choose to present geometric parameters because the data are certainly skewed, and lognormal distributions are frequently approximated by environmental measurements. A more complete analysis will be published in the future. Political (state) boundaries have been chosen in this study because they may facilitate action by state departments of health or environmental resources, not because they represent logical aggregates of similarly distributed data.

While radon levels in public ground water supplies, which serve 32.2% of the US population, have been extensively studied, data on private ground water supplies, which serve 18.3% of the population (1) are fragmentary. Our study and others (2) suggest that private wells usually have several times the radon concentration of municipal supplies, so that they may present significantly more risk even though they serve a smaller portion of the population. It is encouraging that the arithmetic and geometric means of the radon concentrations are not alarmingly high in most states; however levels exceeding 20,000 pCi/L (74,000 $Bq/m^3$) were found in 13 states, even with very limited sampling. A level of 10,000 to 20,000 pCi/L has been informally proposed by several workers (see for example reference 3) as a practical concentration limit. Almost all workers conclude that the risk of lung cancer due to inhalation of airborne radon exsolved from water used in the home is at least an order of magnitude greater than risks arising from ingestion of the water itself. On the basis of results from public water supplies, $5 \times 10^{-8}$ to $7 \times 10^{-7}$ excess lung cancers per pCi/L (lifetime) have been predicted (4). Waterborne radon levels and lung cancer incidence have been correlated (5). If waterborne radon poses a significant health threat, the greatest population risk is probably to consumers of private wellwater.

METHODS

We use the liquid scintillation method first developed by Prichard and Gesell (6) and modified by the USEPA (7). A Packard Model 3255 or 2425 scintillation spectrometer is used to count samples for 40 minutes each with the discriminator set as wide as practicable. For each test, we provide a disposable 10cc syringe to which a 6 cm length of 2mm ID Tygon(R) tubing has been attached, and two 20 mL "cone capped" polyethylene scintillation vials which contain 5 mL each of NEN mineral oil-based scintillator cocktail. Instructions state that 10 cc of water should be slowly removed, with the syringe, from a cup which has been filled and then allowed to overflow for two minutes with the spigot below the surface of water in the cup. The Tygon(R) tubing on the syringe minimizes degassing during transfers, and is, of course, safe for home use and postal transport. Alternatively, some samples were collected in two standard 15 mL glass water analysis vials with TFE backed silicone septum caps, by immersing the vials and caps in water collected as specified above, and capping the vials underwater. In this case, a syringe with a double needle was used in the laboratory to remove 10 mL of sample and inject it into 5 mL of cocktail in a 20 mL scintillator vial. Standards are prepared by dilution of a calibrated solution of Radium-226 in 0.05 M nitric acid obtained from the Quality Assurance Division of the Environmental Monitoring Systems Laboratory, USEPA, Las Vegas, and traceable to a NBS standard. Radon levels are calculated by standard methods (7) while lower limits of detection (LLD) are calculated (8,9) by means of the formula

$$LLD = [\ 2(2)^{.5} * 1.645 * (BC)^{.5} * 100\ ] / (CT*CF*DF)$$

where 1.645 is the value of the standard normal variate (for .05% probability of concluding that there is no activity where there is some, and concluding that there is activity where there is none), BC is the background count accumulated in the count time CT, CF is the conversion factor between measured counts and radon level in pCi determined from the standard, and DF is the decay factor, $e^{.0076T}$, where T is the time between sampling and measurement. Samples are typically measured within 3-7 days of sampling, so that LLDs range from 80 to 120 pCi/L. Our laboratory participated in the interlaboratory methods assessment conducted by E.L. Whittaker[1].

Test Kit Dissemination

All measurements which are reported here were requested by individual citizens, by a variety of public service or governmental organizations, by radon mitigation or measurement firms who contract our services, or by building inspection firms. Requests were generated substantially by word of mouth information from state agencies or the USEPA, by mention of the Survey at radon mitigation/measurement seminars sponsored by various agencies, or by mention of the Survey in various publications. While we are measuring waterborne radon in a selected and controlled population for a separate study (10), no attempt has been made in the current report to elimate possible sampling biases due, for example, to respondents' prior knowledge of airborne radon levels. We have asked respondents to report whether they know the airborne radon level in their homes (and if so what it is) to allow for partial control of this bias. Many respondents do not know the airborne radon level, and the correlation between waterborne and airborne radon levels (where reported) apprears to be weak. Geographical distribution has not been controlled, but will be in the future as regions of particular concern can be identified. We probably do, however, get a majority of samples from areas where news media have reported a radon problem, and the methods of distribution are likely to introduce other biases. The present paucity of data on the distribution of radon in private wells probably justifies a non-selective distribution of samples.

RESULTS

The accompanying Table presents preliminary, summary of the data that are presently in machine readable form. For each

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[1]Lockheed Engineering and Management Services Co., Inc., Environmental Programs Office, 1050 E. Flamingo Rd., Suite 120, Las Vegas, NV 89119.

state, we report the number of measurements (see below) that were made, the high and low values in pCi/L, the arithmetic mean (AM), geometric mean (GM) the arithmetic (normal) standard deviation (ASD), and the geometric standard deviation (GSD). Every effort has been made to eliminate redundancies that result from repeated testing before mitigation, after mitigation, or both. We have not reported results for supplies reported as "springs" or "municipal," although it is sometimes difficult to distinguish between small private community water supplies and municipal ones.

Because our lower limit of detection is generally in the neighborhood of 100 pCi/L, we have converted all levels below 100 pCi/L to 100 pCi/L for statistical treatment. Normally, these levels would be reported as "below LLD" when we provide results, and the LLD for the particular sample, calculated as described above, would be given. Lognormal statistics preclude zeros as data, and assigning the LLD value to all measurements below the LLD is not an uncommon practice that may, in fact, provide more reasonable descriptive statistics.

We have found that samples show an apparent exponential decrease in level superimposed on the exponential decrease due to decay of the radon. The values we report have been adjusted for decay of radon between sampling and measurement but we do not apply a second correction for the additional loss, which is insignificant for most samples, compared to sampling errors. The loss is apparently temperature dependent and probably reflects leakage and diffusion of radon into the vials.

DISCUSSION

Our study generally corroborates previous measurements of private water supplies; differences between the geometric means reported here and those in other reports (2) probably result from paucity of data. The even more marked difference between the high values measured in this study and in other studies may also indicate the incipiece of present knowledge.

Sampling errors as high as 10-20% may result from factors such as variability in well and plumbing volume, level of water use over several hours before sampling, and possible seasonal variations in groundwater radon levels. The last factor is probably much less important than the others (11,12). The average deviation between A and B samples in our survey is about 6%. Statistics dictate that counting errors for the 95% confidence level will be in the neighborhood of 2% and 6% for samples measuring 10,000 and 1000 pCi/L respectively, and rise to 100% as the LLD is approached. Since counting errors for samples of real concern are small compared to sampling errors, and interferences from other radionuclides (which are normally at much lower concentrations) are unlikely, the liquid scintillation method appears to be appropriate.

It appears that none of the studies (1, 5, 13) of the airborne radon levels that result from the domestic use of radon-containing water have incorporated the contribution of intentional air humidification, which may be a major factor. In cases where water use does contribute significantly to airborne radon levels, the resulting radon may be undetected in cases where initial screening is done in an area of a house were neglible water use occurs, for example, in the cellar of a house where radon-rich water is used for humidification of upper floors but not the basement.

Levels of radon in individual wells, and (especially) variability in levels between neighboring wells, do not seem to be determined as much by broad geological province, or even by the radioelement concentrations in the province, as much as by microgeological factors operating within a few meters of the well. These may include disruption by well digging, friation close to the well, flow rate, exsolution of radon near the surface, temperature, and other factors. If this is true, it follows that only extensive testing of individual wells will characterize the distribution of radon in private water supplies.

The work described in this paper was not funded by the U.S. Environmental Protection Agency and therefore the contents do not necessarily reflect the views of the Agency and no official endorsement should be inferred.

TABLE: SUMMARY STATISTICS ON RADON LEVELS (pCi/L) IN PRIVATE WELLS

| State | Number | High | Low | AM | GM | ASD | GSD |
|---|---|---|---|---|---|---|---|
| AK | 9 | 765 | 100 | 452 | 353 | 281 | 2.63 |
| AL | 1 | 893 | - | - | - | - | - |
| AZ | 1 | 590 | - | - | - | - | - |
| CA | 15 | 1854 | 100 | 563 | 332 | 575 | 2.90 |
| CO | 33 | 29383 | 100 | 4677 | 2081 | 5983 | 4.47 |
| CT | 469 | 377479 | 100 | 10786 | 2822 | 33377 | 4.70 |
| DC | 1 | 409 | - | - | - | - | - |
| DE | 2 | 953 | 361 | - | - | - | - |
| FL | 10 | 402 | 100 | 216 | 191 | 107 | 1.69 |
| GA | 75 | 23292 | 100 | 2542 | 1141 | 4175 | 3.48 |
| IA | 3 | 512 | 203 | 307 | - | - | - |
| ID | 2 | 880 | 764 | - | - | - | - |
| IL | 6 | 745 | 100 | 288 | 228 | 219 | 2.03 |
| IN | 18 | 1532 | 100 | 515 | 231 | 479 | 2.79 |
| KS | 9 | 429 | 100 | 224 | 189 | 127 | 1.89 |
| KY | 1 | 122 | - | - | - | - | - |
| MA | 60 | 54724 | 180 | 5773 | 2765 | 9044 | 3.49 |
| MD | 66 | 61209 | 103 | 3554 | 1451 | 7841 | 3.84 |
| ME | 154 | 41516 | 134 | 4199 | 2168 | 5744 | 3.23 |
| MI | 15 | 2450 | 100 | 497 | 259 | 688 | 2.89 |
| MN | 8 | 1799 | 127 | 518 | 344 | 533 | 2.50 |
| MO | 2 | 266 | 198 | - | - | - | - |
| MT | 1 | 648 | - | - | - | - | - |
| NC | 23 | 18693 | 100 | 3587 | 1504 | 4214 | 4.79 |
| ND | 3 | 384 | 253 | 335 | - | - | - |
| NE | 1 | 100 | - | - | - | - | - |
| NH | 165 | 105305 | 100 | 9206 | 3358 | 16947 | 4.20 |
| NJ | 166 | 92350 | 100 | 5720 | 2042 | 10728 | 4.37 |
| NY | 75 | 431320 | 100 | 9920 | 1036 | 52383 | 4.74 |
| OH | 67 | 4505 | 100 | 482 | 324 | 617 | 2.27 |
| OR | 1 | 295 | - | - | - | - | - |
| PA | 661 | 103803 | 100 | 3338 | 1179 | 10360 | 3.52 |
| RI | 10 | 73855 | 2344 | 21740 | 12073 | 21925 | 3.36 |
| SC | 5 | 2682 | 320 | 1339 | 920 | 1064 | 2.69 |
| SD | 3 | 2779 | 118 | 1884 | - | - | - |
| TN | 6 | 512 | 185 | 317 | 290 | 135 | 1.59 |
| TX | 11 | 460 | 100 | 250 | 215 | 129 | 1.82 |
| VA | 43 | 19718 | 100 | 2902 | 1433 | 3619 | 3.83 |
| VT | 4 | 6965 | 226 | 2368 | 1122 | - | - |
| WA | 4 | 351 | 100 | 166 | 142 | - | - |
| WI | 13 | 45245 | 145 | 5647 | 710 | 12914 | 6.32 |
| WV | 3 | 10532 | 100 | 3641 | - | - | - |

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