

EXECUTIVE SUMMARY

SURVEY OF RESIDENTIAL INDOOR AND OUTDOOR RADON
CONCENTRATIONS IN CALIFORNIA

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This research was conducted to develop the data necessary to assist the California Air Resources Board (ARB) in assessing residential indoor and outdoor radon concentrations in California. As required by the California Health and Safety Code (HSC) Chapter 3.5, the ARB, in consultation with the California Department of Health Services (DHS), evaluates the public health risk of substances which are being considered for possible identification as toxic air contaminants (TACs). HSC Section 39660.5 requires the ARB to consider indoor exposures as well as outdoor exposures in conducting risk assessments for the TACs Program. Under HSC Sec. 39655, the ARB is specifically required to identify as toxic air pollutants those substances which have been designated as hazardous air pollutants under Section 7412 of Title 42 of the United States Code. Radionuclides, which include radon, have been so designated under the federal program.

The specific objectives of the study were 1) to determine the annual average radon concentrations in and near California residences, 2) to determine the approximate fraction of the California population regularly exposed to residential radon concentrations exceeding 4 and 8 picocuries per liter of air (pCi/l), and 3) to the extent possible, to identify factors (such as geologic region or building type) which may be useful in predicting high risk areas or groups in California for focusing future investigations. This study had several major components, which included 1) a pretest, 2) a main survey of statewide, randomly-selected residences, 3) a focused survey within or near the southern Sierra Nevada foothills, and 4) an in-depth study of a subset of the residences including soil and other measurements on-site.

In the pretest, 40 residences in Santa Cruz and Monterey Counties were studied to enable investigators to evaluate methods prior to their use in the main survey. In the main survey, 360 homes were selected statewide to be monitored so that annual average radon concentrations and the fractions of California residences exceeding 4 and 8 pCi/l could be estimated. The focused survey of 40 residences within or near the southern Sierra Nevada was carried out to determine if radon concentrations in this general area were elevated with respect to the rest of the state, as was expected based on geological considerations. The field work carried out at a subset of 60 residences was designed to provide detailed, site-specific information on soil (e.g., permeability to air, radium content, radon emanation rate, etc.) from each residence, and to relate that information to indoor radon concentrations.

To recruit participants throughout the entire state, vehicle registration records maintained by the California Department of Motor Vehicles were used to select addresses. To assure a wide geographic coverage, recruitment and selection of participants were based on zip code zones.

Two questionnaires were used in this study. A mini-questionnaire was sent with the recruiting letter to obtain information on volunteer residences for selection of participants and comparison of participants with the general public. A long questionnaire was mailed to the participants with the radon samplers to collect detailed information on housing characteristics and household activities.

Indoor and outdoor radon concentrations were measured using alpha track samplers provided by Tech/Ops Landauer. With the exception of 20 pretest samplers which were exposed for two months, all samplers were exposed for a year. Participants were instructed to place samplers in the living room/main activity room that was occupied for the greatest amount of time, in the master bedroom, and in the basement (if there was one). At the 60 residences visited, the field team checked the deployment of the radon samplers, checked the accuracy of responses in the questionnaires, measured air permeability of soil and radon in soil gas, and collected soil samples and, when appropriate, water samples.

The radon concentrations of 17 two-month samplers retrieved in the pretest ranged from 0.6 pCi/l to 2.9 pCi/l, with a geometric mean of 1.65 pCi/l. The 37 samplers retrieved from the bedrooms after one year varied from 0.2 pCi/l to 1.9 pCi/l with a geometric mean of 0.85 pCi/l, and the 36 samplers retrieved from the living rooms varied from 0.3 pCi/l to 5.9 pCi/l with a geometric mean of 0.93 pCi/l. The average of two-month averages was significantly higher than that of annual averages. The concentrations measured in the bedrooms were not significantly different from those measured in the living rooms. Annual average outdoor concentrations obtained from 10 pretest residences varied from 0.3 pCi/l to 1.0 pCi/l with a geometric mean of 0.55 pCi/l. The ratio of indoor to outdoor concentrations ranged from 0.75 to 4.9 with a median of 1.9.

Survey materials were sent to 360 residences randomly selected from the volunteers for the statewide main survey. The selection procedure was based on zip code zones, and adjusted for the number of registered motor vehicles

at each household. Of the 360 recipients, 332 returned completed questionnaires. A year later, 310 participants sent back at least one of the exposed samplers. The radon concentrations measured in the 308 bedrooms ranged from 0.1 pCi/l to 11 pCi/l with a geometric mean of 0.83 pCi/l. In the 300 living rooms, the concentrations varied from 0.2 pCi/l to 16 pCi/l with a geometric mean of 0.85 pCi/l. When the whole-house value was calculated by averaging the concentrations in the bedroom and living room, the geometric mean was 0.85 pCi/l and the geometric standard deviation was 1.91. The geometric mean of the concentrations in the 27 basements was 2.17 pCi/l, which was significantly higher than that of whole-house concentrations. The geometric mean of the outdoor radon concentrations was 0.42 pCi/l, which was significantly lower than that of indoor concentrations. The ratios of indoor to outdoor concentrations ranged from 0.7 to 22.3 with a median of 1.85.

Thirty-seven Sierra foothill participants returned their completed questionnaires and all of those completed the one year study. The radon concentrations measured in 36 bedrooms ranged from 0.4 pCi/l to 2.5 pCi/l with a geometric mean of 1.16 pCi/l. The concentrations measured in 37 living rooms varied from 0.4 to 16 with a geometric mean of 1.37 pCi/l. After averaging the concentrations in the bedroom and living room, the whole-house values ranged from 0.4 pCi/l to 8.8 pCi/l with a geometric mean of 1.28 pCi/l. The geometric mean of outdoor radon concentrations was 0.66 pCi/l, which was slightly higher than the results of the pretest and the statewide survey. The ratios of indoor to outdoor concentrations ranged from 0.78 to 6 with a median of 1.85.

The estimated fractions of residences in the State of California having radon concentrations exceeding 4 pCi/l and 8 pCi/l are 0.8% and 0.03% respectively. Out of approximately 11 million housing units, the estimated number of residences exceeding 4 pCi/l is 88,000, with 95% confidence limits of 66,000 and 121,000. The expected number of residences exceeding 8 pCi/l is 3,300, with 95% confidence limits of 2,200 and 4,400. This yields an approximate number of California residents exposed to concentrations exceeding 4 and 8 pCi/l of 240,000 and 8,900, respectively.

The best single predictor of indoor radon concentrations found in this study for the (non-randomly chosen) subset of 60 intensively-studied residences was the emanation rate of radon from soil. The Pearson correlation coefficient between the natural logarithm of the emanating radium-226 content of the soil and the natural logarithm of indoor radon concentration was 0.43. Other variables found to be associated with indoor concentrations were geographic region, ventilation, type of substructure, type and age of residence. In addition to the Sierra foothills, Ventura County was identified as an area with elevated radon concentrations. Residences with rarely-opened windows and doors, dwellings with a concrete slab, single-family houses, and new structures were found in general to have higher radon concentrations.