



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY  
WASHINGTON, D.C. 20460

October 9, 1987

SAB-RAC-88-002

OFFICE OF  
THE ADMINISTRATOR

The Honorable Lee M. Thomas  
Administrator  
U. S. Environmental Protection Agency  
401 M Street, S. W.  
Washington, D. C. 20460

Dear Mr. Thomas:

On June 18, 1986, the Office of Radiation Programs asked the Science Advisory Board's Radiation Advisory Committee to review the design of the national radon survey. The Committee accepted the request and formed a Subcommittee, chaired by Dr. Oddvar Nygaard of Case Western Reserve University, to conduct the review.

The Subcommittee met for the first time on September 24, 1986, but did not prepare a report at that time because the Office of Radiation Programs planned substantial revisions to the design presented.

The revised document, Survey Design for the National Radon Survey, which outlined the current plans for the national radon survey, was transmitted to the Committee and Subcommittee April 30, 1987. The Subcommittee met on June 10-11, 1987, in Washington, D. C. to review the document and prepare its report. The Radiation Advisory Committee heard and discussed the Subcommittee's report on June 12, 1987.

Generally, the Subcommittee finds that the document presented a valid approach to designing a national radon survey. The Subcommittee's other major conclusions and recommendations are summarized below:

1. The primary objective of the national radon survey, that of determining the nationwide frequency distribution of radon concentrations in residential structures, is an important one and achievable with adequate precision within the study design. Achievement of secondary objectives, such as regional distribution estimates, is also possible. However, oversampling (disproportionate stratification) must not be employed to satisfy requirements for such regional estimates since oversampling will adversely impact the quality of the national figures. (See discussion under Issue #2 of the report.)

2. A pretest should be conducted to determine the relative advantages of a telephone survey versus face-to-face interviews. Although cost is an obvious and legitimate concern of the Agency, the choice of the interview method for the national radon survey should be chosen primarily on considerations of the quality of the data collected rather than on cost.
3. Data should be also obtained to allow estimates of effective dose equivalent occupancy figures to individuals, which will be of significant value to EPA and other government agencies. The effective dose equivalent provides a better representation of the radon exposure than concentration since this unit of dose can be readily translated in terms of potential health effects to the public.
4. In addition to providing data on indoor radon concentrations, the national radon survey could be a valuable mechanism for investigating correlations between radon and certain variables. The insights into factors affecting radon levels provided by this form of analysis constitute a major contribution of the national radon survey. To realize this contribution, additional data should be collected including: bedrock geology, climate, basement radon levels, housing characteristics and household heating/air conditioning practices. (See discussion under Issue #4 of the report.)
5. The Subcommittee identified areas of concern that the Agency should address or clarify. For example, rental units should be included in the national survey. It is noted that the Superfund Amendments and Reauthorization Act (SARA, P. L. 99-4991) stated that EPA was to include, "structures where people normally live and work, including educational institutions" in the national assessment of radon gas. However, only residential structures were included in the objectives covered in the Office of Radiation Programs' June 18, 1986 memorandum to the Science Advisory Board.

Additional areas of concern are criteria for evaluating the pretest results; identification of homogeneous strata for the sample design; a detailed description of the approach to defining sample size; identification of subgroup populations; minimum sensitivity of radon concentration measurements; and the need for defining how the survey will deal with multiple measurements in a single dwelling unit.

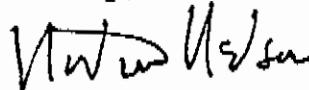
6. The Subcommittee also recommends that the Agency consider how the results of the national survey will be used and how the information derived will be reported. Such planning is not described in the current document and should be added. Explicit

consideration of how the results will be used, prior to initiating the survey will greatly enhance both data collection and analysis and thereby strengthen the quality and defensibility of the study.

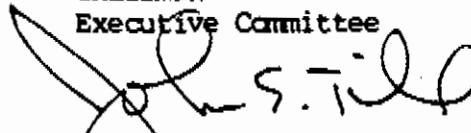
Both the Radiation Advisory Committee and the National Radon Survey Design Subcommittee conclude that this study is important from a national health point of view, and that all efforts must be made to insure that a survey of high quality is conducted. As it develops an actual survey design from the plan presented to the Science Advisory Board, the Agency should bear in mind that an inadequate national radon survey would be a disservice because it might well preempt the execution of any future study of significant scientific value.

The Committee appreciates the opportunity to conduct this review and would be pleased to discuss it further with you. We also acknowledge the cooperation of the Office of Radiation Programs. We request a formal response to the conclusions and recommendations presented in the attached report.

Sincerely,



Norton Nelson  
Chairman  
Executive Committee



John E. Till  
Acting Chairman  
Radiation Advisory Committee

cc: S. Meyers  
T. Yosie

REVIEW OF THE  
OFFICE OF RADIATION PROGRAMS'

NATIONAL RADON SURVEY DESIGN

by the

NATIONAL RADON SURVEY DESIGN SUBCOMMITTEE

RADIATION ADVISORY COMMITTEE

SCIENCE ADVISORY BOARD

U. S. ENVIRONMENTAL PROTECTION AGENCY

October 1987

## NOTICE

This report has been written as a part of the activities of the Science Advisory Board, a public advisory group providing extramural scientific information and advice to the Administrator and other officials of the Environmental Protection Agency. The Board is structured to provide a balanced expert assessment of scientific matters related to problems facing the Agency. This report has not been reviewed for approval by the Agency and, hence, the contents of the report do not necessarily represent the views and policies of the Environmental Protection Agency, nor of other agencies in the Executive Branch of the Federal government, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

U.S. ENVIRONMENTAL PROTECTION AGENCY  
SCIENCE ADVISORY BOARD  
RADIATION ADVISORY COMMITTEE  
NATIONAL RADON SURVEY DESIGN SUBCOMMITTEE

ROSTER

CHAIRMAN

Dr. Oddvar Nygaard, Department of Radiology, Case Western Reserve  
University, Cleveland, Ohio 44106

MEMBERS/CONSULTANTS

Dr. Graham Kalton, Institute for Social Research, Department of  
Biostatistics, University of Michigan, Ann Arbor, Michigan 48106-1248 .

Dr. Leonard LoSciuto, Institute for Survey Research, Temple University,  
Philadelphia, Pennsylvania 19122

Dr. Jaqueline Michel, Research Planning Institute, Post Office Box 328,  
Columbia, South Carolina 29202

Dr. Donald Schutz, Teledyne Isotopes, 50 Van Buren Avenue  
Westwood, New Jersey 07675

Dr. Richard Sextro, Building Ventilation and Indoor Air Quality Program,  
Lawrence Berkeley Laboratory, Building 90, Room 3058, Berkeley,  
California 94720

Executive Secretary

Kathleen W. Conway, Deputy Director, Science Advisory Board  
U.S. Environmental Protection Agency, 401 M Street, S.W.,  
A101-F, Washington, D.C. 20460

Staff Secretary

Dorothy M. Clark, Secretary, Science Advisory Board, U.S. Environmental  
Protection Agency, 401 M Street, S.W., A101-F, Washington, D.C. 20460

TABLE OF CONTENTS

	PAGE
I. Responses to the Issues Raised by ORP	1
A. Issue #1-Objectives	1
B. Issue #2-Stratification	3
C. Issue #3-Samples Size	4
D. Issue #4-Subgroup Populations	6
II. Additional Subcommittee Comments	7
A. Mode of Data Collection	7
B. Relationship Between Indoor Radon Levels and Soils	8
C. Inclusion of Housing Construction Data in the Questionnaire	8
D. Detector Placement	8
E. Questionnaire	8
F. Incentives	9
G. Minimum Radon Concentration Sensitivity	9
H. Derivation of Representative Radon Concentrations	9

## I. RESPONSES TO THE ISSUES RAISED BY ORP

On June 18, 1986 the Office of Radiation Programs referred four issues relating to the national radon survey to the Radiation Advisory Committee of the EPA's Science Advisory Board. The issues as stated by the Agency and the comments of the National Radon Survey Design Subcommittee follow.

### A. ISSUE #1--OBJECTIVES

As stated in ORP's June 18 memorandum, "The primary objective of the national radon survey is to determine the frequency distribution of radon concentrations in residential structures. This will provide data on the average indoor residential radon levels to which the population of the United States is exposed. It will also provide information on the number of homes that exceed various radon levels. Another objective is to investigate relationships between several parameters, including geography, geology, and house construction with indoor radon levels.

"We would like the Committee to review these objectives and determine if they are consistent with the needs of the scientific community, as well as providing recommendations for other objectives that may be appropriate."

#### 1. Primary Objectives

The Subcommittee finds that the primary objective of the national radon survey, to describe the overall frequency distribution of radon concentrations within residential structures in the United States, requires some refinement. For example, whether residential structures refers only to owner-occupied single family homes or also includes rental units, and apartment/condominium complexes, influences the design of the survey and the utility of the results.

The Subcommittee does not believe that the Agency should assume, a priori, that the distribution of radon in dwelling units is a single log-normal distribution. The Agency should empirically determine the nature of the distribution. Although the same size may not be sufficient to evaluate whether observed radon concentrations in the tail belong to a separate distribution than the lower concentration values (as might be the case), the shape of the high-concentration tail should be determined as accurately as possible.

The Subcommittee is very concerned about the bias that may arise if only owner-occupied housing is sampled. Approximately 60% of the dwelling units in the United States fall into the owner-occupied category. The

survey also plans to exclude participants who move during the year. About 20% of the U. S. population move annually. Because of the logistical difficulties of getting owner and occupant permission to sample rental units, the higher moving frequencies in such units, and the subsequent decrease in response rates, the present study plan ignores about half of the housing stock. The restriction of the survey to residences already contrasts with SARA language concerning the workplace and schools.

It is possible that radon levels in rental units may be, because of the higher frequency of multiple-story apartment complexes, less energy-efficient rental units, and other factors associated with multiple-family dwellings. If this is the case, the exclusion of rental units would introduce an unknown bias. By sampling only owner-occupied units, the survey could over-estimate indoor radon levels.

If it is not possible, for legal or other reasons, to collect indoor radon concentration measurements from rental units and units from which a family has moved, as much data on these units (e.g., questionnaires) should be collected to permit comparison with the dwelling units for which EPA has measurements.

## 2. Secondary Objectives

Two secondary objectives for the study were subsequently reiterated by ORP in the June 10, 1987 briefing package, National Radon Survey. They were: (1) to "investigate whether building characteristics affect the distribution of radon levels," and (2) to "investigate whether, on a broad regional basis, the distribution is affected by geological and soil structure features." ORP noted that the secondary objectives would be "pursued to the extent that available resources make the overall sample size large enough to support separate estimates for these reporting groups."

Although both secondary objectives are valid, the second does not appear to be feasible within the limits of the present study design. If the country were divided into sufficiently homogenous regions, there would be so many and some would be so small that, for the majority of regions, it would be impossible to obtain regional estimates of adequate precision with the kind of sample size that is envisioned.

## 3. A New Secondary Objective--Information on Occupancy Patterns

The survey should attempt to address exposure to individuals. Although the study is not optimally designed for exposure assessment, the opportunities to learn a great deal from very little extra work at low marginal cost are great. For example, information could be collected via the questionnaire on the number and ages of persons,

and the approximate occupancy patterns of the various rooms in the house for each person. There may be important differences in room and floor use among regions and housing types. These occupancy data can be used, along with the radon data, to provide more realistic exposure estimates.

B. ISSUE #2-STRATIFICATION

As stated in ORP's June 18, 1986 memorandum, "Our present plan calls for the use of stratification based upon geologic characteristics, because we believe this is the parameter most directly relevant to indoor radon concentrations. Ten geologic regions have been defined for stratification of the sample used for the national radon survey.

"We request that the Committee: (1) evaluate the present plans for stratification by geologic regions and make recommendations for stratification based on other parameters, if appropriate, and (2) recommend whether minimum precision requirements should be established for each stratum.

"Two main purposes of stratification have been identified for the national radon survey:

- (1) To increase the level of precision of national estimates.
- (2) To permit estimates of adequate precision to be obtained for specific strata."

For the first purpose, and assuming no cost difference in data collection for different strata, the optimum allocation of the sample across the strata is achieved by setting the sampling fraction in a stratum proportional to the standard deviation of the variable of interest in that stratum. Often the standard deviation is approximately constant across the strata, in which case the optimum allocation is obtained by use of the same sampling fraction in each stratum. This proportional allocation produces a sample with the same distribution across the strata as the population.

For the second purpose, the sample fractions in small strata of analytic interest might be increased to make the sample sizes in those strata large enough to produce strata estimates of adequate precision. However, such a disproportionate allocation means that, for the same overall sample size, the national estimates will be less precise than would be the case with a proportionate allocation. The loss of precision can become substantial when a sizeable variation in sampling fractions occurs.

The Subcommittee endorses the plan to include geographical and other variables (such as soil and climate, but not housing structure) in the stratification for the national radon survey. However, it does not consider that separate estimates for individual regions are of sufficient importance to warrant the use of a disproportionate allocation to insure adequate sample sizes in the smaller regions. Rather, it recommends the use of a proportionate, or at least an approximately proportionate, allocation. Although a proportional allocation will not provide estimates of adequate precision for the smaller strata, it will enable separate estimates to be made for larger strata and for groupings of strata.

The gains in precision of national estimates from the use of proportionate stratification depend on the way in which the strata are formed. The greater the homogeneity of the survey variables within strata, or equivalently the greater the heterogeneity of the variables among strata, the greater the gains in precision. Thus, the aim is to choose stratification factors that divide the population into strata, each of which is homogeneous with respect to the survey variables.

While the eight regions delineated on the basis of generalized physiographic, hydrologic, and geologic features as presented in the proposed national radon survey design have some validity with regard to grouping homogeneous features, they actually encompass many diverse geologic environments. These diverse environments could be expected to produce radon in both high and low concentrations in soil gas. For the purpose of sample design, the Subcommittee recommends that these regions should be further subdivided to create smaller, more homogeneous strata. This would improve the precision of the national survey with little additional cost. This subdivision could involve creating smaller strata that are more homogeneous with respect to geology, soils and climate. Further stratification in the North-South and East-West directions would provide control with regard to cold-hot, wet-dry conditions.

### C. ISSUE #3-SAMPLE SIZE

As stated in ORP's June 18, 1986 memorandum, "The sample size for the national distribution is directly related to two questions. First, the degree of accuracy with which we want to define the national distribution, and second, whether there are subgroups for which separate estimation capabilities are needed. The sample size will depend primarily on the national distribution, on the number and characteristics of subgroup populations for which frequency distributions are desired, and on the level of accuracy needed for the distributions.

"We request that the Committee address the issue of sample size and make recommendations on the sample size appropriate for the survey."

The sample size for the national radon survey must be large enough to provide overall national estimates of adequate precision. The critical estimates are the percentages of dwelling units in the upper tail of the radon level distribution, for instance with radon levels above 4 or above 10 pCi/l. The question of what is an adequate level of precision for such estimates is debatable. If, for example, the sample estimate of the percentage of dwelling units with radon levels above 4 pCi/l is 7%, a 95% confidence interval for the population percentage of 6% to 8% would be acceptable, i.e., a standard error of plus or minus 0.5%. The sample size required to give a standard error of this magnitude depends on the sample design employed.

Although the Subcommittee believes it would be inappropriate for it to calculate the requisite sample size for the Agency, and in any case lacks the information with which to do so, the following comparison illustrates the impact design may have on sample size. For illustrative purposes, suppose that for an unclustered telephone sample design, a sample size of about 2500 might suffice. A clustered face-to-face interview survey design would require a larger sample size (perhaps 4000 dwelling units). The actual difference in sample size depends on how much cluster there is. Clustering of face-to-face interviews results from the practical and economic need to make good use of the interviewer's time by selecting dwelling units in groups ("clusters") that can be interviewed efficiently.

Another issue in the determination of sample size is the need to provide subgroup estimates of reasonable precision. This issue is often the driving force in determining sample size. It would be desirable to expand the sample size above the minimum for national estimates in order to enable subgroup estimates of adequate precision to be produced, and to enable useful comparisons of subgroup estimates to be made.

Under issue #4 below, the Office of Radiation Programs states its intention to develop separate estimates for single versus multiple family houses. The Subcommittee, as noted above, believes that it is also necessary to look at rental units. The need to address more than owner occupied single family houses in a national survey is important and should be taken into account in the sample size determination. Whether the sample size will be adequate for this task will depend on the proportion of such houses in the population. In determining final sample size, consideration should be given to whether the number of multiple family houses will be adequate to provide separate estimates of useful precision.

Provided that the sample size is adequate, the Subcommittee believes that the survey will be a valuable source for investigating the correlates of radon. Thus, for instance, the survey data can be analyzed to examine the relationship between radon level and soil types, housing characteristics, housing insulation, and household practices in heating and air conditioning. The insights into factors affecting radon levels provided by this form of analysis constitute a major potential contribution of the survey.

The Subcommittee agrees that an achieved sample of 2500 dwelling units is the minimum needed to accomplish the primary objective of the study. This size does not include any safety factors to allow for the uncertainties in design factors and sources of error. It will allow some of the subgroup analyses that might be of interest. For further subgroup analysis, which is an important part of the study, the sample size should be increased.

The Subcommittee recommends that the assumptions and calculations regarding determination of sample size be presented in a more straightforward and logical manner. If possible, this should be summarized in a table or figure.

#### D. ISSUE #4-SUBGROUP POPULATIONS

As stated in ORP's June 18, 1986 memorandum, "The subgroup populations for which separate frequency distribution estimates are desired influence the design in one of two ways. If a specified precision is needed for the subgroup's estimate, then the overall sample size for the survey may be increased. If a subgroup is of secondary interest, pertinent questions can be included in the questionnaire but the sample size will not be changed to guarantee precision for that subgroup estimate. We currently plan to establish specific precision requirements only for the subgroups of the geologic regions and the single versus multiple family houses.

"We request recommendations as to the subgroups that the Committee believes to be of interest. In addition, we would like the Committee to distinguish those subgroups that are of sufficient importance that separate estimation capability be insured (via specified minimum precision requirements.)"

The Subcommittee strongly believes that when the study is complete, the Agency should be able to analyze the data for two factors at once. For example, comparisons of radon levels in dwelling units with basements and selected soil types by geographic regions would be of great interest.

The factors, or subgroups of greatest interest are:

1. soil-type characteristics
2. outdoor temperature
3. rainfall
4. bedrock geology
5. substructure type
6. heating and cooling systems (e.g., forced air vs. other types)
7. construction techniques/materials (e.g., poured vs. block walls)

## II. ADDITIONAL SUBCOMMITTEE COMMENTS

### A. MODE OF DATA COLLECTION

One of the most critical aspects of the study is the mode of data collection. The ORP document extensively discusses the relative merits of face-to-face and telephone data collection, and proposes a pretest to determine which approach would be the most cost-effective way of collecting data of the highest quality, but no criteria were presented for the evaluation of the pretest and for making a final selection.

The Subcommittee is concerned that this decision not be dictated by cost, because the major issue here is data quality, especially with regard to the accuracy of the information collected on the questionnaire, proper placement of detectors in the dwelling units, recovery rate of exposed detectors, and overall survey response rate.

Nor should the survey design be overly driven by the higher geographical spread obtained by the use of telephones. The increased overall precision of the results due to the better geographical spread may be offset by the increased quality in data obtained with the questionnaire by the face-to-face method.

The Subcommittee agrees with ORP that a pretest should be conducted to select the preferable data collection method, and to refine the survey instrument. In addition, the Subcommittee recommends that ORP review the survey conducted by the State of New Jersey to help evaluate the face-to-face approach. The recently completed New Jersey survey consisted of a sample of dwelling units. The Office of Radiation Programs might find it useful to discuss the New Jersey survey with the investigators, especially the face-to-face interviews, to determine what lessons were learned that could be applied to the conduct of the national radon survey.

B. RELATIONSHIP BETWEEN INDOOR RADON LEVELS AND SOILS

Based on preliminary results of research presented at the Subcommittee's September 24, 1986 meeting by the U.S. Geological Survey it appears that, in considering factors which influence indoor radon concentration levels, soil characteristics are as important as housing construction. Information on soil type should be included in the survey data collection. During the pretest, the feasibility of collecting soil type data should be evaluated. Soil information is mapped on detailed aerial photographs published for each county by the Soil Conservation Service. Soil type is probably more important than geological substrata as a factor controlling indoor radon levels.

C. INCLUSION OF HOUSING CONSTRUCTION DATA IN THE QUESTIONNAIRE

The Subcommittee believes that the housing construction items in the proposed questionnaire are very important and should definitely be included. One of the most important goals of the EPA radon strategy is to collect information on the factors that contribute to elevated indoor radon levels. Housing construction is considered as important as soil characteristics. Statistical analysis of the survey data can be used to attempt to assess the relative importance of the various factors on a regional basis.

D. DETECTOR PLACEMENT

The current ORP plan is to place the detector for a single-level dwelling unit in the master bedroom. The Subcommittee recommends that the detector be placed in the common living space rather than the master bedroom to conform with current EPA guidelines. This placement will also provide a common basis for comparison among the various dwelling unit types. In addition, in all housing units with basements, a detector should also be placed in the basement (regardless of whether it is used as a living space) so that results of this study may be more easily compared with other studies of indoor radon concentration. Also, such measurements will permit correlation of radon concentration in basements with concentration on upper floors.

E. QUESTIONNAIRE

ORP has revised the questionnaire since its initial submission to the Subcommittee, and its plans additional revision before it is administered. The Subcommittee hopes that it will be comprehensible to the respondents and that all the proper topics (such as household composition) will be included in the final questionnaire.

F. INCENTIVES

A good response rate contributes to a sound survey, and the Agency is considering whether incentives might enhance that response rate. Some Subcommittee members questioned whether the proposed \$5 incentive would be effective. The experience of New Jersey, which used a \$5 incentive, and of the Bureau of the Census, which gives credit card calculators as an incentive, might be informative. It is possible that people may participate simply to obtain the survey results--the radon measurements of their homes (for which they might otherwise pay \$50).

G. MINIMUM RADON CONCENTRATION SENSITIVITY

In order to determine the shape of the distribution accurately, the minimum sensitivity will have to be better than 0.5 pCi/l and, if possible, closer to 0.1 pCi/l. The documentation provided the Subcommittee does not address this point.

H. DERIVATION OF REPRESENTATIVE RADON CONCENTRATIONS

In the national radon survey, as currently designed, some dwelling units may be characterized by a single radon measurement. In other dwelling units, more than one measurement may be made. Such multiple measurements are a bonus rather than a problem because they give the Agency flexibility in its analysis. While the data can, and should be, analyzed in a variety of ways, a common basis for summarizing data from each dwelling unit needs to be specified so that comparisons can be made within and among the dwelling units. The living space concentration, measured in each dwelling unit, represents the common data point in all sampled dwelling units and might be used for such comparison. However, for dwelling units with multiple measures, a scheme for weighting individual data might be developed to yield a representative radon concentration to be used in a national radon distribution.