LOCAL RADON RESEARCH: MEANINGFUL AND COST EFFECTIVE

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ABSTRACT

The Columbus Ohio Health Department has developed a radon survey format that can be implemented by local jurisdictions with limited financial and personnel resources. Through coordination of resources and expertise of local, state, and federal agencies, as well as, private business, media, and universiti s, and inexpensive and informative study can be conducted. The format provides a menu of techniques including air sampling utilizing both a volunteer group deploying short-term detectors and a randomly selected group deploying long-term detectors in addition to construction material, private water supply, and soil gas testing. Established procedures are strictly observed to preserve statistical significance. By gridding the investigation area, date is more site specific than zip code data and allows a correlation with local geology, yet retains participant confidentiality. Through careful utilization of resources, a meaningful survey is conducted at a manageable cost.

A need existed for radon information in Columbus, Ohio. Although state agencies employed personnel competent in radiation issues, little research was being conducted to determine radon levels in most of the state's major metropolitan areas. Therefore, it became necessary for Columbus to develop a workable and cost effective research format to adequately characterize the frequency and distribution of elevated indoor radon levels in Columbus and Franklin County, Ohio.

The survey format is designed to achieve eight goals: 1). Increase the community awareness of radon, 2). approximate the frequency of elevated radon levels in Columbus, 3). identify "Hot Spots" or areas of high concentrations of elevated radon levels, 4). estimate levels of radon exposure, 5). determine the contribution of radon sources, 6). quantify variations in source concentrations, and 7). correlate radon data with geological data.

Development of a survey design to achieve the seven goals has resulted in a flexible research strategy that can be implemented at minimal cost, with limited personnel, and deliver reliable information concerning the study area. A menu of study parameters allows the inclusion of only selected parameters while neglecting other parameters not pertinent to a specific location.

The study design includes indoor air sampling by two procedures and two methods: short-term screening measurements taken under a "worst case" scenario and long-term screening measurements taken under normal living conditions and in the room of the home where the family spends most of its time. Source contributions are measured by sampling water supplies, construction materials, an soil gas to establish their emanation potential for indoor air. All data, when possible is correlated with existing geological data. Structural questionnaires and site specific data contribute to the utility of survey data.

PREPARATION

Proper planning will facilitate implementation of the designed study parameters. Foremost in preparation is selection of a project director, designation of a steering committee, and formulation of a community support group. Careful selection of this position and these committees will remove many of the concerns an agency may deal with in a project of this sort.

The project director should be able to dedicate 90% of the working day to the radon project. A project director should become familiar with USEPA, DOE, and NIOSH radon data as well as the BEIR IV report. Access to substantial technical libraries will permit the project director to acquire expertise in the major areas of the project design. In addition to technical documents, the project director should develop a network of experts, aside from the steering committee, who can assist in handling specific technical questions as they arise.

The function of the steering committee is to provide supervision in selection, development and implementation of methods and procedures. The steering committee will also serve as a peer review for survey findings. The steering committee should include for each technical area of the project design at least on member with expertise in that area. Members should be research oriented. Selection of steering committee members recognized by the community will be of value in mustering community support. A strong willingness to participate in committee activities is a necessary ingredient in an effective member.

Community support will be essential to a successful radon survey. Health organizations, the media, and local businesses interested in or engaged in radon testing, consultation or mitigation. The community support group will provide a sound basis for disseminating advertising information about the survey. The support group will also prove valuable in releasing results at the completion of the survey. The support group will not, however, be a formal committee but a loose association of interested persons and organizations.

SELECTION OF STUDY PARAMETERS

A significant number of study parameters require careful consideration. Issues such as study validity and the overall scope of the survey should be introduced at this point in the design formulation a "wish list" of features should be drawn up. Also, a careful inventory of available resources should be detailed.

VOLUNTEER VS. RANDOM SURVEYS

No attempt will be made here to delineate all of the features of volunteer and random surveys. Only broad generalizations will be used to characterize the differences as they relate to radon studies. Volunteer surveys are generally inexpensive and occasionally "free" of agency cost,(1) however the large volume of results are usually skewed and the nature, extent, and cause of error is difficult, if not impossible, to determine. Lack of control over most of the critical steps in a volunteer survey can be frustrating for the researcher. Random surveys, while reducing the error introduced by volunteer surveys, carries varying degrees of reliability subject to the random selection design and procedures. Although a great degree of control is exercised over the critical steps, maintaining the control is time consuming and more expensive than a volunteer survey.

QUESTIONNAIRE

A questionnaire can be designed to investigate structural features, local geologic conditions, or any information the researcher would like to examine in relationship with radon levels. A wide variety of questionnaires have been used in previous surveys.(2) It is effective to use an existing questionnaire since some information on their effectiveness is available. A composite of existing questionnaires can also be effective.

SITE SPECIFIC INFORMATION

Analysis of information can be conducted in a variety of ways. Frequently, zip code is as site specific as information is available. Zip code data may not be satisfactory for correlation with local geology or local construction characteristics. Gridding the survey area into one half mile square (160 acres) and plotting the data using a system of coordinates can permit significant site specificity while maintaining participant confidentiality. A substantial amount of personnel time can be recovered by having the participant obtain the site coordinated rather than having an employee determine all site coordinates.

DATA CAPABILITIES

An inventory of data management capabilities will begin to place restrictions on the length of the questionnaire. Estimate the magnitude of community response, particularly if a volunteer format is selected, to determine the adequacy of a data management system. The management system should be as flexible as possible to accommodate multivariable analysis of data.

PERSONNEL RESOURCES

In addition to existing staff, volunteers can be recrui ed from a number of sources. Local colleges and universities can provide a pool of volunteers who will assist with a variety of duties in order to satisfy course requirements. Interested employees of other agencies as well as qualified members of the community can fill vacancies left by a deficiency of funds. Existing employees have been known to volunteer time toward interesting and worthwhile pursuits.

INDOOR AIR SAMPLING

The focal point of most radon surveys, particularly the initial radon survey in community is to characterize the levels of radon gas in residential buildings. In order to evaluate the health risk associated with radon exposure, it is necessary to measure radon levels. The US EPA has established a format for screening residences to identify structures with elevated radon levels.(3) Two methods can be employed to obtain residential data: Volunteer or random selection.

When the volunteer and random section methods are both used in parallel surveys, one method may be used as a quality check against the other. The large volume of somewhat skewed data normally associated with volunteer surveys can be correlated with more reliable random selection data to expand the researchers ability to interpret the findings.

Another significant aspect of residential radon testing is the variation of short-term and long-term tests. It is recognized that the radon level in a structure varies form season to season, month to month, day to day, and hour to hour. Arguments have been presented suggesting the longer the test period, the more representative of a season is the test.(4) Considering these aspects, the survey design presented here will consist of a short-term volunteer screening method and a long-term random selection screening method, employing follow-up procedures, conducted concurrently.

SHORT-TERM VOLUNTEER SURVEY

Frequently, a short-term volunteer survey is conducted by providing detectors at a reduced cost while a television or other media news department vigorously promotes the survey. A large amount of data is collected in a short period of time at little or no expense to the researcher.

A short-term volunteer survey consists primarily of the following elements: 1) detector selection, 2) vendor and laboratory selection, 3) media selection, 4) detector distribution, 5) management of funds, 6) questionnaire management, 7) site-specific information, 8) data management, and 9) quality control. Each of these elements must be addressed before the volunteer survey can be initiated.

Selection of a detector is the first step. Charcoal canister, alpha track,(5) and electret(6) detection devices are appropriate for short-term volunteer sampling. Electrets will be cumbersome to use and, depending on the damage the shells will incur, could prove expensive. Alpha track measurements are convenient to handle, simple for the volunteer to use, but are expensive because a number of large volunteer surveys have been conducted using charcoal detectors, they are recommended for volunteer surveys.

Selection of the detector vendor will necessarily include a variety of considerations. Experience with volunteer surveys of this type is an important qualification. The volume of response to the survey will create unique problems for the laboratory analyzing the detectors and a researcher will be at an advantage to avoid association with these problems. Another obvious qualification is the capacity of the laboratory to promptly analyze the detectors. Since most radon laboratories can expand the detection apparatus by adding modules, it is more important to consider the number and qualifications of the employees, rather than the quantity of detection equipment. Data management capability is another qualification a prospective vendor must demonstrate. If a laboratory meets these qualifications and expresses the willingness to work closely with the researcher, the laboratory should receive every consideration. Lastly, the cost of the detector and analysis to the volunteer should be considered from these criteria a/laboratory can be selected.

A short-term radon measurement is usually conducted using a "worst case" scenario in which the test is conducted in the lowest livable area of the home and the test area is kept closed through the duration of the measurement. When conducted during the heating season, the measurement will represent the highest radon levels a structure will attain. This sampling scenario is designed to determine the highest radon level within the tested structure and does not necessarily relate to occupant exposure.

Media coverage will play an active role in the survey by communicating the intent of the survey, the availability of detectors, and generally raising community awareness of radon to generate interest in participation. It is necessary to select one member of a media to act as a "sponsor". While it is not necessary to include media on the project steering committee, it is necessary to keep them informed of all aspects of the survey once they have initiated coverage. Whether print, television or radio is selected, the researcher must educate the reporters presenting radon data if responsible reporting is decided.

Detector distribution can be achieved by two avenues. An established retail outlet, such as a grocery store or hardware store is selected as distributor. A display, provided by the vendor, is placed in the store and identified in a way that distinguishes the survey detectors from other detectors sold by the retail outlet. Volunteers purchase the detector as they would other merchandise. Distribution at a regional shopping center or similar facility is another ethod of distribution. With a regional distribution format a third party is engaged to the method of distribution will dictate the management of funds. When detectors are distributed through a retail outlet a wholesaler retailer relationship is established between the vendor and the distributor. When a regional distribution format is employed, the third party handling distribution collects the detector and analysis fee, accounts for unsold detectors along with sale proceeds.

Questionnaire distribution is facilitated by effective preparation. Questionnaires are included in the detector packet with the detector number preprinted for identification. When the detector is purchased, the volunteer completes the questionnaire and encloses it when the detector is sent for analysis. The laboratory collects the detectors during analysis and the researcher then obtains the questionnaires from the laboratory.

Site specific information can be obtained by requiring volunteers to identify the coordinates within which their residence lies. The coordinates are then recorded on the questionnaire and replaced in the envelope. Another method of obtaining site specific data is to obtain the addresses of the volunteers from the laboratory and having personnel obtain the coordinates by plotting each address on a map of the survey area, the latter is extremely time consuming.

A review of data management capabilities is prudent. Confirm that the data management system can accommodate the volume of data collected. Reexamine the ability of data manipulation, especially the ability to manipulate the data when the estimated amount of data is entered.

Quality control can be approximated by submitting a number of duplicates, blanks, and splits to the laboratory. However, this proves to be a quality control on the laboratory rather than reflecting the reliability of the survey data. Since volunteers control the handling of the detector during the test, the error introduced by mishandling renders laboratory error of lesser consequence. If another quality check such as a concurrent long-term survey or other existing research is available, quality control on the volunteer survey seems frivolous.

LONG TERM RANDOM SELECTION SURVEY

In general, a long term random survey is accomplished by selecting a sample group from a list of randomly generated telephone numbers. Long term detectors are distributed to participants usually at no cost to their participant, along with a questionnaire. The detector is deployed for the desired duration and returned to the researcher with the completed questionnaire.

A long term random survey consists of the following elements: 1) random selection of participants, 2) detector selection, 3) detector location 4) detector distribution, 5) vendor and laboratory selection, 6) questionnaire management, 7) site specific information, 8) data management, and 9) quality control. Each of these elements must be addressed before beginning the survey.

Random selection of participants can be tedious and, consequently expensive. Many methods are available to generate a list of random telephone numbers with adequate geographic representation of the study area. An acceptable list can be obtained from several sources including universities and private companies. Small batches of telephone numbers should be segregated and an exhaustive attempt should be made to contact each telephone and the participation of each qualified telephone should be stressed to minimize the nameless bias of a high ratio of non-participation.

Detector selection will be limited to alpha track and electret measurement methods. The method of detector distribution should be established before a detector is selected.

A long-term radon measurement will diminish the significance of short-term fluctuations due to a longer measurement period. When the detector is placed in the room of the structure where the occupants spend most of their time, the radon levels obtained become more representative of occupant exposure. It is necessary to remember that the readings obtained are screening measurements and not annual averages.

Detectors may be distributed through the mail or through placement by personnel. When detectors are sent through the mail, alpha track detectors may prove more efficient because of the cost savings of mailing smaller detector. However, if personnel are to place the detectors electrets may be as efficient as alpha track detectors if the cost of the shell is not prohibitive. Detector placement by personnel is preferable to mail distribution because of the error introduced by participant handling of the detector with mail distribution.

Vendor selection for long term random surveys is facilitated by the limited number providers. Because these vendors have experience with surveys and because the volume of detectors is small in comparison with short term volunteer surveys, the researcher may find that vendor selection is based more on cost and support services rendered by the vendor than on other qualifications of a laboratory.

A questionnaire is delivered to the participant at the time the detector is distributed. A self addressed stamped envelope is included with the questionnaire and the participant is encouraged to return the completed questionnaire immediately. A check list of participants will allow the researcher to remind those who are tardy in the return of the questionnaire.

Data management should be straightforward. Most data systems will be able to handle the volume of data generated. A personal computer should provide an adequate capacity for data storage and manipulation since the volume of detectors in the long-term random segment will be substantially smaller than the short-term volunteer segment.

Quality control is an essential element of a random survey. Since error introduced from many sources, particularly error from participant handling of detectors if detectors are delivered by personnel, is removed it becomes a simpler task to identify error introduced by personnel handling and other error factors. At least ten percent of the random sample should be used for quality control. Duplicates, blanks, splits, and standards should be deployed in manner th t will allow the identification of error introduced from every source the researcher suspects can skew results.

SOURCE SAMPLING

Source sampling is not always a fruitful endeavor. Of the three sources for indoor radon: soil gas, water supply, and construction materials; the former is acknowledged to be the only significant source in most areas of this country.(7) Before a statement of this nature can be made with any degree of reliability in describing a specific area, testing must be conducted to verify the conclusion. A local agency should closely examine its commitment to radon investigation and reexamine financial resources before embarking on source sampling. Although correlations between elevated source and elevated indoor radon levels have been demonstrated, applying these principles to a community may be more expensive than productive.

SOIL GAS SAMPLING

Soil gas sampling is simply described as extracting gas samples from the soil to determine the radon content of the soil gas. Soil gas sampling consists of the following elements: 1). identification of testing routes, 2). site specific information, 3). field method, 4). laboratory method, 5). equipment design, and 6). quality control. The methods below are cost effective while delivering usable results. Other methods may prove less cumbersome and provide more precise information.

The first step in identifying soil gas routes is to examine the geologic characteristics of the study area. Testing is conducted along lines perpendicular to geologic features in order to detect variations in soil gas concentrations of radon due to changes in geologic feature. Another significant factor is accessibility of the sampling lines. Direct access of sampling sites by roads facilitates an accelerated sampling schedule. Permission of owner, when present is necessary.

Site specific information can be obtained by plotting site data on a grid of one quarter mile square (40 acre). This grid can be adapted from the grid used in air sampling by drawing a line between each existing line on the map. For a broad survey of the sample area it is not necessary to record the site location specifically. If an anomaly is detected, the immediate area of the site grid will be investigated in greater detail.

At each sample site and equilateral triangle with sides of one meter in length is formed by driving soil gas probes to a depth of 3/4 meter.

The cavity of each probe is evacuated and a 30cc sample of soil gas is extracted from each probe. Samples are identified by sample number, date, time, grid coordinates, probe depth, and operator. Samples are capped and transported to the laboratory for analysis.

Laboratory procedure is to filter the grid sample into an evacuated Lucas cell and counted for two minutes. The readings are adjusted to the time the sample was drawn Samples must be held for at least 5 minutes to allow substantial decay of thoron, another alpha emiting component of soil gas..

The soil probe is a steel tube with 5/16" outside diameter and 3/32 inside diameter. Five holes 1/16" in diameter are drilled 3/4 of 1 meter from the lowest driving block. Each probe is measured and the capacity is calculated to determine the amount of evacuation necessary to expel surface air before drawing a soil gas sample.

Quality control is achieved by introducing at least 10 percent duplicates, splits, and blanks into the laboratory analysis stream. In addition to quality control factors, some allowance should be made for the diurnal effect exhibited by radon in soil gas as well as annual fluctuation.(8)

WATER SUPPLY SAMPLING

Water supply sampling includes selecting a number of wells geographically distributed around the study are for the purpose of determining the potential contribution of water supplies to indoor radon levels.

It has been determined that radon in public groundwater supplies do not present a significant public health threat.(9) Surface waters have not exhibited radon concentration high enough to contribute to indoor radon levels.(10) Procedures necessary to purify groundwater to a potable state and the time and handling methods used to deliver water to the consumer efficiently strips radon from the water supply. Private water supplies, however have demonstrated elevated radon levels, particularly in the northeast.(11)

An effective water supply testing survey will include the following elements: 1). site selection, 2). laboratory selection, 3). site specific information, and 4). quality control.

Wells are included in the private water supply sample based on the water-bearing geologic formation in which the well lies. An examination of local, county, or state records permits the researcher to inspect the well diggers log to determine the geologic formation of individual wells. Descriptions of the location of wells, particularly with older wells, may not be sufficient to find the well and another well must be selected to replace it in the survey. Other important factors are the accessibility of the well and permission of the owner.

A laboratory for radon in water analysis is selected by scrutinizing the method employed by the laboratory, the reputation and reliability of the laboratory, and the cost of the test. The field procedures of any laboratory selected should not require skills unavailable to the researcher and the procedures should be easily implemented. A reliable laboratory that has demonstrated its ability to analyze radon in water should be selected. The cost of the tests should not be so high as to preclude an adequate number of samples.

Site specificity is achieved by employing the grid system previously discussed. If participant confidentiality is not a concern of the survey, longitude and latitude may be used for site location since this information is frequently available from the well diggers log.

By including an appropriate number of blanks, duplicates and splits, quality can be controlled. In addition, as wells are selected more than one well should be selected from each of the water-bearing formations included in the survey.

CONSTRUCTION MATERIAL SAMPLING

Construction material sampling is a process by which various construction materials are examined to determine its radon emanation capacity. Specific materials examined include cement, a variety of aggregate, brick, and stone.(12) The contribution to indoor radon levels is determined from the surface area and the emanation capacity of construction material in individual homes. Generally only broad conclusions cannot be drawn from construction material testing.

A construction material sampling survey consists of the following elements: 1). materials selection, 2). site selection, 3). method and laboratory selection, and 4). quality control. Dealing with these elements will prepare the researcher for the survey.

A list of frequently used building materials can be obtained by contracting local building trade organizations. Building material manufacturers and users have cooperated to supply materials for testing. Origin information has also been provided for aggregate to allow the researcher to extrapolate findings to other customers of an aggregate provider.

Sampling sites are selected to represent the geographic distribution of construction materials across the study area. In some study areas sampling may prove expensive if local providers of construction materials are not available and materials must be obtained from a distant source.

The method of construction material analysis described herein is expensive and an examination of alternative methods may uncover a more cost effective method. Of particular interest is a method employed by Harrel and Kumar. Emanation capacity is determined by grinding the construction material to increase the surface area and analyzing the material by gamma spectroscopy. A laboratory with an established reputation in gamma spectroscopy should be selected.

Quality control is achieved by introducing duplicates into the sample stream. In addition, quality control procedures are employed by the laboratory performing the gamma spectroscopy.

DATA REPRESENTATION

For visual inspection of the data maps are drawn to represent the findings of each segment of the survey. Using the coordinates previously associated with site specificity short-term air results, long-term air results, soil gas results, water analysis results, and construction material analysis results are plotted on individual mylar maps and overlaid existing maps of geologic features.

COMMUNITY IMPACT

A significant factor, particularly of personnel requirements, during a radon survey that includes a short-term volunteer segment of the type herein described is community response. The researcher is usually deluged with telephone inquiries and correspondence. For the purpose of preparing to accommodate these responses it is useful to segregate inquiries into two groups: initial responses and contingency responses.

Initial responses can easily overwhelm an unprepared agency. It is not uncommon for one or two telephone lines to be tied up continuously for three or four days once media coverage begins. Even a small article in a newspaper may tie up an employee for an entire day with community response. General inquiries are best handled by sending a pamphlet or packet of general radon information. Specific questions must be handled individually and a worker should possess a general knowledge of the health effects of radon and radon mitigation technology. An adequate supply of literature on these topics and a list of agencies, organizations, and experts for referrals will expedite responses.

Contingency plans should include a prepared response for any outcome the findings could present. The research agency should have written contingencies for low, moderate, and elevated radon readings in the overall survey area as well as contingencies for neighborhoods with elevated levels. Plans should be completed before the survey is initiated because time demands during the survey, particularly once data is generated, will preclude planning at that time.

When considering the community impact of a radon survey it is prudent to consider the needs of the business community, government agencies, and the media. Building industries and real estate professionals will be affected by raising community awareness of radon. Other agencies, both within and adjacent to the study area, should receive timely updates of survey progress and findings. The media will perceive a need for regular updates and pacing the release of data may be a solution to untimely media intrusions.

COST ESTIMATES

Cost estimates will not include dollar amounts. Estimates will be broken down into two categories: 1). equipment which will include supplies and laboratory analysis, and 2). personnel resources. Equipment will be described and personnel requirements will be expressed in hours allowing anyone estimating the cost of a similar study can obtain quotes for equipment and apply local employee costs. Whenever possible, personnel requirements will be expressed as hours per function performed to facilitate estimation of surveys of varying magnitude. The cost of the researcher is assumed. Some of the personnel requirement described below can be performed by the researcher and the associated cost removed from the estimate.

The magnetic aspect of short-term volunteers surveys is that the agency expends little or no funds throughout the entirety of the survey. Detectors and their analysis are paid for by the participants and publicity is provided by the media "sponsor". Personnel costs associated with short-term volunteer surveys include provisions for a full-time employee to answer general telephone requests for the period of time that detectors are distributed plus an additional week. Data entry will require from 5 to 10 minutes per response to sort, qualify, and enter radon results and questionnarie data. If an employee is to plot the coordinates for site specific information, an additional minute per response will be required.

Long-term random survey equipment necessary to complete the study includes a list of randomly generated telephone numbers, detectors, and mileage. Randomly generated telephone listings vary widely in cost depending on the extent of qualifications the list has met. Detector cost will vary somewhat with manufacturer, however it is important to include the number of detectors to be used for quality control before estimating cost. The cost of mileage to deliver and retrieve detectors to participant homes is 20 miles per participant based on a 675 square mile survey area with the distribution point centrally located. Cost for other area conformations can be extrapolated from this model. Personnel costs will include 2 hours of telephone personnel time to discover one willing, qualified participant 40 minutes of delivery personnel time to deploy and retrieve detectors and 5 to 10 minutes per response to enter data.

Soil gas sampling will require a soil probe to extract samples, syringes to transport samples, and a monitor to analyze samples. A variety of manufacturers offer systems capable of this procedure and some can eliminate the need for transporting samples. In addition to a choice of systems, lease or purchase arrangements are available to accomodate a flexible funding arragenment. Personnel costs will consist of combined field and laboratory personnel requirements of about 20 minutes per site.

Water supply sampling will necessitate the purchase of test kits and analysis. Many commercial and university laboratories have the capacity to reliabley analyze radon in water. Personnel requirements will include 3 hours per site to select sites and 30 minutes per site to draw samples.

Construction material sampling costs will include laboratory analysis by gamma spectorscopy and is available from private and commercial laboratories, personnel costs will entail about 30 minutes per sample to obtain the sample.

RESULTS

The short-term voluntary survey culminated in 4312 test readings from across Franklin County with a questionnaire accompanying each reading. Approximately 71% of the readings exceeded 4.0 pC./L and 24% exceeded 10.0 pC./L.

The long-term random survey included 120 respondents. Approximately 92% of the readings were above 4.0 pC./L and 43% were above 10.0 pCi/L.

No correlation to increased radon levels was found with age of structure, type of heating unit, or weatherization of structure in either the short-term volunteer survey or the long-term random survey.

The water supply survey of 36 wells, selected by the water bearing geologic features of the well, determined the highest concentration of radon in water to be 1660 pCi/L. which does not represent a significant public health threat.

Soil gas sampling and construction material sampling is not yet complete and will not be discussed.

SUMMARY

The complete survey outline is composed of segments designed to achieve the seven original goals of the survey format. The short-term voluntary segment, through publicity provides by media coverage, will measurably raise community awareness of radon and radon related issues. Data provided from bot the short-term voluntary segment and the long-term random segment will enable the researcher to approximate the frequency of elevated radon levels. Through careful management of the questionnaire, housing characteristics that contribute to elevated radon levels can be identified if, indeed, any housing characteristics contribute to elevated radon levels in the survey area. The short-term volunteer and long-term random segments will serve to identify "hot spots" should any be present. By locating detectors in the main living area in the long-term random segment, levels of radon exposure can be more closely approximated. The source sampling segments will allow confident recommendations for remediation options. By quantifying source contributions and the pattern of variation, possible "hot spots" can be predicted in areas where inadequate indoor radon data is available. Mapping of results will allow identification of any correlations with geologic data. An agency with a database of this nature is prepared to respond to community issues relating to indoor radon levels.

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