Radon Monitoring and Data Collection in the United States
Environmental Public Health Tracking Network

Radon Task Force

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1 Introduction

This white paper was prepared by members of the Radon Task Force of the Environmental Public Health Tracking Program (EPHTP) to investigate the merits (opportunity, cost and value) of developing public health indicators associated with residential exposure to naturally occurring radon gas. The current status of radon monitoring and data collection in the U.S. and the suitability of these data for inclusion in the EPHTN are described. Significant challenges in using the current data and improving the quality and quantity of available radon data are also addressed. Recommendations are provided to resolve issues prior to use of the data. This white paper was intended for use by members of the EPHT Radon Task Force and the greater EPHTP.

1.1 The Radon Task Force

The Radon Task Force was established during 2010 to explore existing datasets on radon and the feasibility of using those data for the CDC/NCEH Environmental Public Health Tracking Program (EPHTP). Environmental public health tracking is the ongoing collection, integration, analysis, and interpretation of data about environmental hazards, exposure to environmental hazards, and health effects potentially related to exposure to environmental hazards. The tracking program has been successful in developing a nationwide environmental public health tracking network (EPHTN) and in developing capacity in environmental health within state and local health departments.

A small workgroup of interested states--Maine, Maryland, Missouri, New Mexico, Oregon, Washington, and Wisconsin--met on a monthly basis to discuss their efforts and progress in determining the availability, quality, and compatibility of residential radon test data. If the data were found usable for the EPHTN, further discussion would define appropriate uses, linkages and data communication strategies.

1.2 EPA Radon State Data Exchange (RSDX)

The Environmental Protection Agency (EPA) formed the Radon State Data Exchange (RSDX) to better coordinate the collection and aggregation of radon data. This partnership effort included federal agencies, states, tribes, and the radon industry. The intent was to create a national database with state-level input to collect radon data so that it could be shared and combined with other data on a national scale allowing for better analyses or other ways to accommodate users' needs. This group was interested in using the EPHTN as a platform to store the database and to display important indicators created from the database to educate and inform the public. An important function of this group was to identify the core data elements that would be collected by a national radon database.

Representatives from both groups came together to determine if the EPHTN could serve as an appropriate platform for the national radon database. Efforts are still underway to secure resources to develop, test, and pilot a database.

2 Background: Radon and Its Characteristics

2.1 What is Radon?

Radon is a naturally occurring radioactive gas that is created as part of the natural radioactive decay chain of uranium. Radon levels vary by location and can accumulate in structures. It can also be found in some natural water sources. Radon is not produced as a commercial product, nor created as a byproduct of a manufacturing process.

Epidemiological studies have shown a causal association between radon exposure and lung cancer development.[1] The EPA states that radon is the second most frequent cause of lung cancer, after cigarette smoking, causing approximately 21,000 lung cancer deaths per year in the United States.[2] It is the number one cause of lung cancer among non-smokers, according to EPA estimates.[2]

2.2 Important Radon Characteristics

[This section adapted from USGS, The Geology of Radon,

http://energy.cr.usgs.gov/radon/georadon/3.html*]*

All rocks contain some uranium, although most contain just a small amount—between 1 and 3 parts per million (ppm) of uranium. In general, the uranium content of a soil will be about the same as the uranium content of the rock from which the soil was derived. The uranium content of soils varies widely depending on local geology.

Because radon is a gas, it has much greater mobility than uranium and radium, which are fixed in the solid matter in rocks and soils. Radon can more easily leave the rocks and soils by escaping into fractures and openings in rocks and into the pore spaces between grains of soil. The ease and efficiency with which radon moves in the pore space or fracture affects how much radon enters a house. If radon is able to move easily in the pore space, then it can travel a great distance before it decays, and it is more likely to collect in high concentrations inside of a building. The method and speed of radon's movement through soils is controlled by the amount of water present in the pore space (the soil moisture content), the percentage of pore space in the soil (the porosity), and the "interconnectedness" of the pore spaces that determines the soil's ability to transmit water and air (called soil permeability). Radon moves more rapidly through permeable soils, such as coarse sand and gravel, than through impermeable soils, such as clays. Fractures in any soil or rock allow radon to move more quickly.

Radon moving through soil pore spaces and rock fractures near the surface of the earth usually escapes into the atmosphere. Where a structure is present, however, soil air often flows toward its foundation for three reasons: (1) differences in air pressure between the soil and the structure, (2) the presence of openings in the structure's foundation, and (3) increases in permeability around the foundation. .

The air pressure in the ground around most structures is often greater than the air pressure inside the structure. Thus, air tends to move from the disturbed zone and gravel bed into the structure through openings in the foundation. All foundations have openings such as cracks, utility entries, seams between foundation materials, and uncovered soil in crawl spaces and basements. Most structures draw less than one percent of their indoor air from the soil; the remainder comes from outdoor air, which is generally quite low in radon. Structures with low indoor air pressure, poorly sealed foundations, and several entry points for soil air, however, may draw as much as 20 percent of their indoor air from the soil. Even if the soil air has only moderate levels of radon, levels inside the structure may be very high.

SOURCE: USGS, *The Geology of Radon,* http://energy.cr.usgs.gov/radon/georadon/3.html

2.3 Key Exposure Pathways

[This section adapted from Agency for Toxic Substances & Disease Registry (CDC), Radon Toxicity,* http://www.atsdr.cdc.gov/csem/csem.asp?csem=8&po=6*]

The average person in the US receives an estimated 625 millirem (mrem)/year dose from ionizing radiation. The largest percentage is from medical radiation (48 percent, 300 mrem), primarily due to the use of computed tomography (CT) scans and nuclear medicine. This is followed by radon (37 percent, 228 mrem), which is the largest source of background radiation. While the dose from radon has remained the same over the years, the percentage that it represents has dropped from 55 percent, based on 1980s data, to 37 percent using 2006 data. Due to the increased use of certain medical procedures, this trend is expected to continue (NCRP 2009). The dose of ionizing radiation from radon comes from soil, water, natural gas, and building materials.

The primary pathway for human exposure to radon is inhalation from soil vapor intrusion into dwellings and buildings. Indoor radon levels can, however, also originate from water usage, outdoor air infiltration, and the presence of building materials containing radium (EPA 2003). The main source of inhalation exposure is radon gas that is released from the soil into an indoor environment and trapped in indoor air. Background levels of radon in outdoor air are generally quite low and represent a target for reducing indoor levels. But radon levels can vary based on location and soil geology. In indoor locations, such as homes, schools, or office buildings, levels of radon and radon progeny are generally higher than are outdoor levels. This is especially true of newer construction that is more energy-efficient. In new construction, indoor radon levels may actually increase, due in part to decreased air entry or exit (i.e., natural ventilation from outdoors) in such energy-efficient homes. Radon releases from groundwater also contribute to exposure. Measurement of radon in water is not within the scope of this white paper.

SOURCE: Agency for Toxic Substances & Disease Registry (CDC), Radon Toxicity, http://www.atsdr.cdc.gov/csem/csem.asp?csem=8&po=6

2.4 Health Impacts

[This section adapted from SOURCES: U.S. EPA, Radon Health Risks, http://www.epa.gov/radon/healthrisks.html and CDC, ATSDR Case Studies in Environmental Medicine: Radon Toxicity, http://www.atsdr.cdc.gov/csem/radon/radon.pdf]

The U.S. EPA has estimated that about 21,000 lung cancer deaths each year in the U.S. are radon-related. As noted above, exposure to radon is the second leading cause of lung cancer after smoking. Radon is a source of ionizing radiation and a proven carcinogen. Lung cancer is the only known effect on human health from exposure to radon in air. Children have higher estimated radiation doses due to the differences in their lung shape and size, and their higher respiration rates compared with adults. Risk of lung cancer in children resulting from exposure to radon may be almost twice as high as the risk to adults exposed to the same amount of radon. If children are also exposed to tobacco smoke, the risk of lung cancer is at least twenty times greater. For smokers, the risk of lung cancer is much greater than for non-smokers due to the synergistic effects of radon and smoking, with the risk for smokers being ten times the risk for nonsmokers or more.

Two studies, a North American study that combined data from seven case-control studies[3] and a European study that combined data from thirteen case-control studies[4] showed evidence of an association between residential radon exposure and lung cancer development. These two studies go a step beyond earlier findings. They support the radon health risks predicted by occupational studies of underground miners who breathed radon for a mean exposure period of 6 years.[5]

The radon health risk is underscored by the fact that in 1988, Congress added Title III on Indoor Radon Abatement to the Toxic Substances Control Act. It codified and funded EPA's then fledgling radon program. Also that year, the Office of the U.S. Surgeon General issued a warning about radon urging Americans to test their homes and to reduce the radon level when necessary (U.S. Surgeon General).

SOURCE: U.S. EPA, *Radon Health Risks,* http://www.epa.gov/radon/healthrisks.html *and CDC, ATSDR Case Studies in Environmental Medicine: Radon Toxicity,* http://www.atsdr.cdc.gov/csem/radon/radon.pdf

3 Key Radon Public Health Interventions

3.1 Public Outreach and Education

Radon programs typically emphasize public outreach and education to encourage testing and mitigation where high levels are found. As discussed below, several methods are used to measure the coverage and effectiveness of outreach and education efforts. These include overall testing and mitigation rates, changes in testing rates (due to specific outreach "pushes"), and testing/mitigation rates estimated via the Behavioral Risk Factor Surveillance System (BRFSS).

3.2 Hazard Assessment

Radon testing should be conducted in any building or basement where its location and characteristics suggest that elevated levels could be found and significant exposures to people are possible. Testing is the only way to determine the radon levels of a structure. There are no immediate symptoms that will alert a person to the presence of radon. It typically takes years of exposure before any health problems can be diagnosed.

Inexpensive test kits can be obtained through state and local radon testing programs or from home improvement retailers. These tests provide detailed instructions and can be easily conducted by the public. Delivery to a laboratory and return of the results is usually completed by mail. Assistance interpreting the testing results and providing follow-up information is available through the test kit manufacturer, the testing laboratory, state and local indoor air quality programs, and certified radon professionals.

Radon concentrations in adjacent buildings, even adjoining ones, can differ by as much as a factor of ten; test results from neighboring properties cannot be relied upon as indicators to the presence or level of radon. These variances can depend upon factors such as the building design, construction practices used, and the surrounding soil composition.

Structures with elevated radon levels have been discovered in every state. The EPA estimates that as many as eight million homes, or one in five, throughout the country have elevated levels of radon. The EPA recommends taking action to reduce radon in buildings that have a radon level at or above 4 picocuries per liter (pCi/L) of air.[6] Radon testing should not be limited to private homes. Testing of day care facilities, schools, long-term care centers, and workplaces is strongly encouraged.

3.3 Radon Mitigation

No known safe level of radon exists; however, the risks from exposure can be greatly reduced by lowering the radon level in the building. Radon mitigation is the process used to reduce radon concentrations in occupied buildings.

Several methods reduce radon in existing buildings. Building design, construction practices used, and site geology are studied by radon professionals to determine the most effective method for each structure. The primary method is known as an active sub-slab depressurization system (ASD). This method utilizes a fan which pulls the radon gas from beneath the structure through a system of vent pipes to exit the building. Some radon reduction systems have been proven to reduce radon levels in existing structures by up to 99 percent.[7]

Radon-resistant construction practices can be highly effective in preventing the entry of radon gas. When installed properly and completely as part of the new construction process, these techniques can help reduce indoor radon levels. These construction techniques do not supersede the need to conduct radon testing. Once ready to be occupied, the structure should be tested. If radon levels are found to exceed 4 pCi/L, then the passive system incorporated into the structural design can be quickly and easily activated by a certified mitigator.

3.4 Assurance of Testing and Mitigation – Radon Control Programs

Assurance of radon testing and mitigation services is a key objective of state radon control programs supported by the U.S. EPA. State radon contacts can be found on EPA's web page at: http://www.epa.gov/radon/whereyoulive.html.

Maine is the only state on the Environmental Public Health Tracking Network (EPHTN) Radon Task Force (Task Force) that has a radon assurance program, and is cited here as an example of how such a program is administered.

Maine law requires that anyone providing any radon services (sampling, analysis, mitigating, advising) in the state or for the residents of the state must be registered with the Maine Radon Control Program. Exceptions to this law include:

1) Testing or mitigation of a structure that is not for sale, done by a homeowner or resident;
2) Post-mitigation testing done by the homeowner or resident;
3) Installation of radon preventive features in new construction when adhering to Maine radon new construction code requirements.

To become a registered radon service provider in Maine involves the completion of three steps:

1) Successfully complete an approved radon training course;
2) Pass an approved national certification exam; and
3) Register with the Radon Section.

All radon service providers are required to maintain their registration and renew yearly, and all results of tests conducted in Maine must be reported to the Maine Radon Control Program. Further, all those registering with the Radon Program are required to submit a Quality Assurance Plan for radon sample collection and/or sample analysis. The plan is required so that radon testers and labs can ensure accurate and precise radon results that can be defended.

4 Radon Data Sources

4.1 Radon Test Data

Task Force members have collected a variety of radon-related data over the years. Using a data inventory approach, the Task Force found that numerous states had data that varied both in completeness and coverage. In contrast to the wide variations in data collected, task force members were able to identify a common core of desired radon data needed to estimate proposed radon mitigation measures and provide information for radon program management. These data are described in greater detail below.

To gain a better understanding of states' current levels for data collection, task force members completed a "Starting Matrix," which outlines data collection assets and practices in their own states (Appendix C). An example of the specific data collected by a state can be found in Appendix A: Maine Case Study.

4.2 Key Data Gaps

While the terminology varied widely for data elements collected by states, where they overlapped, there was broad consistency in the actual data elements themselves. The more serious challenges to the estimation of radon measures from these data were gaps in both data availability (coverage) and internal gaps in data resolution. The gaps in data coverage result from differences in states' allocation of resources for radon testing and different requirements for radon test reporting. A significant number of states currently have outdated or incomplete databases. The two types of internal gaps in data resolution are:

- **Lack of address level data.** In these cases only coarser geographic (e.g. zip codes) level data are available for the individual test results. This gap precludes de-duplication of tests conducted on the same structure. Inclusion of re-tests therefore biases the testing rate high, and makes the data less useful for map development and measure estimation.
- **Lack of pre/post mitigation testing indicator.** It appears that only about half of the testing laboratories record whether a test is being conducted pre- or post-mitigation. When this indicator is absent, the data will be biased toward a high testing rate because re-tests on mitigated facilities are double-counted. In addition, estimates of radon incidence above EPA action levels will be biased towards low values, because re-tests of mitigated (and therefore lower radon level) structures are included. Lack of this flag makes it impossible to calculate mitigation rates from the test data.

Although several Task Force member states had access to large numbers of individual test results, issues with these gaps prevented their use for most purposes. For example, as illustrated by the Maine case study (Appendix A), the program had access to over 190,000 test results, but the lack of individual address data made this data less useful for program management and measure calculation. Until recently (after data coverage improvements), Maine's primary source of data has been the BRFSS (described below).

4.3 Behavioral Risk Factor Surveillance System (BRFSS)

BRFSS is the longest ongoing health survey in the nation.[8] In coordination with the Centers for Disease Control and Prevention (CDC), states participate in implementing the survey and data collection. Colorado, Maine, and New Hampshire, three states participating in the Radon Task Force, collect BRFSS data using optional state-added questions regarding radon awareness, testing, and mitigation. Although similar, the questions from individual states are not identical and may cause a degree of uncertainty when comparing the data across states. It was recommended by the Task Force that some effort be put into identifying core information sought and developing consistent wording for regularly asked questions. Currently, states ask the radon questions at varying intervals. The states that participate in the BRFSS and that are part of the Task Force along with information on the questions asked can be found in Appendix B - EPHT Radon Task Force Grantee State BRFSS Collection Practices. From 2000-2004, 10 states (IA, ID, MO, NE, NH, NY, TN, VT, WV, WY) and the District of Columbia (DC) collected radon information through BRFSS.[9] The Task Force did not identify any other surveys with wide availability.

The Task Force discussed how a federal radon module for the BRFSS would be a powerful, national-level data source; exploration of this option is advised in the recommendations section below.

5 Considering Radon Nationally Consistent Data Measures: Candidate Measures and Challenges

5.1 Overview of Candidate Measures and Challenges

Given the coverage and internal gaps and incompatibilities identified above, it is premature to consider implementation of Nationally Consistent Data Measures (NCDMs) for radon at this time. There simply would not be enough states able to provide the information, especially historical estimates. However, analysis by the Task Force and by members of EPA's RSDX suggests that once additional data become available a simple set of Radon NCDMs could be established. (The role of a national database in supporting these NCDMs is discussed below). The table below provides an overview of these proposed candidate measures. Each proposed measure is described in greater detail in the sections which follow.

Candidate Measure Title	Candidate Measure Detail
Radon Public Awareness	Proportion of households with basic radon awareness.
Radon Testing Rate	Proportion of households tested for radon.
Elevated Radon Levels	Proportion of tested households with elevated levels detected.
Mitigation Prevalence	Proportion of households with elevated levels detected which have been mitigated.
Mitigation Effectiveness	Average percent level decrease achieved by mitigation.
Additional Measures	Longitudinal Testing Rates

5.2 Candidate Measure: *Basic Public Awareness*

Measure Detail: *Proportion of households with basic radon awareness.*

Basic awareness of the risks posed by radon and the availability of testing are precursors to actual testing. Data supporting this candidate measure is likely available only through surveys such as the BRFSS or other more targeted surveys. As indicated in Appendix B, several state radon programs include basic awareness questions in their BRFSS. Like estimates of testing, estimates of changes in awareness could be tracked by radon programs to determine the effectiveness of various outreach strategies.

5.3 Candidate Measure: *Radon Testing Prevalence*

Measure Detail: *Proportion of households tested for radon.*

Since elevated levels of radon must be detected before they can be mitigated, the prevalence of radon testing is a key measure. Using zip code level test results and census data for the number of households it is possible to estimate the prevalence of radon testing at the state or county level. In many cases, however, these estimates do not account for pre- and post-mitigation tests on the same structure (only about 50 percent of laboratories provide this data). This produces a high bias in the testing rate by double counting tests on the same structure. Recognizing this, states may decide to implement new testing policies and work with radon contractors and laboratories to identify tests as pre- or post-mitigation. This will help build a more robust data set for future work. Testing prevalence can also be estimated from BRFSS.

5.4 Candidate Measure: Prevalence *of Elevated Radon Levels*

Measure Detail: *Proportion of tested households with elevated levels detected.*

The prevalence of radon tests over a limit is another candidate measure. In most cases, test results of 4 picocuries/liter (pCi/L) or higher would be counted in this measure, and used as an indicator of risk for an area. However, some states may decide to use the lower value of 2 pCi/L as an indicator of risk in recommending that homeowners in an area test their homes for radon. In Colorado, for example, the EPA identifies most counties as high risk, at or above 4 pCi/L, and the remaining at moderate risk, expecting a test result between 2–4 pCi/L.[10] It is useful to understand that a combination of test result analysis in the range of 2–4 pCi/L or greater than 4 pCi/L is useful in developing radon programs.[10]

5.5 Candidate Measure: *Mitigation Rate*

Measure Detail: *Proportion of households with elevated levels detected which have been mitigated.*

Given the current state of many data sets, it is very difficult (and in many cases impossible) to determine prevalence of mitigation from test results since only about 50 percent of laboratories provide a pre-/post-mitigation data element. This is a key area where it would be useful to evaluate current data collection practices and form partnerships with testing laboratories to collect these data. By requesting and obtaining access to data sets where the results are flagged as pre- or post-mitigation, radon program personnel can better estimate mitigation rates. For states without broad testing data coverage including pre-/post-mitigation flags, the next best source of information for mitigation prevalence are radon-related questions included in the BRFSS by some states (see Appendix B). Some states use this survey to ask if an action was taken and resulting responses to a high radon test result.

5.6 Candidate Measure: *Mitigation Effectiveness*

Measure Detail: *Percentage of mitigations which reduce radon to below 4 pCi/l, below 2 pCi/l, and below 1 pCi/l.*

As discussed above, approximately ten grantee state radon programs collect results with pre-/post-mitigation flags. These data can also be used to estimate mitigation effectiveness by comparing the pre- and post-mitigation test result levels. These data may allow radon program staff to identify patterns of deficient mitigation installations, or, conversely to identify installers with especially good indications of mitigation effectiveness. This candidate measure is more likely to be of use for local program management rather than for national collection as an NCDM.

5.7 Additional Measures

Longitudinal Testing Rates

Typically, a radon test result will include the date sampled and date analyzed. Collection of these data helps to determine the number of new samples submitted annually. Testing date information can also be used to detect patterns (rises, declines, peaks or valleys) in the rate of new testing, and correlate these to other factors such as awareness promotion activities. As discussed above, the lack of pre- and post-mitigation flags tend to result in higher testing rates. However, this bias should not change the general testing patterns and so can still inform programs. These data are probably more useful for local program management than for NCDM development.

6 Considering a National Radon Database

EPA and CDC continue discussions on the possibility of creating an integrated national database for radon data. Much work has already been done on the data elements needed for such a database; this includes the work done by EPA's Radon State Data Exchange group as well as work by New Jersey Department of Environmental Protection (NJ DEP, – relevant New Jersey material is being added to the Exchange Network website). Benefits of such a national system could include:

- Improved Data Compatibility: Establishing a common core set of elements and providing these fields as a target for other systems to map should increase the consistency, compatibility, and availability of these data.
- Direct Support of State Programs: Some states may elect to use the national database for direct support of their state programs, eliminating the need (and costs) of developing and maintaining a local system. Use of a national system for program support would likely require inclusion of additional data elements, beyond those strictly required for the proposed measures, such as those identified by NJ DEP. See possible security considerations below.

- Common Target for National Laboratories: A national database could provide a common repository for the national testing laboratories; this may reduce the burden on the part of the laboratories for reporting this data, and act as an incentive for them to provide more consistent and complete data.

Ideally, a comprehensive national radon database would include address level data, in order to de-duplicate and geo-locate tested structures. States using the national system (only) to manage their primary test data would need this functionality. However, storing this data nationally could present confidentiality and security issues. Some data providers may simply refuse to provide data if they know that it will be nationally aggregated and possibly publicly released. Some of these issues might be addressed by de-duplicating and geo-referencing the data but then also de-identifying the data, before transmitting it to the national database. This approach would require some local system to perform these functions, since they would not be performed in the national database itself. It could be possible to jointly develop such local software but doing so would entail the usual shared software challenges of functionality and version management. Still, this option may be worthy of further exploration.

7 Recommendations

Radon represents a large environmental public health risk. Through working with radon exposure data, it is feasible to make a difference in public health outcomes. To accomplish this, the Radon Task Force developed the recommendations outlined below.

- **Place development of radon NCDMs on hold for now.** Currently available data will not support sufficient coverage for the proposed measures to justify their addition to the current NCDMs. CDC should continue to monitor the availability of radon data from data partners and grantees to identify when sufficient coverage (perhaps 12-15 grantees) exists to include radon measures in the national set. Once new data become available, the candidate measures listed here could be piloted.
- **Explore how radon can receive continued attention from the Tracking Program**. Per the findings by the Radon Task Force, current data collection methods do not support development of radon NCDMs. However, given the relative magnitude of the risk represented by radon, the Tracking Program should consider other ways of supporting radon programs. Options could include:
    - Including information about radon on the National Portal, with links to grantee Radon program pages.
    - Including data where it exists for the measures identified by the Task Force.
    - Partnering with EPA’s Radon State Data Exchange program to support grantees in leveraging their Tracking Portals for Radon public outreach.
    - Consider taking opportunities to provide radon-related technical assistance.
- **Explore the addition of optional radon questions into the optional BRFSS module.** Given the data gaps identified by the Task Force, the BRFSS survey represents the next most powerful data source for radon measures and program management. The Tracking

Program should explore the addition, as is done in some states, of radon-related questions to the national BRFSS set. The first four of the proposed radon measures could be effectively estimated by a national Radon module for BRFSS.

- **The Tracking Program should continue the discussions with EPA about establishing a national radon database.** A national radon database could significantly improve the consistency, quality and availability of radon testing and mitigation data; it could provide laboratories with an easier unified way to report data; and it could provide program management functionality to state radon programs without local test data management systems. As a next step in their discussions, CDC and EPA could develop exploratory scenarios for usage and data ownership, security and formatting issues. Even without a national system, EPA and CDC could work with the national testing laboratories to develop a standardized reporting format, especially one that includes address level data and the critical pre-/post-mitigation testing data element.

8 References

1. National Cancer Institute at the National Institutes of Health. Radon and Cancer. Available at URL: http://www.cancer.gov/cancertopics/factsheet/Risk/radon

2. U.S. Environmental Protection Agency (EPA) Radon (Rn) Health Risks. Available at URL: http://www.epa.gov/radon/healthrisks.html

3. Krewski D, Lubin JH, Zielinski JM, Alavanja M, Catalan VS, Field RW, Klotz JB, Letourneau EG, Lynch CF, Lyon JI, Sandler DP, Schoenberg JB, Steck DJ, Stolwik JA, Weinberg C, Wilcox HB. Residential radon and risk of lung cancer:a combined analysis of 7 North American case-control studies. Epidemiology, 2005 Mar; 16(2): 137-45.

4. Darby S, Hill D, Auvinen A, Barros-Dios JM, Baysson H, Bochicchio F, Deo H, Falk R, Forastiere F, Hakama M, Heid I, Kreienbrock L, Kreuzer M, Lagarde F, Mäkeläinen I, Muirhead C, Oberaigner W, Pershagen G, Ruano-Ravina A, Ruosteenoja E, Rosario AS, Tirmarche M, Tomásek L, Whitley E, Wichmann HE, Doll R. Radon in homes and risk of lung cancer: cpllaborative analysis of individual data from 13 European case-control studies. BMJ, 2005 Jan 29; 330(7485):223.

5. Committee on Health Risks of Exposure to Radon (BEIR VI), National Research Council Health Effects of Exposure to Radon. Available through National Academies Press at URL: http://www.nap.edu/catalog/5499.html

6. U.S. Environmental Protection Agency (EPA) Radon (Rn) Basic Information Why is Radon the public health risk that it is? Available at URL: http://www.epa.gov/radon/aboutus.html

7. U.S. Environmental Protection Agency (EPA) Radon (Rn) A Consumers Guide to Radon Reduction. Available at URL: http://www.epa.gov/radon/pubs/consguid.html

8. Methodologic Changes in the Behavioral Risk Factor Surveillance System in 2011 and Potential Effects on Prevalence Estimates. MMWR Weekly June 8, 2012 / 61(22); 410-413 Available at URL: http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6122a3.htmBRFSS

9. Centers for Disease Control and Prevention (CDC) Behavioral Risk Factor Surveillance System (BRFSS) Available at URL: http://www.cdc.gov/brfss/index.htm.

10. U.S. Environmental Protection Agency (EPA) Radon (Rn) Where You Live, Colorado. Available at URL: http://www.epa.gov/radon/states/colorado.html.

Appendices

Appendix A: Maine Case Study

Synopsis

Maine has over 20 years of air radon test data, comprising approximately 240,000 tests. These tests results are of limited usefulness for environmental public health tracking because they do not contain address level information until 2009. The Maine CDC has included radon testing and mitigation questions in its BRFSS. These questions have provided Maine with information on radon testing prevalence, high radon households, and the percentage of high radon households that have undergone mitigation. Data are currently summarized at the state and public health district levels. Maine plans to continue with these questions. It also hopes to develop a database that will store radon test results with address level information. These data will provide Maine with more local information on radon levels, as well as pre- and post-mitigation results by which intervention effectiveness can be assessed. Water radon data can also be stored in this database, possibly in a manner that can be linked with other private well water test information.

Introduction

Maine has had some level of radon outreach, education, training, and/or research since the mid-1950s, and established its Radon Control Program through legislation in 1989. One of the program's requirements is that all laboratories doing business in the State of Maine must submit their test results to the program. There are approximately 500,000 habitable structures in Maine, most of which are residences. Maine has approximately 500–1,000 school buildings. To date, the program has collected over 300,000 test results on Maine buildings; approximately 240,000 have been air tests and about 80,000 have been water tests, for an average of 10,000 air tests and 3,500 water tests per year. Most of these tests are from residences. Maine does not know how many of these test results were from individual buildings, because radon test data were only available at the zip code and town level until recently.

Of approximately 1,000–1,400 lung cancer deaths per year in Maine, 80–85 percent are attributable to smoking. Based on modeling and risk projections from the National Research Council BEIR VI report, radon exposure accounts for most of the remainder. Thus, as a crude approximation, radon exposure is responsible for roughly 150–200 lung cancer deaths per year in the state. [5]

Air radon is a very suitable candidate for NCDM development, when considered from the perspective of the original environmental public health tracking paradigm (hazard–exposure–health effect–intervention). There are established methods to measure radon hazard (pre- and post-mitigation), a clear association between radon exposures and lung cancer risk, effective mitigation measures to reduce risk, and a well-established program for training and certification of radon mitigators.

Ideal set of Indicators

Ideally, Maine's goal is to have every house tested for radon, and every house with radon levels above 4 pCi/L (or even 2 pCi/L) effectively mitigated. It would like a similar outcome for all schools and day care centers. To accomplish and verify this goal, Maine would need the radon test results for every house, school, and day care facility, as well as evidence that all high radon buildings have been mitigated effectively.

For Maine's purposes, indicators would not only focus on compiling a set of hazard (indoor air) data, but in also organizing those data in ways that could motivate public action to test and reduce indoor radon levels. To accomplish this, it is important that such data be organized at a local level. These data and results can be scaled up as needed to county and regional levels (public health district) levels in Maine.

Maine's Radon Data

A state indoor radon survey conducted by EPA in the late 1980s indicated that approximately 30 percent of Maine homes had radon levels above 4 pCi/L (see table below).

Radon Levels in Maine Homes by County

County	Number of Homes Sampled	Indoor Air Radon Levels (pCi/L)			
		50th Percentile	Maximum Level	Percent > 4 pCi/L	Percent > 2 pCi/L
Androscoggin	47	2.4	11.4	23 %	57 %
Aroostook	102	3.6	25.2	41 %	63 %
Cumberland	132	3.2	82.7	39 %	72 %
Franklin	22	1.7	103.2	18 %	33 %
Hancock	53	2.2	19.4	28 %	51 %
Kennebec	61	2.0	19.4	28 %	50 %
Knox	30	1.6	9.7	23 %	41 %
Lincoln	18	1.7	6.9	11 %	35 %
Oxford	42	4.2	30.3	52 %	65 %
Penobscot	79	1.7	7.5	15 %	36 %
Piscataquis	42	1.9	22.5	26 %	47 %
Sagadahoc	34	1.6	8.0	18 %	39 %
Somerset	31	1.6	5.8	19 %	31 %
Waldo	27	2.1	13.0	22 %	51 %
Washington	40	1.6	12.2	15 %	39 %
York	79	2.9	33.0	41 %	67 %

The Table above contains screening indoor air radon data from the EPA/State of Maine Residential Survey of Maine conducted during 1988 and 1989. Data represent 2-7 day charcoal canister measurements from the lowest level of each tested home. SOURCE: EPA's Map of Radon Zones: MAINE, U.S. Environmental Protection Agency, Air and Radiation, 402-R-93-039, September, 1993.

Household test data through Maine's Radon Control Program:
Laboratories submitting test results to Maine's Radon Control Program provided town (and zip code) level information. Until recently, however, the test information did not contain addresses; thus, assessing the historical database multiple tests results on the same house is not possible.

These are the fields contained in the air and water test reports from the laboratories.

Data field	Detail/Comment
Medium	Air/Water
Company ID number	Company that collected sample
Lab ID Number	Lab that analyzed sample
Test kit/Sample	Sample identification – for further information
Zip code	
Result (pCi/L)	
Building level (basement, 1^{st}, 2^{nd}, etc.)	which floor of the building was tested for radon
Address	Note- address level data has always been requested and occasionally received; only recently was it made mandatory.
Town	
Charcoal test	Yes/No
Alpha track test	Yes/No
Working Level test (derived)	Yes/No (asking if the test being reported was a working level measurement)
Working Level result (actual)	Yes/No (if a working level measurement, what was the result)
Notes	
Mitigation	Yes/no (added to the database in 2010)

Summary data of these results indicate that approximately 30 percent of the tests show levels above the 4 pCi/L action level (consistent with the EPA survey), with appreciable variation across the state. Because these results are based largely on historical tests which lack address level information, they are only approximations of the number of homes tests. While they can discriminate between pre-mitigation and post-mitigation tests, they cannot de-duplicate among multiple tests done either before or after mitigation.

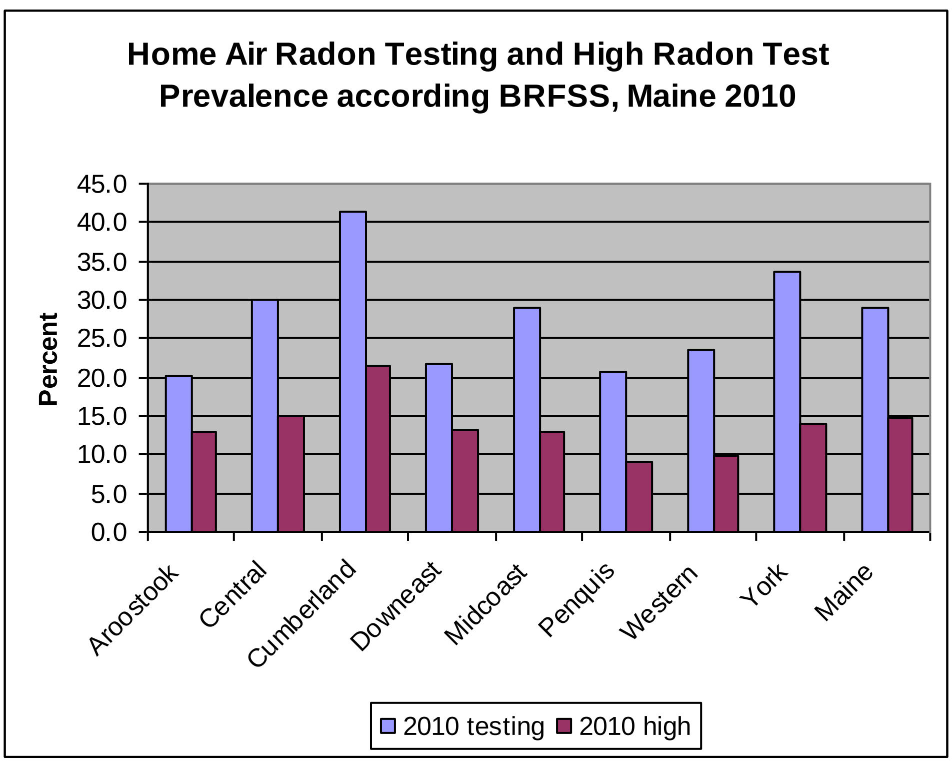
The Radon program currently stores this information in three datasets: air radon test results; water radon test results; and mitigation test results. All of these datasets are housed in a legacy dBase III system, which has several limitations. For example, it does not recognize any date after December 31, 1999, thereby limiting the radon program's ability to track trends in test results; processing time slows down when over 50,000 records are analyzed; it lacks networking capabilities; and it does not work at all over the Internet.

BRFSS: Behavioral Risk Factor Surveillance System:

While test level data does provide local (e.g., town or zip code level) information which can inform and motivate public health action, it is limited in its ability to provide precise estimates of radon testing prevalence due to the lack of address level information. This limitation can be addressed through the use of BRFSS information, which provides population based prevalence estimates at state, public health district, and county levels.

Over the past decade, the Radon Program and Maine EPHT have worked collaboratively to include radon questions on the Maine BRFSS. These questions focus on number of households that have been tested for air radon, the number of households with high radon (e.g., over 4 pCi/L), and the number of homes within the high radon category that were mitigated. This provides prevalence estimates for all three measures, although spatially estimating these prevalences at a public health district level is the most feasible at this time. Overall, according to the most recent BRFSS (2009, 2010), approximately 30 percent of Maine households have tested for radon.

Approximately 15 percent of those households that tested had "high" radon levels (a proxy question for levels above 4 pCi/L). Of these high radon households, approximately 80 percent reported having had their homes mitigated.



School data:

The Bureau of Public Improvements, later renamed the Bureau of General Services, conducted a radon survey of all Maine schools from 1988 to 1991. Results showed that approximately one third (just over 200) of Maine schools had one or more rooms with radon levels above 4 pCi/L. No comprehensive follow-up action or mitigation was undertaken. Currently, Maine schools are not required to enact radon mitigation measures when high radon is found, either in new or existing structures.

Summary of findings:

An EPA survey and subsequent radon test data gathered through Maine's Radon Control Program, indicates that approximately one third of Maine's residences have radon levels exceeding the 4 pCi/L action level. Furthermore, about the same percentage of schools were also found to exceed this benchmark. One limitation, however, associated with the interpretation of the historical air radon test data has been the absence of radon address level information,(which recently became available. This limitation has prevented the Radon Program from: 1) distinguishing between the number of homes tested and the homes with multiple radon tests; and 2) analyzing pre- and post-mitigation tests from the same building. Maine has explored alternative approaches to estimating the proportion of high radon homes and the amount of mitigation activity undertaken through the BRFSS. BRFSS results indicate that only fifteen percent of Maine homes have high radon levels (i.e., above 4 pCi/L), about half the estimate indicated from both the EPA survey and the household radon test results. Reasons for this disparity are currently being investigated. The BRFSS is Maine's only current source of information regarding the percentage of homes being mitigated (an encouraging 80 percent).

Moving forward

Moving forward, a tracking system that uses radon test data submitted to the Radon Control Program and the BRFSS results is envisioned. BRFSS results could continue to provide overall prevalence information, but at best a county or public health district level. The submitted test reports--now having address level information-- will be able to provide de-duplicated household data, including both pre-mitigation and post-mitigation readings, at a community level. In this respect, the air radon test data will function similarly to the private well water test data, which will eventually also house water radon data. Evaluating intervention effectiveness of radon mitigation efforts will also become possible with the ability to compare pre- and post-mitigation test results for the same address.

Database Development

The Maine Radon Control Program is at a crossroads with respect to its database development. It is clear that the current dBase III system is inadequate, but unclear what new system should be developed to take its place. Conceptually, the most logical system would be in the Healthy Homes database (HHLPPS). Yet the future of that database is unclear. Also, radon data are not currently included in that database. Another possibility is to develop a database for air and water radon, and align this database with one currently under consideration for other private well water data. Yet another possibility is to consider the development of a national database. Such a system could avoid the data analysis and display problems, as well as multiple reporting requirements for data providers that exist when several jurisdictions are developing data independently.

Appendix B: EPHT Radon Task Force Grantee State BRFSS Collection Practices

Grantee	Collecting Radon-Related BRFSS Questions?	If yes, what questions?
Colorado	Yes	– Do you know what radon is? – Has your household air been tested for the presence of radon gas? – Were the radon levels in your household above 4 pCi/L (picocuries per liter)? – In response to a high radon test result, did you… (retest, do a long term test, have a mitigation system installed, no longer go into the basement, other, do nothing)?
Maine	Yes – annually	– Has your home been tested for radon? – Was the level high? – Did you mitigate?
Missouri	No	–
New Hampshire	Yes – every other year	– How would you best describe the construction of the type of home you live in? – Have you heard of radon? – Which of the following most clearly describes radon? – What health condition is most often associated with radon in air? – To the best of your knowledge, has your present home been tested for radon in the indoor air? – Was the result of the radon test equal or greater than the maximum recommended value of 4 pCi/L? – Has a radon venting system, other than a fan in the window, been installed in your home in response to a high radon test result?
New Mexico	No	
Wisconsin	No	

Appendix C: EPHT Radon Task Force Starting Matrix: Data collection practices in selected states.

	Oregon	Wisconsin	Maryland	New Hampshire	Missouri	Maine	Colorado
Data available electronically?	Yes	Yes	No	Yes	Yes	Yes	Yes
Beginning date radon data is available?	1/1/1990	At least as far back as 2004. Investigating if we can access data older than that.	No	1987	2004 (some previous data available; however it is spotty)	1988 (sporadic) 1993 (regularly received)	1/1/2005
Ending date radon data is available?	7/1/2011	Current	No	2010	Current	Spring 2009 (data since then needs to be entered into database)	2009 (Will update with 2010 and 2011, including pre-/post-mitigation, next quarter.
Approximate number of records?	16,000	120,000	N/A	25,000	Approximately 16,000 laboratory results and 31,000 kit requests	190,000	20,000/year (Based on 102,851 total tests for 2005-2009)
Format data is stored in (Excel, Access, etc.)?	Excel	Access	N/A	Access	Access	dBase III+	Access
Is a data dictionary available?	No	No	No	No	No - currently in development	No	No

	Oregon	Wisconsin	Maryland	New Hampshire	Missouri	Maine	Colorado
How often is the data set updated?	Whenever new data is received, typically monthly.	Annually	N/A	Annually	Kit requests - daily, Schools - when testing is completed, Laboratories & Daycares – monthly	Intermittently due to lack of staff/resources	Intermittently due to lack of staff/resources
Is address information available?	Yes, from some of the test kit manufacturers.	No	No	Yes, but data quality not completely evaluated.	Yes, street address available for kit requests, laboratory results, daycares, & schools.	On limited past data. Will be available for future data.	Yes, from some of the test kit manufacturers, but data quality not evaluated.
Smallest level of geography data is available for (e.g., Zip Code, County, etc.)?	Most data is to the Zip Code level. Some results are geocoded down to street address.	Zip code	N/A	Recorded at address level, currently available to public at town level.	Street address	Zip code	Code; displayed on Tracking Portal by county.
What types of radon data are available (e.g., residential, daycare, laboratories only, etc)?	Data from test kit manufacturers.	Residential	N/A	Residential	Residential kit requests, laboratory results, daycare testing, & school testing	Radon data for all tests in Maine, but does not have any building type identifier (residence vs. daycare, etc.)	Data are from all do-it-yourself test kits statewide, so probably includes a small number of other buildings.

	Oregon	Wisconsin	Maryland	New Hampshire	Missouri	Maine	Colorado
What actions is this data used for?	Looking for trends in high radon results to target educational outreach.	Mitigation	N/A	Mitigation advice, public awareness.	Trends, public awareness, technical assistance requests, strategic planning performance measures	Limited occurrence rate.	Public awareness, educational outreach, support need for local regulation (building permits), distribution of state Radon Program grant funds.
What products are created from this data?	Occasionally maps are created.	Aggregated by geography for presentation on the state's radon website	N/A	NH EPHT Issue Briefs, other publications	Missouri-specific testing maps for residential & schools	None at this time.	Colorado Tracking Portal, BRFSS results / analysis / interpretation, PowerPoint presentations of data, analysis and mapping to local / state / federal agencies.
Additional Comments			No data currently collected.			Lack of staff and resources to properly add data to the database, and no staff time to do data analysis, prohibit adequate or appropriate use of this data.	