

# CDC Science Ambassador Workshop 2015 Lesson Plan

## Lurking Radon and Lung Cancer

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The findings and conclusions in this Science Ambassador Workshop lesson plan are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention (CDC).

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## Lurking Radon and Lung Cancer

### Summary

Radon is an odorless, colorless, radioactive gas produced naturally from the breakdown or the radioactive decay of uranium. Rocks, soil, and in certain cases groundwater can contain uranium and serve as radon sources. Because radon comes from multiple sources, persons are always exposed. Exposure can result from breathing air in buildings and homes (inhalation) and by eating or drinking (ingestion). Radon gas can seep through cracks in buildings and become trapped in poorly ventilated areas exposing occupants to the radioactive gas. Radon exposure can lead to cancer of the lung (including the bronchus).<sup>1</sup> Radon testing is the only way to determine if levels are high in a particular home or building.

Lung cancer is the leading cause of cancer-related death and radon is the second leading cause of lung cancer in the United States. Radon is estimated to cause approximately 10% of all lung cancers in the United States. The U.S. Environmental Protection Agency (EPA) and the Surgeon General's office estimate that radon is responsible for 21,000 lung cancer deaths each year. Identifying any immediate symptoms related to radon exposure is difficult, and many years will pass before health problems appear. Whether in workplaces, homes, or schools, understanding how radon gets into buildings, its health effects, and ways to reduce its level are important. Sources: [http://www.cdc.gov/nceh/radiation/brochure/profile\\_radon.htm](http://www.cdc.gov/nceh/radiation/brochure/profile_radon.htm) and <http://www.atsdr.cdc.gov/csem/csem.html>.

In this lesson plan, students will use public health surveillance data to investigate radon levels and lung cancer rates at the national level and in their local counties. Students will identify geographic patterns in data, graph radon levels and lung cancers rates, and then calculate lung cancer rates associated with high levels of radon. Students will learn about EPA recommendations for radon, how to test for radon, and have in-depth discussions about the social and political implications to control and prevent future exposure, specifically in schools and day care centers. The targeted grades for the lesson plan are 9–12. Prior knowledge should include data collection, graphing, and laboratory safety procedures.

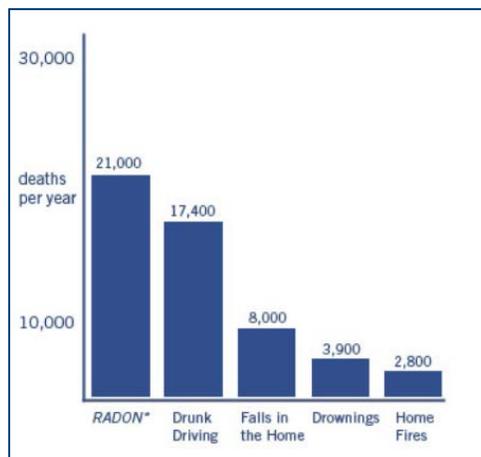


Figure 1. Radon is estimated to cause thousands of lung cancer deaths in the United States per year. According to EPA's 2003 Assessment of Risks from Radon in Homes, radon is estimated to cause about 21,000 lung cancer deaths per year. The number of deaths from other causes are taken from CDC's 2005–2006 National Center for Injury Prevention and Control Report and 2006 National Safety Council Reports. See: <http://www.epa.gov/radon/pubs/citguide.html> for more information.

<sup>1</sup> Lung cancer data are often presented as “cancer of the lung and bronchus.” The bronchus is part of the lung and separate data are rarely given. In the interest of simplicity and brevity, the term “lung cancer” is used here to refer to “cancer of the lung and bronchus.”

## **Learning Outcomes**

After completing this lesson, students should be able to:

- analyze different forms of public health surveillance data (e.g., tables, maps, and graphs);
- describe patterns in lung cancer rates and radon exposure levels by geographic location;
- estimate lung cancer rate associated with radon exposure; and
- tailor a public health intervention aimed at improving indoor air quality in schools to meet the social and political needs of their school.

## **Duration**

This lesson can be conducted as one, 90-minute lesson, or divided into two, 45-minute lessons.

## Procedures

### Day 1: Radon and Lung Cancer by the Numbers (45 minutes)

#### Preparation

Before Day 1,

- Prepare materials for the cloud chamber demonstration. You can consider building the cloud chamber before class. Refer to the following website for safe use of dry ice in classroom settings, available at: <http://www.wrh.noaa.gov/vef/kids/dryice.php>;
- Purchase a radon test kit from a hardware store;
- Print copies of Worksheet 1: Lurking Radon and Lung Cancer (Appendix 1A), one copy per student;
- Look up the incidence rate of lung cancer in your state and county, available at <http://statecancerprofiles.cancer.gov/incidencrates/index.php>. Complete the answer key (Appendix 1B) with correct data; and
- Print copies of Worksheet 2: Indoor Air Quality School Action Plan (Appendix 2A) and rubric (Appendix 2C), one copy of each per student.

#### Materials

- Worksheet 1: Lurking Radon and Lung Cancer (Appendix 1A).
- Worksheet 2: Indoor Air Quality School Action Plan (Appendix 2A) and rubric (Appendix 2C).
- Cloud chamber:
  - Metal pie pan or similar metal container  
Description: This will act as the bottom of the cloud chamber.
  - Clear glass bowl or similar dome shaped container (e.g., large watch glass)  
Description: Container should fit securely with metal pie pan.
  - Black felt  
Description: Felt should fit the container and cover the dry ice. It will be saturated with alcohol.
  - Dry ice  
Description: Dry ice will fill the container.
  - Cooler, goggles, heavy gloves, and hammer  
Description: These materials are needed to transport and safely work with dry ice.
  - Isopropyl alcohol (rubbing alcohol) or ethyl alcohol  
Description: Alcohol will saturate the black felt.
  - Plumber's putty  
Description: Putty is used to seal the gap between the pan and container.
  - Illumination source  
Description: bright LED flashlight or cell phone flashlight
- Radon Test Kit  
URL: <http://www.radon.com>.  
Description: An Internet link to test kits. Test kits are accessible at other Internet sites (certain sites offer free test kits).
- Graphing materials  
Description: Graph paper and rulers; alternate options include a computer with Microsoft® Excel®, (Microsoft Corporation, Redmond, Washington) graph (i.e., chart) software, and online program with a graph maker tool.
- Electronic device with Internet access  
Description: Computers, telephone, or other device for accessing Internet databases

## Online Resources

- How to Build a Cloud Chamber Video  
URL: <https://www.youtube.com/watch?v=xky3f1aSkB8>.  
Description: Video demonstrating the concepts used to build a cloud chamber. Use this video in conjunction with the following video.
- Cloud Chamber Video  
URL: <https://www.youtube.com/watch?v=VJImbQU5w4A>.  
Description: A useful resource when learning to construct the cloud chamber and to show students what high radon levels will look like in a cloud chamber.  
**Note:** The cloud chamber will show tracks from any radiation that originates inside or passes from the outside through the chamber. For radon, that would be from the radon that is trapped inside. It is unclear what your source of “high radon levels” would be, since the source and its injection into the chamber are not mentioned or identified. Depending on the radon concentration, you might just be seeing the interaction of gamma or cosmic radiation from outside the chamber passing through it and knocking off electrons or producing muons.
- Dry Ice Safety  
URL: <http://www.wrh.noaa.gov/vef/kids/dryice.php>.  
Description: Provides information concerning dry ice safety in classroom settings.
- AirChek Radon Level Reports  
URL: <http://www.radon.com/>.  
Description: Reported radon readings in the United States by state and county.
- A Citizen’s Guide to Radon  
URL: <http://www.epa.gov/radon/citizens-guide-radon-guide-protecting-yourself-and-your-family-radon>  
Description: Contains basic information about Radon in the home, how to test and read the results.
- County Health Rankings & Roadmaps  
URL: <http://www.countyhealthrankings.org/>.  
Description: Reported smoking prevalence by county for each state.
- Institute for Health Metrics and Evaluation  
URL: <http://vizhub.healthdata.org/us-health-map/>.  
Description: Interactive map visualization of adult smoking in the United States by state and county.
- Lung Cancer Incidence Rates  
URL: <http://statecancerprofiles.cancer.gov/incidencerates/index.php>.  
Description: Provides cancer incidence rates in the United States by state and county.

## Activity

1. Present information regarding basic physics of radiation, how it relates to radon, and how radon exposure can result in lung cancer. Key points can include the following:
  - radon is a radioactive decay product of uranium;
  - radiation from radon can damage DNA and cause cancer;
  - radon is colorless, odorless, and has no taste; thus, it is difficult to detect;
  - testing for radon is necessary to know the concentrations in your home or building; and
  - radon remediation can reduce exposure.
2. As a class, use a diagram to explain and discuss how radon gets into buildings and homes. Explain that radon can be found in all places, but at low levels. A helpful resource for this discussion is A Citizen's Guide to Radon (see Online Resources) and includes one key point.
  - explain how radon accumulates in homes when it enters from the ground and is then cycled through the indoor air.
3. Use the cloud chamber to show students that radon and cosmic radiation can be found in the classroom. Explain how the cloud chamber works. Note that the cloud chamber demonstrates potential radiation exposure. Explain that this chamber will not allow for a distinction between radon inside the chamber and other sources of radiation both inside and outside (e.g., cosmic rays) the chamber the chamber, unless a magnetic field is applied. The shape of the particle paths indicate what particle caused it. The cloud chamber videos can be used instead of or in conjunction with this activity.
  1. Apply a bead of plumber's putty all along the top rim of the pie pan and firmly press down.
  2. Cover the bottom of the pie pan with dry ice.
  3. Saturate the black felt with alcohol and place it over the dry ice.
  4. Cover the pie pan with the container. Press down on the rim to create a seal.
  5. Turn off all lights. Shine the flashlight beam so it travels parallel above the glass dome.
  6. Have students huddle around to see if any radiation particles become visible. If necessary, use a MILD heat source (e.g., a hand or container of hot water on the top of the glass bowl) to facilitate the condensation development. **DO NOT USE A FLAME! ALCOHOL IS FLAMMABLE!**
4. Explain how a cloud chamber showing radiation demonstrates that radiation, including that from radon, can be found in the room. This does not necessarily mean that dangerous radon levels are everywhere. It also does not exclude radiation from other sources. Explain that a radon test kit must be used to determine radon levels. Then, show a radon test kit available from a hardware store or a state radon program, and explain how to use it and how it collects data regarding radon levels.
5. Hand out Worksheet 1: Lurking Radon and Lung Cancer (Appendix 1A) to students. Discuss public health surveillance and how it collects data regarding radon levels throughout the United States. Explain to students that they will be using radon maps from AirChek, Inc., lung cancer data from CDC's National Vital Statistics System, and cigarette smoking data from Behavioral Risk Factor Surveillance System (BRFSS) survey on the County Health Rankings & Roadmaps website.
6. Ask students to complete Worksheet 1: Lurking Radon and Lung Cancer (Appendix 1A). As students get started, make Table 1 on the board. After they have located their data, ask students to report the data on the board. Students will then copy the data for the remaining counties onto their table. Have students complete the remainder of the worksheet.
7. For homework, students will complete Worksheet 2: Indoor Air Quality School Action Plan (Appendix 2A) and prepare for the discussion on Day 2. Provide students with the grading rubric (Appendix 2C) for the discussion on day 2.

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## Day 2: Indoor Air Quality School Action Plan, 45 minutes

### Preparation

Before Day 2,

- Review the EPA Indoor Air Quality Design Tools online.

### Materials

- Worksheet 2: Indoor Air Quality School Action Plan (Appendix 2A), Indoor Air Quality Action Plan, Answer Guide (Appendix 2B), and Indoor Air Quality School Action Plan, Rubric (Appendix 2C).
- Radon test kit.  
URL: <http://www.radon.com> or <http://www.epa.gov/radon/whereyoulive.html>.  
Description: Internet link to test kits. Test kits are accessible at other Internet sites (certain sites offer free test kits).

### Online Resources

- EPA Indoor Air Quality Design Tools  
URL: <http://www.epa.gov/iaq-schools> (Radon).  
Description: This website reviews the Indoor Air Quality Tools for Schools regarding radon remediation in schools. Direct students to scroll to the bottom of the page and click on “managing radon in schools.” Students will use the information on this site to help them organize a school action plan.

## Activity

1. Review the activity from Day 1.
2. As a class, review the directions for the radon test kit and describe how it is used to monitor radon. Place the test kit(s) in the school as per kit directions. The kit will remain for the allotted time (approximately three days). If possible, the test kits should be sent for evaluation.

**Note:** Basements and lower levels are likely to have higher concentrations. Additionally, the kit should be in a low-traffic area to reduce air movement, but the test kit should not be placed in areas where people do not live, e.g., crawl spaces.

Students might want to discuss placing a kit in their home with parental permission, and ask their parents if they are okay with knowing the radon concentrations in their home. Others might want to test various locations within the school building. Note that once you know the radon levels in your home, you might be required to tell any potential buyer.

**Note:** A home test provides information concerning radon levels. If high levels are reported, the test should be repeated for a longer period of time, and if still high, a licensed professional should test for radon to confirm the finding.
2. Ask students to take out Worksheet 2 with their notes. Remind students that two grades will be assigned; a class grade on the basis of the quality of their action plan by end of the discussion, and an individual grade on the basis of participation and quality of contribution. Prompt the discussion.

**Discussion Prompt:** After you test for radon at your school, you find that your school has high levels of radon. Review the indoor air quality design tool for schools and decide on an action plan as a class to address the issue.
3. Guide students through the development of an action plan by using Worksheet 2: Indoor Air Quality School Action Plan (Appendix 2A) and the Answer Guide (Appendix 2B). They should discuss the following key drivers: organize, communicate, assess, plan, act, and evaluate, and identify action strategies that are feasible in their school. Ensure that the class discussion covers all six key drivers, with the remaining time designated to agreeing upon components of the action plan. At the end of the discussion, students should have a clear list of actions to be completed at a school with high radon levels. An overall grade should be given for the quality of the action plan as well as individual participation grades. See the rubric for this activity (Appendix 2C).

## Conclusions

The purpose of this activity is to increase student interest in a public health issue that can be directly connected to their lives. AirChek, Inc. has estimates of indoor radon risk for every county in every state (<http://www.radon.com/>). Additionally, collaborative efforts of CDC and the National Cancer Institute provide incidence rates for lung cancer in each state. Epidemiologic studies in the United States, Europe, and China indicate that a connection exists between exposure to indoor radon gas and developing lung cancer. More information is available at the EPA website: <http://www.epa.gov/radon/healthrisks.html>. This activity guides students to make their own connections between the causes of health and disease through epidemiologic thinking, and to learn how a public health approach is used to improve human health and prevent disease. Students will use scientific data that directly relates to their county and state, and will be able to estimate the incidence rate of lung cancer resulting from radon exposure in their county or state. Students will learn how to apply analytical and mathematical skills and generate a best-fit line graph. Student will use epidemiologic thinking to provide evidence-based rationale in their decision-making.

## Assessments

- Worksheet 1: Lurking Radon and Lung Cancer (Appendix 1A)  
Learning Outcome(s) Assessed
  - analyze public health surveillance data in a variety of forms (e.g., tables, maps, and graphs);
  - describe lung cancer rate patterns and radon exposure levels by geographic location; and
  - estimate lung cancer rate associated with radon exposure.
- Worksheet 2: Indoor Air Quality School Action Plan (Appendix 2A)  
Learning Outcome(s) Assessed
  - tailor a public health intervention designed to improve indoor air quality in schools to meet the social and political needs of his or her school.

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## Educational Standards

In this lesson, the following CDC Epidemiology and Public Health Science (EPHS) Core Competencies for High School Students<sup>1</sup>, Next Generation Science Standards\* (NGSS) Science & Engineering Practices<sup>2</sup>, and NGSS Cross-cutting Concepts<sup>3</sup> are addressed:

**HS-EPHS1-3.** Apply epidemiologic thinking and a public health approach to a model to explain cause and effect relationships that influence health and disease.

### NGSS Key Science & Engineering Practice<sup>2</sup>

#### Developing and Using Models

Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or components of a system.

### NGSS Key Crosscutting Concept<sup>3</sup>

#### Cause and Effect

Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about the smaller scale mechanisms within the system.

**HS-EPHS3-3.** Use empirical data from an observational study to mathematically quantify an association between an exposure and disease.

### NGSS Key Science & Engineering Practice<sup>2</sup>

#### Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

### NGSS Key Crosscutting Concept<sup>3</sup>

#### Scale, Proportion, and Quantity

Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another.

**HS-EPHS 4-1.** Describe a model illustrating how scientific, social, economic, environmental, cultural, and political systems influence intervention performance patterns.

### NGSS Key Science & Engineering Practice<sup>2</sup>

#### Developing and Using Models

Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

### NGSS Key Crosscutting Concept<sup>3</sup>

#### Cause and Effect

Changes in systems may have various causes that may not have equal effects.

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\* Next Generation Science Standards is a registered trademark of Achieve. Neither Achieve nor the lead states and partners that developed the Next Generation Science Standards was involved in the production of, and does not endorse, this product.

- <sup>1</sup>Centers for Disease Control and Prevention (CDC). Science Ambassador Workshop—Epidemiology and Public Health Science: Core Competencies for high school students. Atlanta, GA: US Department of Health and Human Services, CDC; 2015. Not currently available for public use.
- <sup>2</sup>NGSS Lead States. Next Generation Science Standards: For States, By States (Appendix F—Science and Engineering Practices in NGSS). Achieve, Inc. on behalf of the twenty-six states and partners that collaborated on the NGSS. 2013. Available at: <http://www.nextgenscience.org/sites/ngss/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf>
- <sup>3</sup>NGSS Lead States. Next Generation Science Standards: For States, By States (Appendix G—Crosscutting Concepts in NGSS). Achieve, Inc. on behalf of the twenty-six states and partners that collaborated on the NGSS. 2013. Available at: <http://www.nextgenscience.org/sites/ngss/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf>.

## Appendices: Supplementary Documents

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## Appendix 1A: Worksheet 1: Data by County

# Lurking Radon and Lung Cancer Data by County

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**Directions:** Read the information below about radon. Then, follow the step-by-step directions to complete the table on page 26. Use your table to help answer questions as you go.

Radon is an odorless, colorless, radioactive gas produced naturally from the breakdown, or by the radioactive decay, of uranium. Rocks, soil, and groundwater contain uranium and serve as radon sources. Radon comes from multiple sources and every person is continuously exposed to it throughout their life. Exposure results from breathing air in buildings, in homes, and outdoors (inhalation) and by eating or drinking (ingestion). Radon gas seeps through cracks in buildings and become trapped in well-insulated and poorly ventilated areas exposing occupants to the radioactive gas. Radon exposure can lead to cancer of the lung (including the bronchus).<sup>2</sup> Radon testing is the only way to know if levels are high in a particular home or building. Even comparable homes next to each other can have widely different levels.

Lung cancer is the leading cause of cancer-related death and radon is the second leading cause of lung cancer in the United States. Radon is estimated to cause approximately 10% of all lung cancers in the United States. The U.S. Environmental Protection Agency (EPA) and the Surgeon General's office estimate that radon is responsible for 21,000 lung cancer deaths each year, with 2,900 of these deaths occurring among persons who have never smoked. Identifying any immediate symptoms related to radon exposure is not possible, and years will pass before health problems appear, if they appear at all. Whether in workplaces, homes, or schools, understanding how radon gets into buildings, its health effects, and ways to reduce its level are important. Source: [http://www.cdc.gov/nceh/radiation/brochure/profile\\_radon.htm](http://www.cdc.gov/nceh/radiation/brochure/profile_radon.htm)

Radon levels and lung cancer rates can be tracked nationwide by using public health surveillance systems. In this activity, you will analyze public health surveillance data and looking for geographic patterns between the two.

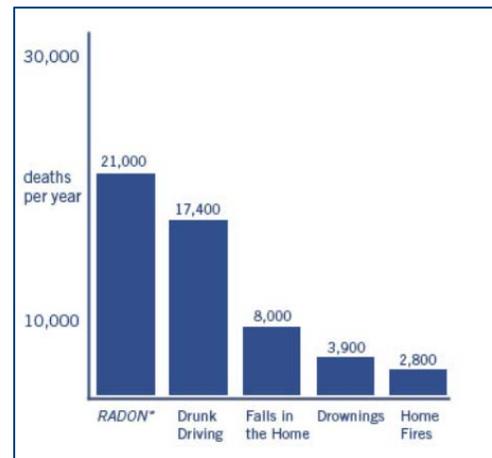


Figure 1. Radon is estimated to cause thousands of lung cancer deaths in the United States per year. According to EPA's 2003 Assessment of Risks from Radon in Homes, radon is estimated to cause about 21,000 lung cancer deaths per year. The number of deaths from other causes are taken from CDC's 2005–2006 National Center for Injury Prevention and Control Report and 2006 National Safety Council Reports. See: <http://www.epa.gov/radon/pubs/citguide.html> for more information.

<sup>2</sup> Lung cancer data are often presented as “cancer of the lung and bronchus.” The bronchus is part of the lung and separate data are rarely given. In the interest of simplicity and brevity, the term “lung cancer” is used here to refer to “cancer of the lung and bronchus.”

## Part 1: Confounding

To analyze public health data and identify associations between lung cancer and radon exposure, considering smoking is important. Smoking is the leading cause of lung cancer. In a location where smoking rates, radon levels, and lung cancer rates are high, it is more likely that lung cancer is associated with smoking rates rather than radon levels. In other words, smoking confounds the association between radon exposure and lung cancer. Two additional confounders exist, and they are silica dust and diesel exhaust particles to which the early miners and some members of the public were heavily exposed.<sup>3</sup>

### What is confounding?

Confounding is the distortion of the association between an exposure and a health outcome by a third factor that is related to both, called the confounder. To be a confounder, a factor (smoking, arsenic, silica, diesel exhaust) must be associated with, but not a consequence of, an exposure (radon), independent of its association with the exposure (radon), and associated with the outcome (lung cancer). For example, if lung cancer is more likely to occur among older people and being older is associated with an increased likelihood of being a smoker, then the observed association between smoking and lung cancer might simply reflect the association between age and lung cancer.

### How are smoking, radiation, and lung cancer related?

Smoking is the leading cause of lung cancer. The majority of persons know that cigarette smoke and tobacco contain toxic substances, including tar, arsenic, nicotine, and cyanide. Common dangers of cigarettes have been known for decades. However, a limited number of persons know tobacco also contains radioactive materials (e.g., polonium-210 and lead-210). Together, toxic and radioactive substances in cigarettes harm smokers. They also harm persons exposed to secondhand smoke.

Radioactive materials, like polonium-210 and lead-210 are found naturally in the soil and air. They are also found in the high-phosphate fertilizers that farmers use on their crops. Polonium-210 and lead-210 get into and onto tobacco leaves and remain there even after the tobacco has been processed. When a smoker lights a cigarette and inhales the tobacco smoke, the toxic and radioactive substances in the smoke enter the lungs where they can cause direct and immediate damage to cells and tissues. The same toxic and radioactive substances can also damage the lungs of persons nearby.

Polonium 210 and lead-210 accumulate for decades in the lungs of smokers. Sticky tar in the tobacco builds up in the small air passageways in the lungs (bronchioles) and radioactive substances get trapped. Over time, these substances can lead to lung cancer. CDC studies have shown that smoking causes 80% of all lung cancer deaths among women and 90% of all lung cancer deaths among men. Source: <http://www.cdc.gov/nceh/radiation/smoking.htm>.

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<sup>3</sup> A total of 11 studies of underground miners were published through the early 1990s. All had poor statistical power. Most indicated that radon had either no cancer risk or a beneficial effect, and none clearly showed a harmful effect. A pooled epidemiological evaluation of 11 U.S. miner studies was conducted to increase the statistical power, was published in 1995, and showed that radon did cause lung cancer. It was not until 2000 for silica and 2012 for diesel exhaust particles that these substances were identified as known human carcinogens. Those confounders have yet to be addressed with the miner results, so that the actual radon lung cancer risk for miners may be lower than previously thought. The magnitude of this change has not been evaluated. Pooled epidemiological studies of residential indoor radon lung cancer risk have since demonstrated that indoor radon does cause lung cancer. Those studies may be better than the miner studies for estimating radon lung cancer risk and mortality rates in the U.S.



## Part 2: Public health surveillance of radon levels and smoking in the United States.

### What is public health surveillance?

Public health surveillance is the ongoing, systematic collection, analysis, interpretation, and dissemination of data concerning health-related events for use in public health action to reduce morbidity and mortality and to improve health. It uses data to monitor health problems to facilitate prevention or control. Evaluation of surveillance data can be useful in setting priorities; planning and conducting disease prevention and control programs; and in assessing effectiveness of these efforts. For example, identifying geographic areas or populations with higher rates of disease can be helpful in planning control programs, targeting interventions, and monitoring effectiveness of interventions.

1. Go online to the AirChek, Inc. website at <http://www.radon.com/> and click the *Radon levels in your area* link. Choose your state by clicking on your state name. Then, choose *County levels* in the site menu. Choose your county. On the first row of the Table 1, fill in your county name and the average indoor radon level in picocuries per liter (pCi/L). If data is not available for your county, you may need to choose a different county for this activity. The data presented by AirChek, Inc. was collected from Air Chek, Inc., the U.S. EPA, and various state and county health departments. Dates collected vary.

### What is a picocurie?

Picocurie (pCi): The curie is a standard measure of the rate at which radioactive materials are transforming (decaying) in a sample, e.g., in a liter of air. The basis for the curie is the radioactivity of one gram of radium. Radium decays at a rate of about 2.2 trillion disintegrations ( $2.2 \times 10^{12}$ ) per minute. A picocurie is one trillionth of a curie. Thus, a picocurie (abbreviated as pCi) is the amount of material in which 2.2 atoms of radioactive material decay per minute, termed disintegrations per minute. To put the relative size of one trillionth into perspective, consider that if the Earth were reduced to one trillionth of its diameter, the "picoEarth" would be smaller in diameter than a speck of dust. In fact, it would be six times smaller than the thickness of a human hair.

### What is the average indoor radon level?

The average indoor radon level is estimated to be about 1.3 pCi/L, and about 0.4 pCi/L of radon is normally found in the outside air. The U.S. Congress has set a long-term goal that indoor radon levels be no more than outdoor levels. Although this goal is not yet technologically achievable in all cases, the majority of homes today can be reduced to 2 pCi/L or below. The EPA recommends that average indoor radon levels be below 4 pCi/L, and that levels above this should be reduced through remediation.

2. Go online to County Health Rankings & Roadmaps website at <http://www.countyhealthrankings.org/> and scroll down to the *Select a Measure* and *Select a State* drop-down menu. Choose *Adult Smoking* as your measure and your state. Find your county and fill in percentages of adults who are current smokers on the first row of the Table 1.
3. Find two additional counties in your state that have similar percentages of adults who are current smokers (within 2–3 percentage points). Fill in row 2 and row 3 of Table 1 with the name of these counties and the percentages of adults who are current smokers.

4. Use the directions in step 1 and step 2 for the two additional counties identified in step 3, Page County, and the United States. Fill in Table 1.

**Table 1.** Radon and Lung Cancer surveillance exercise

Title of your data table:

Column 1	2	3	4	5	6
County	Average Radon Level (pCi/L)	Percentage of Adults who Currently Smoke	Lung Cancer Annual Incidence Rate per 100,000 Persons	Conversion (Multiply column three by 0.1 to estimate that 10% of all lung cancer is	Lung Cancer Potentially from Radon Exposure per 100,000 Persons
[Your county]				× 0.1	
				× 0.1	
				× 0.1	
				× 0.1	
				× 0.1	
				× 0.1	
				× 0.1	
				× 0.1	
				× 0.1	
				× 0.1	
Page County, Iowa	9.4 (Answer)	16.3% (Answer)	92.8 (Answer)	× 0.1	9.28 (Answer)
U.S. Average	1.3 (Answer)	17.8%	63.7 (Answer)	× 0.1	6.37 (Answer)

## Part 2, Questions

1. a. How does your county's average indoor radon level compare with the U.S. average indoor radon level?
  - b. Is the average indoor radon level higher than the U.S. average indoor radon level for any of your counties in your state?
  - c. Go to <http://www.epa.gov/radon/whereyoulive.html> and create an online map for radon levels in your state. Describe patterns among data.
  
2. a. How does your county's percentage of adults who currently smoke compare with the U.S. percentage?
  - b. Why were you asked to choose two additional counties with similar smoking rates?
  
3. a. What is the average indoor radon level in Page County, Iowa?
  - b. On the basis of the radon risk charts in A Citizen's Guide to Radon (<http://www.epa.gov/radon/citizens-guide-radon-guide-protecting-yourself-and-your-family-radon>), how does the risk for lung cancer from radon exposure compare with the risk for lung cancer from cigarette smoke?
  - c. How does it compare with the risk for those who never smoked?

### Part 3: Public health surveillance of lung cancer incidence

1. Go online to the State Cancer Profiles website at <http://statecancerprofiles.cancer.gov/incidencerates/index.php>. Using the drop down menus: Choose *state*: your state, *cancer*: lung; *race/ethnicity*: all races; *sex*: both sexes; and *age*: all ages. Find your county. On the first row of Table 1, fill in your county name and the annual incidence rate of lung cancer per 100,000 persons.

#### **What is an incidence rate?**

An incidence rate describes how much disease or injury occurs among a population and is standardized to a rate per 100,000 persons per year. Standardizing it to the number of cases per 100,000 persons per year allows you to compare regions with substantial populations to those with limited populations. It is calculated by dividing the number of new cases of disease or injury during a specified period by the total population during that period. In this case, it is the number of new cases of lung cancer from the most current period, per 100,000 persons per year.

#### **What is a confidence interval?**

Next to the annual average incidence rate, the online table displays a 95% confidence interval in parentheses. Statistics are used to analyze lung cancer data. Results are based on probability, or the likelihood, that an event will occur. A 95% confidence interval, the interval used most commonly by epidemiologists, indicates that researchers are 95% confident that the true value lies within the range given. For example, the annual incidence rate in Georgia is shown as 68.8 (68.0, 69.6). Researchers are 95% confident the annual incidence lung cancer rate during 2008–2012 is between 68.0 and 69.6 per 100,000 persons. Because this is a limited range, it is supportive of the estimate of 68.8 per 100,000 persons per year.

2. Repeat step 1 for all counties in your table, including Page County, Iowa, and the U.S. rate.
3. Report your findings to your teacher. Your teacher will complete Table 1 on the board. Use Table 1 on the board to complete your table. You should now have data for 10 counties in your state, Page County, Iowa, and the United States

### Part 3, Questions

1.
  - a. How does your county's lung cancer incidence rate compare with the U.S. rate?
  
  - b. Is the lung cancer incidence rate higher than the U.S. rate for any of your counties in your state?
  
  - c. Using the State Cancer Profiles website at <http://statecancerprofiles.cancer.gov/incidencerates/index.php>, choose the *Make a Map* option for your state. Describe patterns among data.
  
2.
  - a. In Iowa, the average annual count of lung cancer was 2,393 cases during 2008–2012. Which county in Iowa had the highest number of cases?
  
  - b. What was the average annual incidence rate in this county?
  
  - c. Using Page County, Iowa and the county you identified in question 2a, explain why discussing the average annual incidence rate rather than the number of cases is important.

#### Part 4: Comparing radon and lung cancer surveillance data

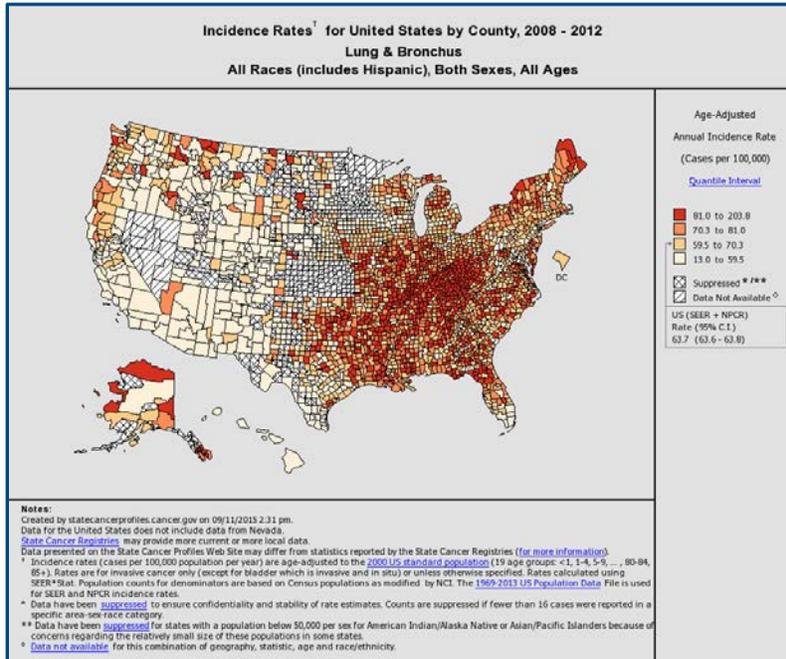
The World Health Organization estimates that radon causes 3%–14% of all lung cancers, depending on the average radon level in a country (<http://www.who.int/mediacentre/factsheets/fs291/en/>). In the United States, radon is responsible for approximately 21,000 lung cancer deaths every year, approximately 10% of lung cancers deaths, with 2,900 of these deaths occurring among persons who had never smoked (<http://www2.epa.gov/radon/health-risk-radon>).

1. To estimate the number of lung cancer deaths associated with lung cancer, multiply the incidence of lung cancer by 10% or 0.1 for each county. Note: this calculation is for the purpose of this activity; smoking rates by county that confound this association are not considered beyond using counties with similar smoking rates, and exposure to other carcinogens is not considered. Fill the last column of Table 1 with this data.
2. Graph the data from Table 1 to formulate a scatter plot. Do not include data for Page County, Iowa. The X-axis will be radon level (pCi/L) and the Y-axis will be lung cancer incidence possibly attributable to radon (cases/100,000 persons). Title the scatter plot and label each axis. When using Excel<sup>®</sup> (Microsoft Corporation, Redmond, Washington), add a line of best fit to the graph to look for an association among the numbers.

#### Scatter Plot

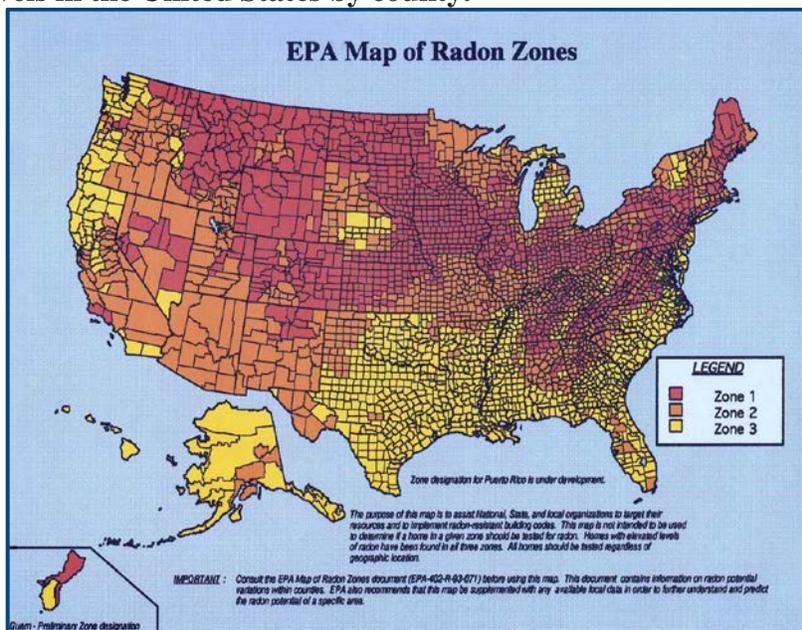


**Figure 2: Incidence rates per 100,000 persons of lung and bronchus cancer for the United States by county.**



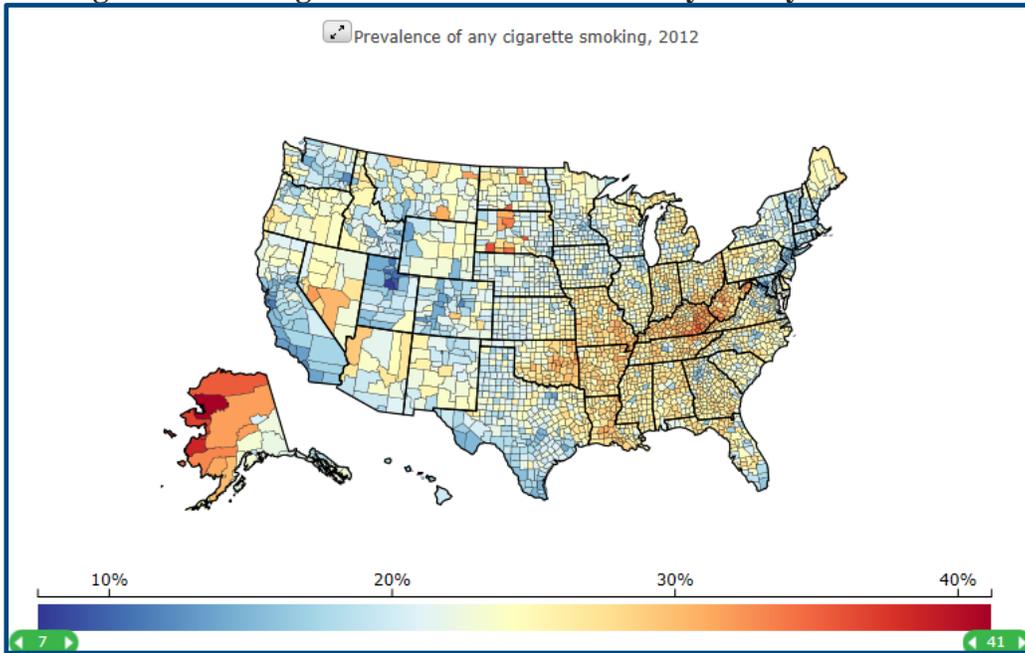
This map, courtesy of National Cancer Institute’s State Cancer Profiles, provides a visual representation of lung cancer rates in the United States. Source: <http://statecancerprofiles.cancer.gov/map/map.noimage.php>.

**Figure 3: Radon levels in the United States by county.**



This map, courtesy of the EPA, provides a visualization of radon levels in the United States by county. Zone 1 counties (red) have a predicted average indoor radon screening level >4pCi/L, Zone 2 counties (orange) 2-4 pCi/L, and Zone 3 counties (yellow) <2pCi/L. Source: <http://www.epa.gov/radon/zonemap.html>.

**Figure 4: Adult cigarette smoking rates in the United States by county.**



This map, courtesy of the Institute for Health Metrics and Evaluation provides a visualization of adult smoking in the U.S. by county.

Source: <http://vizhub.healthdata.org/us-health-map/>.

4. If approximately 322.7 million persons are living in the United States, what is the number of lung cancer cases attributable to nonsmoking (and possibly radon) exposure? Hint: use the U.S. data from Table 1.
5. Consider the long-term elevated exposure levels to radon needed to potentially cause lung cancer. On the basis of the patterns or lack of patterns, what additional data or information might you consider? Hint: What other confounders might you consider besides cigarette smoking?

## Appendix 1B: Worksheet 1: Data by County, Answer Key

# Lurking Radon and Lung Cancer Data by County

Name: \_\_\_\_\_ Answer Key \_\_\_\_\_

Date: \_\_\_\_\_

**Directions:** Read the information below about radon. Then, follow the step-by-step directions to complete the table on page 26. Use your table to help answer questions as you go.

Radon is an odorless, colorless, radioactive gas produced naturally from the breakdown, or by the radioactive decay, of uranium. Rocks, soil, and groundwater contain uranium and serve as radon sources. Radon comes from multiple sources and every person is continuously exposed to it throughout their life. Exposure results from breathing air in buildings, in homes, and outdoors (inhalation) and by eating or drinking (ingestion). Radon gas seeps through cracks in buildings and become trapped in well-insulated and poorly ventilated areas exposing occupants to the radioactive gas. Radon exposure can lead to cancer of the lung (including the bronchus).<sup>4</sup> Radon testing is the only way to know if levels are high in a particular home or building. Even comparable homes next to each other can have widely different levels.

Lung cancer is the leading cause of cancer-related death and radon is the second leading cause of lung cancer in the United States. Radon is estimated to cause approximately 10% of all lung cancers in the United States. The U.S. Environmental Protection Agency (EPA) and the Surgeon General's office estimate that radon is responsible for 21,000 lung cancer deaths each year, with 2,900 of these deaths occurring among persons who have never smoked. Identifying any immediate symptoms related to radon exposure is not possible, and years will pass before health problems appear, if they appear at all. Whether in workplaces, homes, or schools, understanding how radon gets into buildings, its health effects, and ways to reduce its level are important. Source: [http://www.cdc.gov/nceh/radiation/brochure/profile\\_radon.htm](http://www.cdc.gov/nceh/radiation/brochure/profile_radon.htm)

Radon levels and lung cancer rates can be tracked nationwide by using public health surveillance systems. In this activity, you will analyze public health surveillance data and looking for geographic patterns between the two.

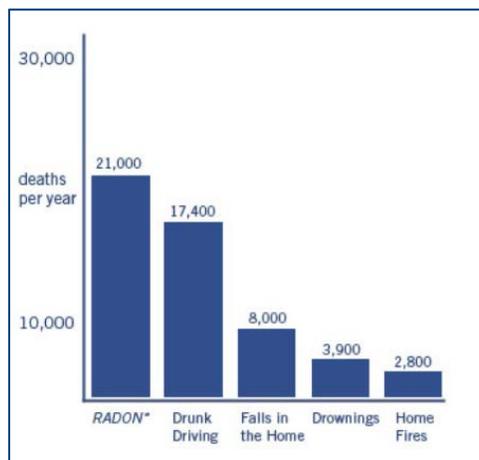


Figure 1. Radon is estimated to cause thousands of lung cancer deaths in the United States per year. According to EPA's 2003 Assessment of Risks from Radon in Homes, radon is estimated to cause about 21,000 lung cancer deaths per year. The number of deaths from other causes are taken from CDC's 2005–2006 National Center for Injury Prevention and Control Report and 2006 National Safety Council Reports. See: <http://www.epa.gov/radon/pubs/citguide.html> for more information.

<sup>4</sup> Lung cancer data are often presented as “cancer of the lung and bronchus.” The bronchus is part of the lung and separate data are rarely given. In the interest of simplicity and brevity, the term “lung cancer” is used here to refer to “cancer of the lung and bronchus.”

## Part 1: Confounding

To analyze public health data and identify associations between lung cancer and radon exposure, considering smoking is important. Smoking is the leading cause of lung cancer. In a location where smoking rates, radon levels, and lung cancer rates are high, it is more likely that lung cancer is associated with smoking rates rather than radon levels. In other words, smoking confounds the association between radon exposure and lung cancer. Two additional confounders exist, and they are silica dust and diesel exhaust particles to which the early miners and some members of the public were heavily exposed.<sup>5</sup>

### What is confounding?

Confounding is the distortion of the association between an exposure and a health outcome by a third factor that is related to both, called the confounder. To be a confounder, a factor (smoking, arsenic, silica, diesel exhaust) must be associated with, but not a consequence of, an exposure (radon), independent of its association with the exposure (radon), and associated with the outcome (lung cancer). For example, if lung cancer is more likely to occur among older people and being older is associated with an increased likelihood of being a smoker, then the observed association between smoking and lung cancer might simply reflect the association between age and lung cancer.

### How are smoking, radiation, and lung cancer related?

Smoking is the leading cause of lung cancer. The majority of persons know that cigarette smoke and tobacco contain toxic substances, including tar, arsenic, nicotine, and cyanide. Common dangers of cigarettes have been known for decades. However, a limited number of persons know tobacco also contains radioactive materials (e.g., polonium-210 and lead-210). Together, toxic and radioactive substances in cigarettes harm smokers. They also harm persons exposed to secondhand smoke.

Radioactive materials, like polonium-210 and lead-210 are found naturally in the soil and air. They are also found in the high-phosphate fertilizers that farmers use on their crops. Polonium-210 and lead-210 get into and onto tobacco leaves and remain there even after the tobacco has been processed. When a smoker lights a cigarette and inhales the tobacco smoke, the toxic and radioactive substances in the smoke enter the lungs where they can cause direct and immediate damage to cells and tissues. The same toxic and radioactive substances can also damage the lungs of persons nearby.

Polonium 210 and lead-210 accumulate for decades in the lungs of smokers. Sticky tar in the tobacco builds up in the small air passageways in the lungs (bronchioles) and radioactive substances get trapped. Over time, these substances can lead to lung cancer. CDC studies have shown that smoking causes 80% of all lung cancer deaths among women and 90% of all lung cancer deaths among men. Source: <http://www.cdc.gov/nceh/radiation/smoking.htm>.

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<sup>5</sup> A total of 11 studies of underground miners were published through the early 1990s. All had poor statistical power. Most indicated that radon had either no cancer risk or a beneficial effect, and none clearly showed a harmful effect. A pooled epidemiological evaluation of 11 U.S. miner studies was conducted to increase the statistical power, was published in 1995, and showed that radon did cause lung cancer. It was not until 2000 for silica and 2012 for diesel exhaust particles that these substances were identified as known human carcinogens. Those confounders have yet to be addressed with the miner results, so that the actual radon lung cancer risk for miners may be lower than previously thought. The magnitude of this change has not been evaluated. Pooled epidemiological studies of residential indoor radon lung cancer risk have since demonstrated that indoor radon does cause lung cancer. Those studies may be better than the miner studies for estimating radon lung cancer risk and mortality rates in the U.S.

**How are silica, diesel exhaust particles, radiation, and lung cancer related?**

Silica (especially freshly cracked silica) and diesel exhaust particles have been identified as known human carcinogens. Not accounting for these confounders can greatly overestimate the lung cancer risk from radon. For example, in a Chinese tin mine study, finally accounting for arsenic as a confounder reduced the estimated lung cancer risk by a factor of 4. Accounting for silica exposure in an iron mine with low radon levels reduced the relative risk for radon by 31%.

**Part 1, Questions**

1. In your own words, explain how smoking, silica dust, and diesel exhaust particles can confound the association between lung cancer incidence and radon exposure.

**Answer:** Answers will vary. If lung cancer is more likely to occur among smokers and smoking is associated with an increased likelihood of radon exposure, then the observed association between radon and lung cancer might simply reflect the association between smoking and lung cancer. To identify if it is a confounder, the association between smoking and the likelihood of radon exposure has to be explored. If lung cancer occurs in individuals who were also exposed to silica dust or diesel exhaust particles, then the risk from radon will be a portion of the total risk.

2. How might you account for confounding when analyzing lung cancer incidence and radon exposure data?

**Answer:** Answers will vary. Two strategies are to analyze data for smokers and nonsmokers separately and to analyze data from counties that have similar rates of smoking. It is unclear how to proceed on evaluating lung cancer risk to individuals who also were exposed to silica or diesel exhaust particles.

## Part 2: Public health surveillance of radon levels and smoking in the United States.

### What is public health surveillance?

Public health surveillance is the ongoing, systematic collection, analysis, interpretation, and dissemination of data concerning health-related events for use in public health action to reduce morbidity and mortality and to improve health. It uses data to monitor health problems to facilitate prevention or control. Evaluation of surveillance data can be useful in setting priorities; planning and conducting disease prevention and control programs; and in assessing effectiveness of these efforts. For example, identifying geographic areas or populations with higher rates of disease can be helpful in planning control programs, targeting interventions, and monitoring effectiveness of interventions.

1. Go online to the AirChek, Inc. website at <http://www.radon.com/> and click the *Radon levels in your area* link. Choose your state by clicking on your state name. Then, choose *County levels* in the site menu. Choose your county. On the first row of the Table 1, fill in your county name and the average indoor radon level in picocuries per liter (pCi/L). If data is not available for your county, you may need to choose a different county for this activity. The data presented by AirChek, Inc. was collected from Air Chek, Inc., the U.S. EPA, and various state and county health departments. Dates collected vary.

### What is a picocurie?

Picocurie (pCi): The curie is a standard measure of the rate at which radioactive materials are transforming (decaying) in a sample, e.g., in a liter of air. The basis for the curie is the radioactivity of one gram of radium. Radium decays at a rate of about 2.2 trillion disintegrations ( $2.2 \times 10^{12}$ ) per minute. A picocurie is one trillionth of a curie. Thus, a picocurie (abbreviated as pCi) is the amount of material in which 2.2 atoms of radioactive material decay per minute, termed disintegrations per minute. To put the relative size of one trillionth into perspective, consider that if the Earth were reduced to one trillionth of its diameter, the "picoEarth" would be smaller in diameter than a speck of dust. In fact, it would be six times smaller than the thickness of a human hair.

### What is the average indoor radon level?

The average indoor radon level is estimated to be about 1.3 pCi/L, and about 0.4 pCi/L of radon is normally found in the outside air. The U.S. Congress has set a long-term goal that indoor radon levels be no more than outdoor levels. Although this goal is not yet technologically achievable in all cases, the majority of homes today can be reduced to 2 pCi/L or below. The EPA recommends that average indoor radon levels be below 4 pCi/L, and that levels above this should be reduced through remediation.

2. Go online to County Health Rankings & Roadmaps website at <http://www.countyhealthrankings.org/> and scroll down to the *Select a Measure* and *Select a State* drop-down menu. Choose *Adult Smoking* as your measure and your state. Find your county and fill in percentages of adults who are current smokers on the first row of the Table 1.
3. Find two additional counties in your state that have similar percentages of adults who are current smokers (within 2–3 percentage points). Fill in row 2 and row 3 of Table 1 with the name of these counties and the percentages of adults who are current smokers.

4. Use the directions in step 1 and step 2 for the two additional counties identified in step 3, Page County, and the United States. Fill in Table 1.

**Table 1.** Radon and Lung Cancer surveillance exercise

Title of your data table: **Answer:** Radon exposure level and lung cancer incidence per 100,000 persons by county; **Answers to table:** Answers will vary. Verify school county data before the lesson.

Column 1	2	3	4	5	6
County	Average Radon Level (pCi/L)	Percentage of Adults who Currently Smoke	Lung Cancer Annual Incidence Rate per 100,000 Persons	Conversion (Multiply column three by 0.1 to estimate that 10% of all lung cancer is caused by	Lung Cancer Potentially from Radon Exposure per 100,000 Persons
[Your county]				× 0.1	
				× 0.1	
				× 0.1	
				× 0.1	
				× 0.1	
				× 0.1	
				× 0.1	
				× 0.1	
				× 0.1	
				× 0.1	
Page County, Iowa	9.4 (Answer)	16.3% (Answer)	92.8 (Answer)	× 0.1	9.28 (Answer)
U.S. Average	1.3 (Answer)	17.8%	63.7 (Answer)	× 0.1	6.37 (Answer)

## Part 2, Questions

1. a. How does your county's average indoor radon level compare with the U.S. average indoor radon level?  
**Answer:** Answers will vary depending on school's county. The U.S. average is 1.3 pCi/L.
- b. Is the average indoor radon level higher than the U.S. average indoor radon level for any of your counties in your state?  
**Answer:** Answers will vary. The U.S. average is 1.3 pCi/L.
- c. Go to <http://www.epa.gov/radon/whereyoulive.html> and create an online map for radon levels in your state. Describe patterns among data.  
**Answer:** Answers will vary.
2. a. How does your county's percentage of adults who currently smoke compare with the U.S. percentage?  
**Answer:** Answers will vary. The U.S. average is 17.8%.
- b. Why were you asked to choose two additional counties with similar smoking rates?  
**Answer:** Smoking potentially confounds the association between radon and lung cancer. By identifying counties that have similar smoking rates, it helps to control smoking as a factor, and allows for comparison among counties.
3. a. What is the average indoor radon level in Page County, Iowa?  
**Answer:** 9.4 pCi/L
- b. On the basis of the radon risk charts in A Citizen's Guide to Radon (<http://www.epa.gov/radon/citizens-guide-radon-guide-protecting-yourself-and-your-family-radon>), how does the risk for lung cancer from radon exposure compare with the risk for lung cancer from cigarette smoke?  
**Answer:** For every 1,000 persons exposed to 10 pCi/L during a lifetime, and who smoke, it means approximately 150 of those 1,000 persons might develop lung cancer. This is comparable with 200 times the risk for dying in a home fire. Source: A Citizen's Guide to Radon (Page 5).
- c. How does it compare with the risk for those who never smoked?  
**Answer:** For every 1,000 persons exposed to 10 pCi/L during a lifetime, and who never smoke, it means approximately 18 of those 1,000 persons might develop lung cancer. This is comparable with 20 times the risk for dying in a home fire. Source: A Citizen's Guide to Radon (Page 5).

### Part 3: Public health surveillance of lung cancer incidence

1. Go online to the State Cancer Profiles website at <http://statecancerprofiles.cancer.gov/incidencerates/index.php>. Using the drop down menus: Choose *state*: your state, *cancer*: lung; *race/ethnicity*: all races; *sex*: both sexes; and *age*: all ages. Find your county. On the first row of Table 1, fill in your county name and the annual incidence rate of lung cancer per 100,000 persons.

#### **What is an incidence rate?**

An incidence rate describes how much disease or injury occurs among a population and is standardized to a rate per 100,000 persons per year. Standardizing it to the number of cases per 100,000 persons per year allows you to compare regions with substantial populations to those with limited populations. It is calculated by dividing the number of new cases of disease or injury during a specified period by the total population during that period. In this case, it is the number of new cases of lung cancer from the most current period, per 100,000 persons per year.

#### **What is a confidence interval?**

Next to the annual average incidence rate, the online table displays a 95% confidence interval in parentheses. Statistics are used to analyze lung cancer data. Results are based on probability, or the likelihood, that an event will occur. A 95% confidence interval, the interval used most commonly by epidemiologists, indicates that researchers are 95% confident that the true value lies within the range given. For example, the annual incidence rate in Georgia is shown as 68.8 (68.0, 69.6). Researchers are 95% confident the annual incidence lung cancer rate during 2008–2012 is between 68.0 and 69.6 per 100,000 persons. Because this is a limited range, it is supportive of the estimate of 68.8 per 100,000 persons per year.

2. Repeat step 1 for all counties in your table, including Page County, Iowa, and the U.S. rate.
3. Report your findings to your teacher. Your teacher will complete Table 1 on the board. Use Table 1 on the board to complete your table. You should now have data for 10 counties in your state, Page County, Iowa, and the United States

### Part 3, Questions

1. a. How does your county's lung cancer incidence rate compare with the U.S. rate?  
**Answer:** Answers will vary depending on school's county.
  - b. Is the lung cancer incidence rate higher than the U.S. rate for any of your counties in your state?  
**Answer:** Answers will vary.
  - c. Using the State Cancer Profiles website at <http://statecancerprofiles.cancer.gov/incidencerates/index.php>, choose the *Make a Map* option for your state. Describe patterns among data.  
**Answer:** Answers will vary by state.
2. a. In Iowa, the average annual count of lung cancer was 2,393 cases during 2008–2012. Which county in Iowa had the highest number of cases?  
**Answer:** Polk County, Iowa.
  - b. What was the average annual incidence rate in this county?  
**Answer:** 60.4 cases per 100,000 persons per year.
  - c. Using Page County, Iowa and the county you identified in question 2a, explain why discussing the average annual incidence rate rather than the number of cases is important.  
**Answer:** On average, Polk County had more cases of lung cancer than Page County. Page County, however, had a higher incidence of lung cancer than Polk County. This indicates that Polk County likely has a larger population than Page County, but Page County has a greater risk for lung cancer among its smaller population. Thus, discussing rates rather than number of cases is important, because they account for the number of persons living in the county (or the population density), which helps to make the data more comparable across counties.

#### Part 4: Comparing radon and lung cancer surveillance data

The World Health Organization estimates that radon causes 3%–14% of all lung cancers, depending on the average radon level in a country (<http://www.who.int/mediacentre/factsheets/fs291/en/>). In the United States, radon is responsible for approximately 21,000 lung cancer deaths every year, approximately 10% of lung cancers deaths, with 2,900 of these deaths occurring among persons who had never smoked (<http://www2.epa.gov/radon/health-risk-radon>).

1. To estimate the number of lung cancer deaths associated with lung cancer, multiply the incidence of lung cancer by 10% or 0.1 for each county. Note: this calculation is for the purpose of this activity; smoking rates by county that confound this association are not considered beyond using counties with similar smoking rates, and exposure to other carcinogens is not considered. Fill the last column of Table 1 with this data.
2. Graph the data from Table 1 to formulate a scatter plot. Do not include data for Page County, Iowa. The X-axis will be radon level (pCi/L) and the Y-axis will be lung cancer incidence possibly attributable to radon (cases/100,000 persons). Title the scatter plot and label each axis. When using Excel<sup>®</sup> (Microsoft Corporation, Redmond, Washington), add a line of best fit to the graph to look for an association among the numbers.

#### Scatter Plot

**Answer:** Answers will vary.

#### Part 4, Questions

1. Describe any patterns in data or on the scatter plot.

**Answer:** Answers will vary.

2. Review the radon map (Part 2, Question 1c) and lung cancer map (Part 3, Question 1c) for your state.

- a. Compare the two maps. Describe patterns that are consistent in both maps.

**Answer:** Answers will vary.

- b. Find the map for your state related to smoking on <http://vizhub.healthdata.org/us-health-map/>. How does it compare with the maps in Part A?

**Answer:** Answers will vary.

- c. What, if any, conclusions can you draw about radon exposure and lung cancer in your state? Explain your answer.

**Answer:** Answers will vary. Students should consider cigarette smoking in their answer.

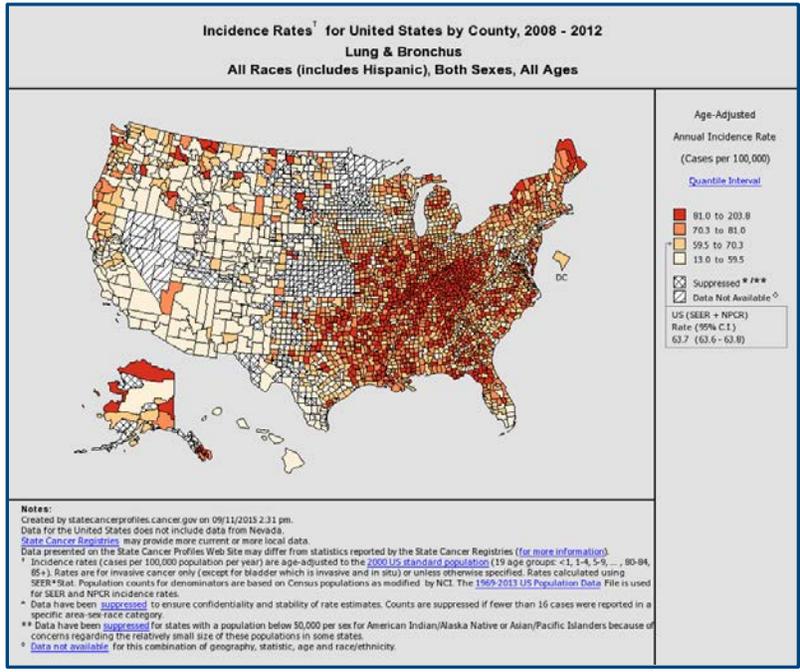
3. a. Using Figures 2–4, identify and describe any patterns in the United States.

**Answer:** Substantial radon levels, adult smoking, and high incidence rates of lung and bronchus cancer in the lower regions of the Appalachian Trail are identified. **Note:** During a class discussion, this is a good time to reiterate that cigarette smoking is the leading cause of lung cancer and cigarette smoking is higher in these regions so an associated higher amount of lung cancer might be expected.

- b. What, if any, conclusions can you draw about radon exposure and lung cancer? Explain your answer.

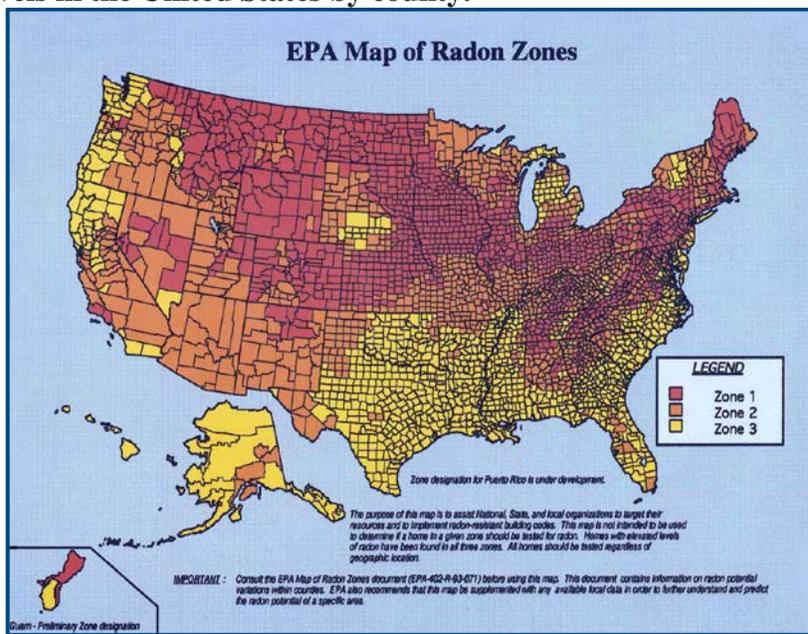
**Answer:** Answers will vary. The high radon levels might contribute to lung cancer incidence rates; however, the high rates of cigarette smoking are more likely associated. Exposure to other carcinogens should be considered in the evaluation.

**Figure 2: Incidence rates per 100,000 persons of lung and bronchus cancer for the United States by county.**



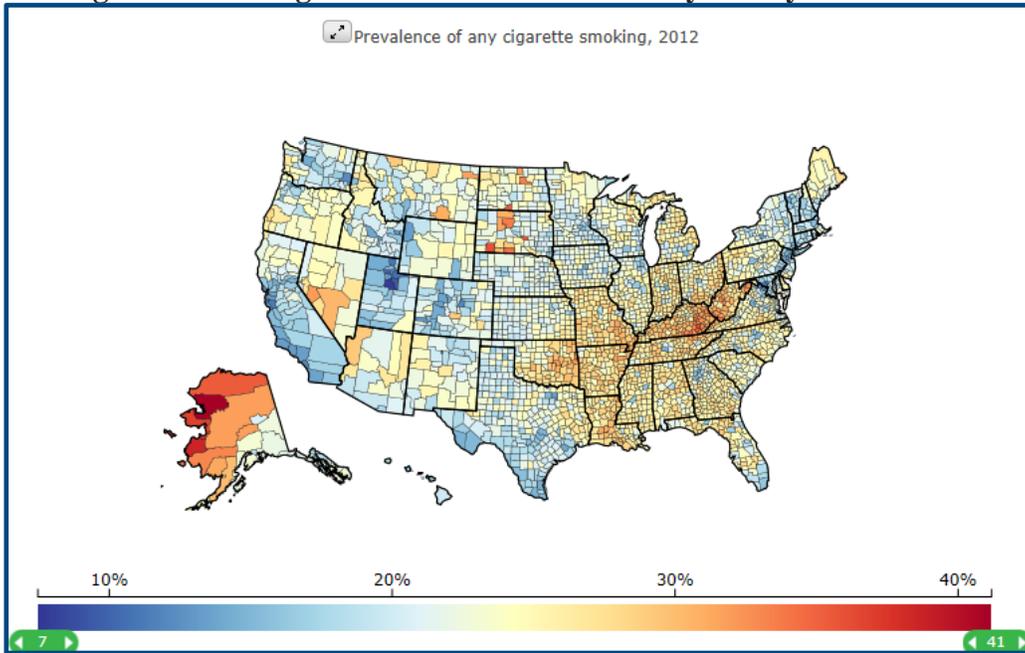
This map, courtesy of National Cancer Institute’s State Cancer Profiles, provides a visual representation of lung cancer rates in the United States. Source: <http://statecancerprofiles.cancer.gov/map/map.noimage.php>.

**Figure 3: Radon levels in the United States by county.**



This map, courtesy of the EPA, provides a visualization of radon levels in the United States by county. Zone 1 counties (red) have a predicted average indoor radon screening level >4pCi/L, Zone 2 counties (orange) 2-4 pCi/L, and Zone 3 counties (yellow) <2pCi/L. Source: <http://www.epa.gov/radon/zonemap.html>.

**Figure 4: Adult cigarette smoking rates in the United States by county.**



This map, courtesy of the Institute for Health Metrics and Evaluation provides a visualization of adult smoking in the U.S. by county.

Source: <http://vizhub.healthdata.org/us-health-map/>.

4. If approximately 322.7 million persons are living in the United States, what is the number of lung cancer cases attributable to nonsmoking (and possibly radon) exposure? Hint: use the U.S. data from Table 1.

**Answer:**  $322,700,000 \times (63.7/100,000 \text{ Lung Cancer Annual Incidence Rate}) = 205,560$  persons per year.

5. Consider the long-term elevated exposure levels to radon needed to potentially cause lung cancer. On the basis of the patterns or lack of patterns, what additional data or information might you consider? Hint: What other confounders might you consider besides cigarette smoking?

**Answer:** Answers will vary, but can include considering radon levels in previous years that are based on the age of lung and bronchus cancer ages, identifying any interventions that might have improved radon levels over the years, or stratifying lung cancer data by age, race/ethnicity, or sex to identify other data patterns. Other factors that might influence the interpretation include whether homes were tested or mitigated for high radon levels and the duration of exposure.



**Table**

Use the table to describe the key drivers and strategies to reduce radon in schools and how those might translate to your school. As you fill in the table, think about which strategies would work best for your school.

Hint: see [http://www.epa.gov/iaq/schools/managing\\_radon.html](http://www.epa.gov/iaq/schools/managing_radon.html).

<b>Strategies</b>	<b>Summarize the strategies in action</b>	<b>Would this work at your school? In your explanation, consider potential obstacles and how to overcome them.</b>
<b>Organize for success</b>		

Strategies	Summarize the strategies in action	Would this work at your school? In your explanation, consider potential obstacles and how to overcome them.
<b>Communicate with everyone all the time</b>		

<b>Strategies</b>	<b>Summarize the strategies in action</b>	<b>Would this work at your school? In your explanation, consider potential obstacles and how to overcome them.</b>
<b>Act to address structural, institutional and behavioral issues</b>		

<b>Strategies</b>	<b>Summarize the strategies in action</b>	<b>Would this work at your school? In your explanation, consider potential obstacles and how to overcome them.</b>
<b>Plan your short- and long-term activities</b>		
<b>Evaluate your results for continuous improvement</b>		

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## Appendix 2B: Indoor Air Quality: School Action Plan, Answer Key

# Indoor Air Quality School Action Plan

Name: \_\_\_\_\_

Date: \_\_\_\_\_

Directions: Read the prompt below. Then, review the two resources that follow. To prepare for a class discussion during the next class period, complete the questions and table.

### Prompt

After you test for radon at your school, you find that your school has substantial radon levels. Review the indoor air quality design tool for schools and decide on an action plan as a class.

### Resources

- A Citizen's Guide to Radon: <http://www.epa.gov/radon/pubs/citguide.html>.
- Design Tool for Managing Radon in Schools:  
[http://www.epa.gov/iaq/schools/managing\\_radon.html](http://www.epa.gov/iaq/schools/managing_radon.html).

### Questions

1. How common is it to find high radon levels in schools?

**Answer:** A nationwide survey of radon levels in schools estimates that 19.3% of U.S. schools, approximately one in five, have at least one frequently occupied ground-contact room with short-term radon levels at or above the EPA guideline level of 4 pCi/L (picocurie per Liter), the level at which EPA recommends mitigation. Source: EPA. Indoor Air Quality (IAQ) design tool, Appendix G. Available at: <http://www.epa.gov/iaq/schools/tfs/guideg.html>.

2. If radon levels above 4 pCi/L are found in a school, does it affect all classrooms?

**Answer:** No. Approximately 73% of schools found to have radon levels at or above 4 pCi/L will have only five or fewer schoolrooms with radon levels above the action level. The other 27% will have six or more such schoolrooms. If a building has a radon problem, it is unlikely that every room in the school will have an elevated radon level. Source: EPA. IAQ design tool, appendix G. Available at: <http://www.epa.gov/iaq/schools/tfs/guideg.html>.

**Table**

Use the table to describe the key drivers and strategies to reduce radon in schools and how those might translate to your school. As you fill in the table, think about which strategies would work best for your school.

Hint: see [http://www.epa.gov/iaq/schools/managing\\_radon.html](http://www.epa.gov/iaq/schools/managing_radon.html).

Strategies	Summarize the strategies in action	Would this work at your school? In your explanation, consider potential obstacles and how to overcome them.
<b>Organize for success</b>		
<b>Answer:</b> Secure senior leadership buy-in	<b>Answer:</b> Encourage administrators and facilities managers to talk with radon professionals to share their stories and solicit advice. Partner with parent groups, local health departments, facilities and maintenance organizations, and other credible organizations to build understanding, trust, and support.	<b>Answer:</b> Answers will vary.
<b>Answer:</b> Develop a systematic approach	<b>Answer:</b> Use the IAQ Tools for Schools Action Kit to tie your goals for radon testing to your overarching IAQ and health and environmental program goals. Coordinate this effort with existing IAQ management program activities.	<b>Answer:</b> Answers will vary.
<b>Answer:</b> Build an effective team	<b>Answer:</b> Assemble a multidisciplinary team to plan for radon testing and mitigation. Include on your team a trained radon professional; start by talking with your state radon program representative. Invite members from existing IAQ or health and safety committees, facilities managers, air-conditioning technicians, IAQ professionals, school administrators, other staff, and parents.	<b>Answer:</b> Answers will vary.
<b>Answer:</b> Design standard operating procedures	<b>Answer:</b> Develop districtwide radon management procedures and adapt testing protocols and remedial action steps according to the needs of each school.	<b>Answer:</b> Answers will vary.

Strategies	Summarize the strategies in action	Would this work at your school? In your explanation, consider potential obstacles and how to overcome them.
<b>Communicate with everyone all the time</b>		
<b>Answer:</b> Make the radon program meaningful	<b>Answer:</b> Include radon awareness as part of your overall IAQ management training and education efforts. Share with parents and staff the association between radon and building operations, and encourage them to test their homes, because the home is often the most substantial source of radon exposure.	<b>Answer:</b> Answers will vary.
<b>Answer:</b> Be transparent and inclusive	<b>Answer:</b> Communicate your action plan to stakeholders and the importance of radon testing. Share your testing results, mitigation plans and follow-up testing plans. In cases of elevated radon levels, ensure that your mitigation plan is in place so you can communicate those plans to parents. Invite stakeholders to examine the concern and be part of the solution. Once a home or building is tested and found to have elevated levels, there will be a financial cost for remediation activities, so clearly communicate the need, look for available funding mechanisms, and identify how the community might do some of the work.	<b>Answer:</b> Answers will vary.
<b>Assess your environments continuously</b>		
<b>Answer:</b> Walk the grounds	<b>Answer:</b> Perform radon assessments in conjunction with your regular IAQ walkthroughs. Obtain floor plans to estimate the number of test kits needed and to determine where to place the test kits. If elevated radon levels are found, survey your buildings for structural or mechanical issues that might be allowing radon to enter (e.g., foundation crack, expansion joints, subslab, HVAC ducts, and building pressurization patterns).	<b>Answer:</b> Answers will vary.

<b>Answer:</b> Use technology	<b>Answer:</b> Track radon test results, assessment data and pending actions on a spreadsheet or in an electronic work order system to build awareness of emerging priorities so that facility maintenance can plan accordingly.	<b>Answer:</b> Answers will vary.
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Strategies	Summarize the strategies in action	Would this work at your school? In your explanation, consider potential obstacles and how to overcome them.
<b>Act to address structural, institutional and behavioral issues</b>		
<b>Answer:</b> Test for radon	<b>Answer:</b> Test according to your plan.	<b>Answer:</b> Answers will vary.
<b>Answer:</b> Implement radon reduction plans	<b>Answer:</b> If you find high radon levels and need mitigation services, consider hiring a mitigation contractor. Certain states have restrictions on who can test for or mitigate a school building. Consult with your state radon office for state-specific recommendations.	<b>Answer:</b> Answers will vary.
<b>Answer:</b> Train occupants to identify radon risks	<b>Answer:</b> Attend radon training to learn about radon and how to effectively test, mitigate, and maintain radon reduction. Empower maintenance and facilities staff to become radon champions, because occupants will likely refer to them for answers about the testing plan and mitigation actions.	<b>Answer:</b> Answers will vary.
<b>Answer:</b> Educate staff about radon	<b>Answer:</b> Include teachers in your testing process to foster awareness and create support. Encourage them to incorporate radon into lesson plans by having students participate in radon-related science projects or in the National Radon Poster Contest.	<b>Answer:</b> Answers will vary.

Strategies	Summarize the strategies in action	Would this work at your school? In your explanation, consider potential obstacles and how to overcome them.
<b>Plan your short- and long-term activities</b>		
<b>Answer:</b> Work in stages	<b>Answer:</b> Working with your radon team, identify your action steps and set a schedule for your testing plan. Determine what type of test kits to use, which rooms will be tested, and plan to retest for longer periods each area exceeding 4 pCi/L. Your state radon program can help you identify next steps and offer other guidance throughout the process of testing and mitigation.	<b>Answer:</b> Answers will vary.
<b>Answer:</b> Prioritize actions	<b>Answer:</b> Identify funding and staff resources available for testing and mitigation. If mitigation is necessary, then initiate radon reduction in the highest radon-risk areas first since radon from those high areas might be migrating to other areas.	<b>Answer:</b> Answers will vary.
<b>Evaluate your results for continuous improvement</b>		
<b>Answer:</b> Solicit feedback	<b>Answer:</b> Request feedback from your radon testing team, district stakeholders, and parents to improve the radon management process. Identify best practices that can improve your process for future follow-up radon testing.	<b>Answer:</b> Answers will vary.
<b>Answer:</b> Ensure continuity of radon Management Plan	<b>Answer:</b> Determine additional testing needs and follow-up. Retest according to plan if schools were mitigated to ensure radon mitigation systems are functioning properly. Schedule retesting after all major renovations, and consider how HVAC modifications or upgrades can affect radon intrusion.	<b>Answer:</b> Answers will vary.

Appendix 2C: School Action Plan Rubric

## School Indoor Air Quality – Class Action Plan Rubric

	<b>Did not Meet Expectations [60%]</b>	<b>Almost Met Expectations [70%]</b>	<b>Met Expectations [90%]</b>	<b>Exceeded Expectations [100%]</b>
<b>Overall</b>				
<b>Aligned with the Framework for Effective School IAQ management</b>	Only included at least 3 of the 6 key drivers, but strategies for action were unclear	Included at least 4 of the 6 key drivers, and strategies for action were mostly clear	Included at least 5 of the 6 key drivers, and strategies for action were mostly clear	Included all of the key drivers, and strategies for action were clear
<b>Feasibility</b>	The strategies for action were not feasible at our school	A limited number of strategies for action were feasible at our school	The majority of the strategies for action were feasible at our school	All of the strategies for action were feasible at our school
<b>Teamwork</b>	A limited number of persons developed the action plan and a few others contributed	At least half the class developed the action plan and a limited number of others contributed substantially	The majority of the class developed the action plan, and a limited number of others contributed substantially	The class worked as a team to develop this action plan
<b>Individual</b>				
<b>Speaking</b>	Contributed at least one time to the discussion	Contributed at least two times to the discussion	Contributed at least three times to the discussion	Contributed at least four times to the discussion
<b>Skilled techniques</b>	Asked at least one question to continue the conversation	Asked at least two questions to continue the conversation	Asked at least three questions to continue the conversation	Asked at least four questions to continue the conversation
<b>Listening</b>	Was not always respectful and did not keep eye contact, face the speaker, or was distracted at times.	Was respectful, but did not make eye contact, face the speaker and keeping all distractions away.	Was respectful by making eye contact, facing the speaker and keeping all distractions away.	Lead the class by reminding others to keep eye contact, to face the speaker and to put distractions away.