RADON MEASUREMENTS IN SCHOOLS—BEST PRACTICES--LECTURE
What we will discuss

- What is radon?
- Why we should care.
- Occurrence
- Protocols for testing
- Interpreting results
- Follow up and Mitigation Strategies
EPA Map of Radon Zones

The purpose of this map is to assist National, State, and local organizations to target their resources and to implement radon-resistant building codes. This map is not intended to be used to determine if a home in a given zone should be tested for radon. Homes with elevated levels of radon have been found in all three zones. All homes should be tested regardless of geographic location.

IMPORTANT: Consult the EPA Map of Radon Zones document (EPA-402-R-93-071) before using this map. This document contains information on radon potential variations within counties. EPA also recommends that this map be supplemented with any available local data in order to further understand and predict the radon potential of a specific area.
Radon Properties

- Radon
  - Colorless
  - Odorless
  - Tasteless
  - Radioactive gas
  - Widely prevalent in soil and rock
  - Produces other radioactive elements
  - Can have high concentrations indoors
Radon is a Cancer Causing Radioactive Gas

- Different in that its atoms ‘emit particles and change’ at a given rate.
- Inert gas—does not react within the soil.
- #1 cause of lung cancer in non smokers
- #2 cause of lung cancer in smokers.
Radon Decay Scheme
The pCi/l

- Nuclei decay at given rates:
  - 1 pCi/l = 2.2 dis./min./l
Why 4 pCi/l?

Choice made in 1986

- We could mitigate to below 4 pci/l.
- False positives and false negatives would be minimized. I.e. we were confident at measuring down to 4 pCi/l.
- At 4 pCi/l, each lung cancer death saved costs $700,000.
- At 3 pCi/l, each lung cancer death saved costs $1.7 million
- At 2 pCi/l, each lung cancer death saved costs $2.4 million
- Outside, northern hemisphere about 0.4pci/l.
<table>
<thead>
<tr>
<th>Location</th>
<th>Action Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>United Kingdom, Norway, Canada</td>
<td>5.4 pCi/l</td>
</tr>
<tr>
<td>Greece, China</td>
<td>10.8 pCi/l</td>
</tr>
<tr>
<td>Switzerland</td>
<td>27 pCi/l</td>
</tr>
</tbody>
</table>
Corroborating Agencies

- US EPA
- US Surgeon General
- American Lung Association
- World Health Organization
- United Nations Scientific Committee on the Effects of Atomic Radiation
How much is too much?

- Action guide---4 pCi/l

- Consider action 2-4 pCi/l
Virginia requires schools be tested since 1994. ref: Va code 22.1-138B

Legend
- Zone 1: Highest Potential (greater than 4 pCi/L)
- Zone 2: Moderate Potential (from 2 to 4 pCi/L)
- Zone 3: Low Potential (less than 2 pCi/L)

48 reds
23 orange
30 yellow
National vs Virginia

- Nationally 15% of all homes ≥ 4pCi/l
- Virginia 20-25% of all homes ≥ 4pCi/l*

*Results indicate radon levels are not elevated in Tidewater, Va, E. of Interstate 90
Why Be Concerned

- 21,000 estimated deaths/yr.
- Widespread contamination in schools at the national level.
- 20% of all schools will have at least one room with a concentrations greater than 4 pCi/l. (nationwide)
Why be Concerned (cont’d)

- EPA recommends testing all schools.
- Every state is expected to have some schools where radon levels are $> 4$ pCi/l.
- Some schools have been found with concentrations $> 100$ pCi/l.
- Class A carcinogen
National School Data

- About 2.7% of ground contact classrooms have radon conc. > 4 pCi/l
- About 19.3% of the nations public schools have at least one ground contact room above 4 pCi/l—That’s about 70,000 rooms!
National Cancer Institute's 2010 Surveillance, Epidemiology, and End Results (SEER)
Annual Radon Related Lung Cancer Deaths
US EPA, Sept, 2007

It takes an estimated 1,542 Mitigations or 5,292 RRNC to save a life

State

CA PA OH IL NY IN GA TN NJ FL VA MD KY TX MI MN MO CO WI NC IA AL AZ

4-5 Draft Sep-07
Who Can Test?

Certified Testers

- Increased costs---$1000 and up/building
- Fewer details for school staff
- Must be NRSB or NRPP certified

School Staff

- Much lower costs—especially if the school intends to repeat testing later---$150/building
- More control of when and other conditions
- Increased education of staff
- Greater sensitivity of staff to testing
No two school buildings alike

- Soil gas concentrations may be different
- Building structures are different
- HVAC designs and operations may be different
 DETECTIVE MYSTERY

- No one knows ahead of time where the radon concentrations will be a problem.
- It will be our job to ‘hunt down’ and identify those rooms.
Radon Entry

- Cracks in solid floors
- Construction joints
- Cracks in walls
- Gaps in suspended floors
- Gaps around service pipes
- Cavities inside walls
- The water supply
- HVAC operations
- Pressure driven flows
HVAC AFFECTS

- May increase ventilation
- May decrease ventilation
- May pressurize a building
- May depressurize a building
Measurement Methods

- Charcoal Canisters
- Liquid Scintillation
- Alpha Track
- Electret
- Continuous Monitors
Charcoal Canisters

- They adsorb the radon gas
- The Radon gas continues to decay
- They must be Returned to lab for analysis quickly.
LSC Vial or Charcoal Canisters

- Weapons of choice:
Liq. Scin. (Cont’d)

- Small amount of charcoal in vial which is deployed just like charcoal canisters.
- When returned to the lab, a small amount of liquid ‘cocktail’ is inserted into the vial.
- The emissions of the radon and daughters ‘light up’ the cocktail and that light is measured by the LS counter. The more light, the more radon.
- These must be returned promptly to the lab.
Alpha Track

- Most commonly used for long term measurements.

Courtesy Accustar
Electrets
Continuous Radon Monitors (CRM)

- Pylon AB-5
RAMP UP TIME

Idealized
Measurement strategy
Initial, then Followup

- Initial
  - Short Term (2-90 days)
    - all frequently occupied rooms in contact with the ground.
    - All rooms to be tested should be tested simultaneously.
    - During the school year, preferably during the heating season.

- OR

- Long Term
  - Greater than 90 days up to one school year.
If Initial (Screening) is Short Term

☐ Followup is either short or long term

☐ Do a follow-up test in every room with a short-term, initial test result of 4 pCi/L or greater.

☐ Perform them in the same location and under the same conditions as the Initial measurement and simultaneously.

☐ If the initial result is between 4 and 10 pCi/l,
  - Followup may be either short or long term.

☐ If the initial result is >10 pCi/l,
  - Followup is recommended to be short term and to be done immediately.

☐ All followups to be done simultaneously
Take Action based on results

☐ If the average of two short term measurements is equal to or greater than 4 pCi/l.

☐ OR

☐ If the result of a long term follow-up measurement is equal to or greater than 4pCi/l.
Testing per Design

- Slab on Grade
- Open-Plan or Pod design
- Crawl Space Design
- Basement Design
Slab on Grade

- Measure only frequently occupied rooms in contact with the ground.
- Not: closets, storage rooms, etc.
Open-Plan or Pod Design

- If sections of a pod have moveable walls that can physically separate them from other sections, measure each section separately.

- If moveable walls are absent or inoperable, measure the pod as one room placing detectors every 2000 square feet.
Crawl Space Design

- If classrooms are above an enclosed crawl space, measure rooms directly above the crawl space.
In addition to measuring all frequently occupied basement rooms and rooms with a floor or wall with ground contact, measure all rooms that have no ground-contact but that are directly above a basement space that is not frequently occupied.
Detector Placement Concerns

- Do not place detectors near drafts resulting from heating, ventilating vents, air conditioning vents, fans, doors, and windows.
- Place detectors where they are least likely to be disturbed or covered up. (Teacher’s desk?)
- Do not place detectors in direct sunlight or in areas of high humidity.
Detector Placement Concerns (Cont’d)

- Place detectors at least approximately 20 inches from the floor and 4 inches from other objects and away from the exterior walls of the building and 3 feet from windows, 1 foot from exterior walls.

- Place detectors about every 2,000 square feet for large spaces.

- Do not disturb the test device at any time during the test.
When to Test--Initially

- Under closed conditions (closed windows/doors except for normal exit/entry).
- After 12-hours of closed building conditions when using a 2 to 5-day test (e.g., initiate testing after a weekend).
- During colder months (October through March, depending on geographical location).
- During weekdays with HVAC systems operating normally when conducting a 2 to 5-day test.
Actual School Room Measurements
When Not to Test

- During abnormal weather or barometric conditions (e.g., storms and high winds).
  - Check the weather
- During structural changes to a school building and/or the renovation or replacement of the HVAC system.
**Decision-Making Flow Chart**

Make initial short-term (2-day to 3-month) measurements in all frequently-occupied, ground-contact school rooms during the coldest months of the heating season.

- **Is the result \( \geq 4\) pCi/L?**
  - **YES**
    - Assess the urgency of the situation in each room, based on the result of the highest initial measurement. For higher radon levels (e.g. \( > 10\) pCi/L), consider conducting a short-term, follow-up test.
    - **Short-term Follow-up Test**
      - Do the short-term follow-up test in the same location as the initial measurement and (if possible) during the coldest months of the heating season.
        - **Is the average of the initial and follow-up tests \( \geq 4\) pCi/L?**
          - **NO**
            - Conduct diagnostic testing and develop a mitigation strategy. The higher the radon level the greater the urgency for mitigation.
              - **Consider retesting in the future.**
          - **YES**
            - Conduct diagnostic testing and develop a mitigation strategy. The higher the radon level the greater the urgency for mitigation.
    - **Long-term Follow-up Test**
      - Confirm using a 9-month measurement during the school year immediately following the initial test period.
        - **Is the follow-up measurement result \( \geq 4\) pCi/L?**
          - **NO**
            - Conduct diagnostic testing and develop a mitigation strategy. The higher the radon level the greater the urgency for mitigation.
          - **YES**
            - Consider retesting in the future.
How Quickly to Mitigate

- How quickly to begin the diagnostic measurements that precede mitigation will depend on the urgency of the situation as dictated by the radon level detected. Elevated radon concentrations (e.g., several times the action level or around 10 pCi/L) demand a quicker response.

- In addition, if radon levels are near 100 pCi/L or greater, school officials should call their State Radon Contact and consider relocating students and staff until the levels can be reduced.
Diagnostic Tools
Mitigation Techniques

- Active Soil Depressurization (ASD or SSD)
- HVAC proper operation and Maintenance
- HVAC pressurization and Ventilation
- Re-locate
SUB SLAB DEPRESSURIZATION
QUALITY ASSURANCE

- Why do QA?
- Duplicates—10% of devices deployed, but not more than 50 (Side by side measurements—4 in. apart)
- Blanks—5% of devices deployed, not more than 25 (Unopened)
Precision vs. Accuracy
Quality Assurance

- **Blanks**
  - Should return with values close to 0.0 pCi/l
  - May come back saying e.g. <0.5 pCi/l
  - Do not deploy, but do unwrap.
Quality Assurance Duplicate log

<table>
<thead>
<tr>
<th>D₁</th>
<th>D₂</th>
<th>M</th>
<th>M ≥ 4</th>
<th>RPD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

D₁ and D₂ are the radon values of one duplicate pair, M is the mean of the two, RPD is the relative percent difference. N represents the total number of duplicate pairs whose mean value is equal to or greater than 4 pCi/l and TRPD is the sum of the RPD column.
### Table

<table>
<thead>
<tr>
<th>$D_1$</th>
<th>$D_2$</th>
<th>$M$</th>
<th>$M \geq 4^*$</th>
<th>RPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.4</td>
<td>1.2</td>
<td>1.3</td>
<td>X</td>
<td>10.2</td>
</tr>
<tr>
<td>0.8</td>
<td>1.1</td>
<td>1.0</td>
<td>X</td>
<td>7.5</td>
</tr>
<tr>
<td>3.9</td>
<td>3.5</td>
<td>3.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.6</td>
<td>5.1</td>
<td>4.9</td>
<td>X</td>
<td>10.2</td>
</tr>
<tr>
<td>4.1</td>
<td>3.8</td>
<td>4.0</td>
<td>X</td>
<td>7.5</td>
</tr>
<tr>
<td>0.3</td>
<td>2.0</td>
<td>1.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.8</td>
<td>0.5</td>
<td>0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.4</td>
<td>7.2</td>
<td>6.8</td>
<td>X</td>
<td>11.8</td>
</tr>
<tr>
<td>4.2</td>
<td>2.5</td>
<td>3.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.8</td>
<td>2.4</td>
<td>2.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td>2.3</td>
<td>2.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td>3.7</td>
<td>4.1</td>
<td>X</td>
<td>19.5</td>
</tr>
<tr>
<td>0.5</td>
<td>0.6</td>
<td>0.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>N</th>
<th>TRPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>49.0</td>
</tr>
</tbody>
</table>

\[ M = \frac{D_1 + D_2}{2} \]

\[ RPD = \left| \frac{D_1 - D_2}{M} \right| \times 100\% \]

\[ ARPD = \frac{TRPD}{N}\% \]

If ARPD > 25%, contact lab.
Checklist

☐ 1. Planning the Testing Program.
☐ 2. Deploying the devices—use anti tampering ideas.
☐ 3. Record Keeping.
☐ 4. Retrieving the devices.
☐ 5. Preparing the devices for laboratory analysis.
☐ 6. Quality Assurance
☐ 7. Letters to teachers, staff and parents
1. Planning the Testing Program

- Plan to test in early part of cold season.
- Consider holidays.
- Count the number of rooms to be tested.
- Add 15% for duplicates and blanks
  - This sum is the number of detectors needed.
- Make sure the device is NRSB/NRPP or state approved.
- Use a simple floor plan, e.g.
<table>
<thead>
<tr>
<th>102</th>
<th>104</th>
<th>106</th>
<th>108</th>
<th>110</th>
<th>112</th>
<th>114</th>
<th>116</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Central</th>
<th>Hallway</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>103</td>
</tr>
<tr>
<td>D</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>105</th>
<th>107</th>
<th>109</th>
<th>111</th>
<th>113</th>
<th>115</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B=blank  
D=duplicate
- Choose a location in each room and put this information on the device placement log.
- Identify those rooms to be used for duplicates and blanks with a D or B on the sample floor plan.
- Count the number of detectors when they arrive and read the directions carefully.
## DEVICE PLACEMENT LOG

<table>
<thead>
<tr>
<th>Room # name</th>
<th>location</th>
<th>Serial #</th>
<th>Start date</th>
<th>Start time</th>
<th>Stop date</th>
<th>Stop time</th>
<th>remarks</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>s. Wall cabinet</td>
<td>65093</td>
<td>1/15/2012</td>
<td>7:22am</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>D</td>
<td>97033</td>
<td>“</td>
<td>7:24am</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>102</td>
<td>Bookshelf</td>
<td>93277</td>
<td>“</td>
<td>7:46am</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>93278</td>
<td>“</td>
<td>7:50am</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2. Deploying the devices

- Notify students and staff prior to deployment.
- Fill out the Device Placement Log while deploying the devices.
- Fill out the QA log while deploying devices.
- Deploy all detectors on the same day. (Tape, paper clips, string.)
- Be careful recording the dates and times when detectors are ‘opened’. Times may be in 5 minute increments.
- Duplicates should be placed 4 inches apart.
- Place “Radon Test in Progress” labels near or on detectors.
Blanks

☐ Do not deploy blanks

■ But record them as if they were deployed in customary rooms.*

☐ Complete any detector forms sent by the laboratory.
3. Record Keeping

- In the comments section, record any unusual weather information, e.g. storms, high winds, building conditions, etc.
4. Retrieving the devices

- Follow detector instructions.
- Confirm the location and serial number with what’s previously filled out on the log sheet.
- Check for damage.
- Record dates and times on the log sheet.
- Sign the log sheet.
# Device Placement Log

<table>
<thead>
<tr>
<th>Room #</th>
<th>location</th>
<th>Serial #</th>
<th>Start date</th>
<th>Start time</th>
<th>Stop date</th>
<th>Stop time</th>
<th>remarks</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>s. Wall cabinet</td>
<td>65093</td>
<td>1/15/2012</td>
<td>7:22am</td>
<td>1/18/2012</td>
<td>4:34pm</td>
<td>Slight damage</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>D</td>
<td>97033</td>
<td>“</td>
<td>7:24am</td>
<td>“</td>
<td>4:45pm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>102</td>
<td>Bookshelf</td>
<td>93277</td>
<td>“</td>
<td>7:46am</td>
<td>“</td>
<td>4:47pm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>93278</td>
<td>“</td>
<td>7:50am</td>
<td>“</td>
<td>4:47pm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## How’s this device placement log?

<table>
<thead>
<tr>
<th>Room name</th>
<th>location</th>
<th>serial number</th>
<th>start date</th>
<th>start time</th>
<th>stop date</th>
<th>stop time</th>
<th>remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>s. wall cabinet</td>
<td>65093</td>
<td>1/15/2012</td>
<td>7:22 a.m.</td>
<td>1/18/2012</td>
<td>4:34pm</td>
<td>slight damage</td>
</tr>
<tr>
<td>102</td>
<td>left on teachers desk</td>
<td>93277</td>
<td>1/15/2012</td>
<td>7:25 a.m.</td>
<td>1/18/2012</td>
<td>4:36pm</td>
<td></td>
</tr>
<tr>
<td>104</td>
<td>on left window sill</td>
<td>10455</td>
<td>1/15/2012</td>
<td>7:31 a.m.</td>
<td>1/18/2012</td>
<td>4:38pm</td>
<td></td>
</tr>
<tr>
<td>108</td>
<td>center bookshelf</td>
<td>20543</td>
<td>1/15/2012</td>
<td>7:25 a.m.</td>
<td>1/18/2012</td>
<td>4:40pm</td>
<td></td>
</tr>
<tr>
<td>109</td>
<td>in corner, on floor</td>
<td>93276</td>
<td>1/15/2012</td>
<td>7:32 a.m.</td>
<td>1/18/2012</td>
<td>4:44pm</td>
<td>found on teacher's desk</td>
</tr>
<tr>
<td>110</td>
<td>above the first ceiling tile</td>
<td>40404</td>
<td>1/15/2012</td>
<td>7:35 a.m.</td>
<td>1/18/2012</td>
<td>4:48pm</td>
<td></td>
</tr>
<tr>
<td>102</td>
<td>in left top drawer of teachers</td>
<td>21345</td>
<td>1/18/2012</td>
<td>7:40 a.m.</td>
<td>1/12/2012</td>
<td>4:50pm</td>
<td></td>
</tr>
<tr>
<td>112</td>
<td>On file cabinet in rear</td>
<td>81222</td>
<td>1/15/2012</td>
<td>7:42 a.m.</td>
<td>1/18/2012</td>
<td>4:52pm</td>
<td></td>
</tr>
</tbody>
</table>

Signature: I.M. Good
Preparing the Devices for Analysis

- Prepare the blanks (fill out the forms).
- Check the log sheet to be sure it’s complete.
- Return Detectors.
- Wait for the results (7 to 10 days).
Prior To Releasing results

☐ Double check for correctness.
☐ Perform and Review all QA calculations.
☐ Place radon concentrations on building plan.
☐ Look for clusters.
☐ Release results via report.
If you need help with interpreting results, contact

- Ryan Paris, Radon Coordinator, VDH
  - 1-804-864-8161
  - Email: Ryan.Paris@vdh.virginia.gov

Or call University Educational Services, Inc.
- 1-570-350-0799
SUMMARY

PRIOR TO TESTING

- Establish floor plan
- Identify rooms to be tested (Label on floor plan as “T”)
- Count up number of detectors needed
  - Include additional 15% for blanks and duplicates.
- Order detectors and anti-tampering devices.
- Check detectors when they arrive for damage, labeling and proper quantity.
SUMMARY

PRIOR TO TESTING (cont’d):
- Establish testing dates
- Check weather forecast and change testing dates as needed.
- Inform all staff and students of dates tests will be ongoing. (provide educational materials)
- Deploy Detectors and complete detector log forms.
DURING TESTING

☐ Record unusual weather.
SUMMARY

- AFTER TESTING
  - Retrieve detectors
  - Check for damage, and labeling.
  - Fill in detector log form.
  - Ship.
SUMMARY

- UPON RECEIPT OF RESULTS
  - Complete log forms.
  - Review blank results.
  - Calculate all QA/QC calculations and assess.
  - Review for clusters.
  - Plan for Confirmatory tests.
  - Create Report. (After confirmatory tests)
Do you have an emergency?

- If so, contact Ryan Paris
  - 1-804-864-8161 or
  - Ryan.Paris@vdh.virginia.gov
FAQs

1. Does radon cause headaches, eye irritation, or sick building syndrome?

   NO

2. Is there any hazard involved in handling radon measurement devices?

   NO
3. Are building materials likely to contain or emit radon?

- Some phosphogypsum materials may emit radon but this material is rare in American buildings.
- Some concrete and cinder blocks may emit radon but the concentrations due to them are likely to be insignificant. (There have been exceptions.)
References

- **RADON MEASUREMENT IN SCHOOLS** Self-Paced Training Workbook  
  EPA 402-8-94-001 October 1994
- **RADON MEASUREMENTS IN SCHOOLS**—Revised Edition EPA 402-R-92-014, July 1993  
  (Use “Corrections in the Second Printing”)
- Radon Reduction Techniques in Schools EPA 520/1-89-020