Radon: Still a Danger?

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Outline

• Brief Review of Radon
  – What the Science Says
• Review of Evidence on Measurement and Mitigation
• WHO Environmental Burden of Disease from Inadequate Housing (Radon)
• National Healthy Housing Standard
• Federal Radon Action Plan
• BARRIER Study
• Conclusions
What is Radon?

• A decay product of uranium, radon is a colorless, odorless radioactive gas that occurs naturally in soil and rock.

• It moves through fractures and porous substrates in the foundations of buildings.

• Collects in high concentrations in certain areas.

• Radon may also enter a house through water systems in communities where groundwater is the main water supply.
A Brief History of Radon

• 1879  excess lung cancer rate among underground miners

• 1896  Henri Becquerel discovers natural radioactivity

• 1924  link between radon and lung cancer suggested

• 1956  cause identified as radon daughters

• 1984  Stanley Watras of Limerick, PA, nuclear power plant worker sets off alarm going to work
Tissue damage and repair ↔ illness → death
Cell death and replacement ↔ illness → death
Disruption of DNA replication → mutation/birth defects
Errors in cell repair/replacement → cancer
Radon decay

*in the ground*

uranium-238 $\Rightarrow \Rightarrow$ radium-226 $\Rightarrow$

4.5 billion years 1600 years

radon-222 *gas* has time to leak into the air $\Rightarrow \Rightarrow$

almost 4 days

lead-210 $\Rightarrow \Rightarrow$ lead-206

22 years stable

radon progeny (daughters)

radioactive isotopes of *lead*, *bismuth*, and *polonium* can be *inhaled and deposited in the lungs*
RADON GETS IN THROUGH:

1. Cracks in solid floors
2. Construction joints
3. Cracks in walls
4. Gaps in suspended floors
5. Gaps around service pipes
6. Cavities inside walls
7. The water supply
8. Floor drains

BUT DOESN’T GET OUT of tightly sealed homes

Sources
- Soil
- Groundwater
- Stone building materials

Sinks (for Rn and progeny)
- Ventilation
- Plate out (as vapor)
- Deposition (as particulate matter)
### A Soup of Radioactivity Units

<table>
<thead>
<tr>
<th><strong>Curie (Ci)</strong></th>
<th><strong>Unit of Activity (A)</strong></th>
<th>A = # of decays per second</th>
<th>**1 curie = (3.7 \times 10^{10}) Decays per second</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Becquerel (Bq)</strong></td>
<td>= 27 pCi</td>
<td></td>
<td><strong>1 decay per second</strong></td>
</tr>
</tbody>
</table>

### Roentgen Absorption Dose

<table>
<thead>
<tr>
<th><strong>RAD</strong></th>
<th><strong>Unit of Absorbed Dose (D)</strong></th>
<th>D = the energy absorbed per gram of tissue in the body</th>
<th><strong>1 rad = 100 ergs per gram</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gray (Gy)</strong></td>
<td>= 100 rad</td>
<td></td>
<td><strong>1 Gy = 1 joule/kg</strong></td>
</tr>
</tbody>
</table>

### Roentgen Equivalent Man (or Mammal)

<table>
<thead>
<tr>
<th><strong>REM</strong></th>
<th><strong>Unit of Dose Equivalent (II)</strong></th>
<th>H = the absorbed dose multiplied by a biological effectiveness factor (Q)</th>
<th><strong>rem = Q \times D</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sievert (Sv)</strong></td>
<td>= 100 rem</td>
<td>alpha particles are more dangerous than beta particles</td>
<td></td>
</tr>
</tbody>
</table>

### ROENTGEN

<table>
<thead>
<tr>
<th><strong>Unit of Ionizing Ability in Air</strong></th>
<th>= charge created in a volume of air</th>
<th>= 1 statcoul/cm³</th>
</tr>
</thead>
</table>
10,000 mSv (10 sieverts) in a short-term dose would cause immediate illness and subsequent death within a few weeks.

1,000 mSv (1 sievert) in a short term dose would probably cause (temporary) illness such as nausea and decreased white blood cell count, but not death. Above this, severity of illness increases with dose. As a dose accumulated over some time, 1000 mSv would probably cause a fatal cancer many years later in 5 of every 100 persons exposed to it.

50 mSv/yr is, conservatively, the lowest dose rate where there is any evidence of cancer being caused. It is also the dose rate which arises from natural background levels in several places. Above this, the probability of cancer occurrence (rather than the severity) increases with dose.

20 mSv/yr averaged over 5 years is the limit for nuclear industry employees and uranium or mineral sands miners, who are closely monitored.

3 mSv/yr (approx) is the normal background radiation from natural sources in North America, including an average of almost 2 mSv/yr from radon in air.

0.3-0.6 mSv/yr is a typical range of dose rates from artificial sources of radiation, mostly medical.

0.05 mSv/yr, a fraction of natural background radiation, is the design target for maximum radiation at the perimeter fence of a nuclear electricity generating station. In practice the actual dose is much less.
Indoor air quality issues: foam blowing insulation, household products, carbon monoxide, molds, vapors from glues and finishes in construction/furniture/fabrics, etc., etc., etc.

With more tightly constructed homes, indoor air pollutants are trapped inside.
Comparative U.S. Cancer Deaths in 2004
Comparison of Annual Deaths by Selected Causes

Source: EPA Home Buyers and Sellers Guide to Radon
Radon Exposure

- Exposure to radon gas is the leading cause of lung cancer among nonsmokers and the second leading cause of lung cancer overall, causing 21,000 deaths annually in the United States.

Health Effect Evidence

• Combined data from several previous residential studies show definitive evidence of an association between residential radon gas exposure and lung cancer.


EPA and NAS Risk Assessments

• EPA 2003
• NAS 1999 (BEIR – Biological Effects of Ionizing Radiation)

• Confirm previous risk estimates
• 4 pCi/liter, some evidence to support lowering allowable dose to 2 pCi/liter
Levels of Exposure

Estimated Lung Cancer Cases in a Population of 1,000

Lung Cancer Cases

4 pCi/L 8 pCi/L 10 pCi/L

Radon Exposure

Non-Smokers
Smokers

National Center for Healthy Housing
Healthy Homes Training Center
Geography and Geology

- Housing with high radon concentrations is more prevalent in certain regions of the country, but any house, regardless of region, can contain dangerous or unhealthy levels of radon
- EPA and Surgeon General recommend all houses be tested
Radon Logic Model

**FIGURE 1** Housing Interventions to Control Chemical Agents Ready for Implementation

<table>
<thead>
<tr>
<th>Interventions ready for implementation</th>
<th>Short-term objectives</th>
<th>Mid-term objectives</th>
<th>Long-term objectives</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Promote active radon air mitigation systems to reduce radon exposure in homes</td>
<td>Increase the number of homes tested for radon</td>
<td>Increase the number of homes that are below the EPA level of concern for radon (4 pCi/L)</td>
<td>Reduce the number of lung cancer cases and deaths due to radon</td>
<td>Healthier people living in homes with less exposure to harmful chemicals</td>
</tr>
<tr>
<td>Promote smoke-free homes policies</td>
<td>Increase the number of new homes constructed to be radon resistant</td>
<td>Reduce the proportion of children and nonsmokers who are regularly exposed to tobacco smoke at home</td>
<td>Reduce illnesses and deaths due to secondhand smoke</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increase the number of homes with smoke-free policies</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**RADON GAS MEASUREMENT METHODS**

**Activated Charcoal Adsorption**
- Radon is absorbed into a charcoal canister
- Short-term detector (equilibration over 2-7 days)
- Laboratory analysis by scintillation (gamma-ray)

**Alpha Track Detection**
- A plastic film is exposed (1 to 12 months)
- Alpha particles from radon decay produce damage tracks
- Number of damage tracks determined
- Integrating detector

**Continuous Radon Monitoring (Scintillation counter)**
- Radon decay event causes electric current pulse in device
- Real-time detector
- Signal can be electronically integrated (pulse counting)

**Electret Ion Chamber (Electrostatically charged disk detector)**
- Radon decay ionizes air
- Air conductivity increases, reducing voltage across chamber
- Real-time detector
- Signal can be electronically integrated

National Radon Safety Board
Short-term Test Reliability

- Tests of 2-4 days
  - Developed primarily for real estate transactions
  - EPA states that if the number is above 4 pCi/l a second test should be done, preferably a long-term test (90+ days)
  - WHO (2010) recommends a 90-day test to get a real sense of a radon issue
Short-term Test Reliability

• Tests of 2-4 days
  – Steck et al. (2005) showed that 2-4 day tests had a standard deviation of 70% compared to long-term averages, for homes that averaged 4.5 pCi/l long-term
  – This means that with a 2-4 day test, about one-third of the time it would be off by 3 pCi/l for these homes
    • This will exclude many homes that aren’t problems, and be highly inconclusive for homes that do read above 4 pCi/l
Evidence of testing ineffectiveness:

The short-term test variability (COV) decreases with the length of the test*:

Active & Passive

• Active soil depressurization is the creation of a negative pressure zone under the foundation so that soil gases are exhausted through the roof instead of entering the building using pipes & fan

• Passive uses only a pipe (no fan)
Passive Sub-SlabDepressurization System (New Construction)

A. Gas-Permeable Layer
B. Plastic Sheeting
C. Seal and Caulk
D. Vent Pipe
E. Junction Boxes
Fans Makes It An Active System
Evidence of active mitigation effectiveness

- Seven studies show that active radon mitigation strategies are effective in reducing exposure to radon in air to less than 4 pCi/L.

- Burkhart JF, Kladder DL. A comparison of indoor radon concentrations between preconstruction and post-construction mitigated single family dwellings. 1991; US Environmental Protection Agency
Radon Mitigation Studies

• Each of these studies enrolled a relatively large number of housing units, ranging from 73 to 238 units.
Radon Resistant New Construction

- Groves-Kirkby showed that active soil depressurization systems were far more effective than installation of membranes during construction.
Active System Effectiveness

• An EPA review concluded that 97% of houses with high baseline radon levels (76% had baseline radon levels ≥10 pCi/L) could be remediated with active soil depressurization systems to less than 4 pCi/L
National Survey Data

- Brodhead national survey
- Showed that 95% of homes undergoing active remediation were less than 4 pCi/L
- 69% were actually remediated to less than 2 pCi/L
- \( n = 238 \) houses.
Durability

- Dehmel showed that 95% of houses were remediated to less than 4 pCi/L 18 months after installation.
Passive Systems

• Several studies demonstrate that mitigation of airborne radon levels by using passive systems (i.e., no exhaust fan) does not consistently reduce indoor radon levels adequately or consistently over time.

Place for Passive Systems

• Passive radon mitigation systems can be effective in many cases and can serve as a cost-effective initial phase of an active mitigation system

• Install fan if passive doesn’t work
Installation & Maintenance

• Both effectiveness of passive systems alone and their cost-effectiveness as part of active systems depend on proper installation of the system components according to available technical guidance and maintenance over time

• Install pressure gauge
Radon in Drinking Water

- Mose et al showed that large reductions of radon in drinking water are achievable through filtration and aeration or a combination of both.
- However, the study also showed that even after filtration and aeration, radon can still be at levels exceeding the proposed EPA maximum contaminant level of 300 pCi/L.

Availability of Unpublished Literature on Radon

http://www.nchh.org/Search.aspx?Source=3&SearchIn=5&Name=radon&Status=0,1&Audience=&Principle=&Keywords=random&Author=&Journal=&From=&To=
Evidence Considered

► Clinical outcomes

► Environmental health outcomes
Peer Reviewed Housing Intervention Studies


Radon Mitigation and Reduced Moisture

• Example of multiple benefits (the healthy homes perspective)

• Radon mitigation does reduce moisture levels in one study (more on-going)

Florence Nightingale

“The connection between health and the dwelling of the population is one of the most important that exists.”

Miasma & Housing-Related Disease

The miasma that was thought to cause cholera was linked to the squalor of the poor.
Cuyahoga River ca. 1960
Is Housing a Shared Commons?

What is The Commons?
“The commons is everywhere. It is the air we breathe, the words we speak, the traditions we respect. It is tangible and intangible, ancient and modern, local and global. It is everything we inherit together, as part of a community, as distinct from things we inherit individually. It is everything that is not privately or state-owned. …”
Health in the Late 19th Century

• Challenge of Tuberculosis, Typhoid, Cholera Seemed Insurmountable

• Lessons for Public Health Officials, Architects and Planners: Light, Fresh Air, Reduce Crowding, Improve Sanitation.

• With Improved Living Conditions & Medical Interventions, Disease Rates Declined
Housing Market Price & Health: Unfinished Business

• Should a Radon Controlled Healthy Home Cost More?
• Why are Radon Home Investments Unlike Other Home Improvements?
• Finding Market Vehicles to Provide Incentives to Promote Environmental Health Investment in Homes & Communities
• Cost of NOT Making Homes & Communities Healthy
Green Communities
Minnesota Case Study
Green Communities Criteria

1. Integrated Design Process
2. Location and Neighborhood Fabric
3. Site
4. Water Conservation
5. Energy Conservation
6. Materials and Resources
7. Healthy Living Environment
8. Operations and Management
## Green Communities Criteria

### Basements and Concrete Slabs – Radon: New Construction

**7-11b**

MANDATORY
For New Construction

**How**

In EPA Zone 1 areas, install passive radon-resistant features below the slab along with a vertical vent pipe with junction box available, if an active system should prove necessary.
Unique Partnership for MN Project

- Southwest Minnesota Housing Partnership
- Minnesota Green Communities
- Greater Minnesota Housing Fund
- Center for Sustainable Building Research (CSBR) at the University of Minnesota
- Residents
- Property Managers and Owners
- National Center for Healthy Housing

- Funders:
  - Blue Cross Blue Shield Foundation of Minnesota
  - U.S. Environmental Protection Agency
  - Enterprise Community Partners
Green Rehab Elements - Health

- Ventilation: ASHRAE 62.2
- Low-VOC adhesives, paints & coatings.
- Radon testing in units before rehabilitation & post-construction.
- Pest management: Contracted with a pest management firm specializing in integrated pest management.
- Non-smoking common areas.
- No carpets in wet areas (kitchens, baths, laundry).
- Energy Star-labeled bathroom fans that exhaust to the outdoors and are equipped with a humidistat sensor or timer.
- Surface drainage of water away from windows, walls, and foundations. French drains installed around the perimeter of all buildings.
Other Green Rehab Elements

• High efficiency geothermal heating and cooling system.
• Enhanced insulation of the building envelope.
• Energy Star appliances.
• Water conserving appliances and fixtures.
• Cement fiber siding.
• Interior finish materials using recycled content.
• On-site recycling of demolition and construction materials.
Energy & Water Consumption

- 46% reduction in total energy use
- An estimated 39% reduction in CO$_2$ emissions from power plants.
Environmental burden of disease associated with inadequate housing

A method guide to the quantification of health effects of selected housing risks in the WHO European Region

Matthias Braubach
David E. Jacobs
David Ormandy
Population Attributable Fraction Due to Radon in Housing

PAF represents the proportion of lung cancer in the population that would be prevented if exposure to radon in the home were reduced to zero Becquerel/m³ or, more realistically, to the average outdoor radon concentration for the specific country.

The PAF estimate is then multiplied by the total burden of lung cancer. This results in an estimate of the proportion of cases, deaths and disability adjusted life years (DALYs) that can be ascribed to radon in the home.
Table 1: Radon surveys in dwellings in some European countries

<table>
<thead>
<tr>
<th>Country and population (millions)</th>
<th>No. of dwellings sampled</th>
<th>Period and approx. duration of measurement</th>
<th>Mean value Bq/m³</th>
<th>Geometric mean Bq/m³</th>
<th>Percent. &gt;200 Bq/m³</th>
<th>Percent. &gt;400 Bq/m³</th>
<th>Max. Bq/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria (8.2)</td>
<td>16 000</td>
<td>1991-2002, 3 months</td>
<td>97</td>
<td>61</td>
<td>12</td>
<td>4</td>
<td>8325</td>
</tr>
<tr>
<td>Belgium (10.4)</td>
<td>10 447</td>
<td>1995-present, 3 months</td>
<td>69</td>
<td>76</td>
<td>2.4</td>
<td>0.5</td>
<td>4500</td>
</tr>
<tr>
<td>Croatia (4.5)</td>
<td>782</td>
<td>2003-05, 1 year</td>
<td>68</td>
<td>n/a</td>
<td>7.2</td>
<td>1.8</td>
<td>751</td>
</tr>
<tr>
<td>Czech Republic (10.2)</td>
<td>&gt;150 000</td>
<td>1984-present, 1 year</td>
<td>140</td>
<td>110</td>
<td>12.0-18.0</td>
<td>2.0-3.0</td>
<td>25 000</td>
</tr>
<tr>
<td>Denmark (5.5)</td>
<td>3120</td>
<td>1995-96, 1 year</td>
<td>53</td>
<td>64</td>
<td>2.9</td>
<td>0.2</td>
<td>590</td>
</tr>
<tr>
<td>Finland (5.2)</td>
<td>3074</td>
<td>1990-91, 1 year</td>
<td>120</td>
<td>84</td>
<td>12.3</td>
<td>3.6</td>
<td>33 000</td>
</tr>
<tr>
<td>France (62.2)</td>
<td>12 261</td>
<td>1980-2003, 3 months</td>
<td>89</td>
<td>53</td>
<td>8.5</td>
<td>2</td>
<td>4964</td>
</tr>
</tbody>
</table>
To illustrate the numerical computation, a crude PAF for Switzerland is calculated using a RR of 1.16 per 100 Bq/m$^3$, a baseline radon concentration of 10 Bq/m$^3$ and a countrywide average indoor radon concentration of 78 Bq/m$^3$. The RR at 78 Bq/m$^3$ against a baseline (comparison) radon concentration of 10 Bq/m$^3$ would be 1.107.
Table 3. Summary of EBD of lung cancer caused by indoor radon exposure

<table>
<thead>
<tr>
<th>Housing exposure</th>
<th>Radon, Bequerel/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health outcome</td>
<td>Lung cancer</td>
</tr>
<tr>
<td>Summary of EBD evidence</td>
<td>2-12% of all lung cancer deaths in the EU can be attributed to radon exposure. For France, Germany and Switzerland, the total number of radon-related lung cancer deaths is estimated to be about 3300 per year.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level</th>
<th>Range</th>
<th>Geographic scope</th>
<th>Source of information</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Exposure risk relationship</td>
<td>RR 1.08/100 Bq/m³</td>
<td>95% CI: 1.04 – 1.12 per 100 Bq/m³</td>
<td>13 pooled case-control studies; further studies with similar results</td>
</tr>
</tbody>
</table>
| (b) Exposure assessment | France 87 Bq/m$^3$  
Switzerland: 78 Bq/m$^3$  
Germany: 49 Bq/m$^3$  
Mean values 20 – 140 Bq/m$^3$, depending on country (see table 1) | National level (data available for other countries)  
National or regional surveys, variable methodology |  |
|-------------------------|------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|  |
| (c) PAF | France 5%  
Switzerland: 8.3%  
Germany: 5%  
EU countries: 2–12%  
95% CI (%)  
France: 2.4–9  
Switzerland: 3–24  
Germany: 2.4–9  
EU countries: 0.3–24 | National level (data available for other countries) | Individual country studies |  |
| (d) Total burden of disease | Deaths per year:  
Switzerland: 2780 (2001)  
Germany: 37 900 (av. 1996-2000)  
WHO European Region: 368 200 (2000)  
See table 2 | National level (data available for other countries) | Individual country studies  
Country reports to European Office of WHO |  |
| (e) EBD from indoor radon exposure | Estimated deaths per year:  
France: 1234 (2.1/100 000)  
Switzerland: 231 (3.2/100 000)  
Germany: 1896 (2.3/100 000)  
National level (data available for other countries) | Combined from (c) and (d) above |  |
9. **Policy implications**

Because radon exposure is a significant risk factor for lung cancer, precautions should be taken to limit this exposure. Both prevention (in new homes) and mitigation (in existing homes) approaches should be promoted, ideally in a comprehensive radon programme that includes, among others, guidance on surveying, on measurements and on radon risk communication and evaluation (WHO, 2009). Several European countries have well-established radon programmes, and the numerous local, national and European radon projects need to be extended further to better protect the population of the WHO European Region from this well-controllable environmental hazard.
### Summary of exposure, population-attributable fraction (PAF) and EBD from inadequate housing conditions

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Health outcome</th>
<th>Exposure–risk relationship</th>
<th>PAF</th>
<th>EBD from housing per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mould</td>
<td>Asthma deaths and DALYs in children (0–14 years)</td>
<td>RR = 2.4</td>
<td>12.3%</td>
<td>45 countries of the European Region: 83 deaths (0.06 per 100 000) 55 842 DALYs (40 per 100 000)</td>
</tr>
<tr>
<td>Dampness</td>
<td>Asthma deaths and DALYs in children (0–14 years)</td>
<td>RR = 2.2</td>
<td>15.3%</td>
<td>45 countries of the European Region: 103 deaths (0.07 per 100 000) 69 462 DALYs (50 per 100 000)</td>
</tr>
<tr>
<td>Lack of window guards</td>
<td>Injury deaths and DALYs (0–14 years)</td>
<td>RR = 2.0</td>
<td>33–47%</td>
<td>European Region: 10 deaths (0.007 per 100 000) 3310 DALYs (2.0 per 100 000)</td>
</tr>
<tr>
<td>Lack of smoke detectors</td>
<td>Injury deaths and DALYs (all ages)</td>
<td>RR = 2.0</td>
<td>2–50%</td>
<td>European Region: 7523 deaths (0.9 per 100 000) 197 565 DALYs (22.4 per 100 000)</td>
</tr>
<tr>
<td>Factor</td>
<td>Condition</td>
<td>RR/Rate</td>
<td>Percent</td>
<td>Reference</td>
</tr>
<tr>
<td>------------------------</td>
<td>------------------------------------------------</td>
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<td>----------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Indoor cold</td>
<td>Excess winter mortality</td>
<td>0.15% per °C</td>
<td>30%</td>
<td>11 European countries: 38 203 excess winter deaths (12.8 per 100 000)</td>
</tr>
<tr>
<td>Traffic noise</td>
<td>Ischaemic heart disease including myocardial infarction</td>
<td>1.17 per 10 dB(A)</td>
<td>2.9%</td>
<td>Germany only: 3900 myocardial infarcts (4.8 per 100 000) 24 700 ischaemic heart disease cases (30.1 per 100 000) 25 300 DALYs (30.8 per 100 000)</td>
</tr>
<tr>
<td>Radon</td>
<td>Lung cancer</td>
<td>1.08 per 100 Bq/m³</td>
<td>2–12%</td>
<td>Three western European countries: France: 1234 deaths (2.1 per 100 000) Germany: 1896 deaths (2.3 per 100 000) Switzerland: 231 deaths (3.2 per 100 000)</td>
</tr>
<tr>
<td>Residential SHS</td>
<td>Lower respiratory infections, asthma, heart disease and lung cancer</td>
<td>Risk estimates range from 1.2 to 2.0 OR = 4.4 PAF estimates range from 0.6% to 23%</td>
<td></td>
<td>European Region: 64 700 deaths (7.3 per 100 000) 713 000 DALYs (80.7 per 100 000)</td>
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<td>-----------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Lead</strong></td>
<td>Mental retardation, cardiovascular disease, behavioural problems</td>
<td>Case fatality rate 3%; 66%</td>
<td>European Region: 694 980 DALYs (79.2 per 100 000)</td>
<td></td>
</tr>
<tr>
<td>Indoor carbon monoxide</td>
<td>Headache, nausea, cardiovascular ischaemia/insufficiency, seizures, coma, loss of consciousness, death</td>
<td>DNS/PNS incidence 3–40%</td>
<td>50–64%</td>
<td>EURO A subregion: a 114–1545 persons with DNS/PNS (0.03–0.4 per 100 000) 114 ± 97 deaths (0.03 ± 0.02 per 100 000)</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>Lower respiratory symptoms in children</td>
<td>OR = 1.4</td>
<td>3.7%</td>
<td>EURO A subregion: a 0.3–0.6% of wheezing in children</td>
</tr>
<tr>
<td>Indoor solid fuel use</td>
<td>COPD, ALRI, lung cancer</td>
<td>RR = 1.5–3.2</td>
<td>6–15%</td>
<td>European Region: 8490 ALRI deaths in children &lt; 5 years (16.7 per 100 000) 293 600 ALRI DALYs in children &lt; 5 years (577 per 100 000) 5800 COPD deaths in adults ≥ 30 years (1.1 per 100 000) 100 700 COPD DALYs in adults ≥ 30 years (19.3 per 100 000)</td>
</tr>
</tbody>
</table>

*Note: OR = odds ratio; RR = relative risk; DALYs = disability-adjusted life years; N/A = not available; COPD = chronic obstructive pulmonary disease; ALRI = acute lower respiratory infections; DNS/PNS = delayed or persistent neurological sequelae.*
National Healthy Housing Standard
Key Elements

1. Duties of Owners and Occupants
2. Structures, Facilities, Plumbing, and Space Requirements
   - Kitchen
   - Bathroom
   - Minimum Space
   - Floors and Floor Coverings
   - Noise
Key Elements

3. Safety and Personal Security
   3.1. Egress
   3.2. Locks/Security
   3.3. Smoke Alarm
   3.4. Fire Extinguisher
   3.5. Carbon Monoxide
   3.6. Walking Surfaces
   3.7. Guards
   3.8. Chemical Storage
   3.9. Pools, Hot Tubs, and Other Water Features

4. Lighting and Electrical Systems
   4.1. Electrical System
   4.2. Outlets
   4.3. Natural Lighting
   4.4. Artificial Lighting
Key Elements

5. Thermal Comfort, Ventilation, and Energy Efficiency
   5.1. Heating, Ventilation, and Air-Conditioning Systems
   5.2. Heating System
   5.3. Ventilation
   5.4. Air Sealing

6. Moisture Control, Solid Waste, and Pest Management
   6.1. Moisture Prevention and Control
   6.2. Solid Waste
   6.3. Pest Management
7. Chemical and Radiological Agents

7.1. General Requirements
7.2. Lead-Based Paint
7.3. Asbestos
7.4. Toxic Substances in Manufactured Building Materials
7.5. Radon
7.6. Pesticides
7.7. Methamphetamine
7.8. Smoke in Multifamily Housing
7.5. Radon.

**Requirement:**

Radon present at levels at or above the EPA action level of four picocuries radon per liter of air (pCi/L) in the lowest habitable level of the dwelling shall be deemed hazardous. Radon levels shall be determined by an approved testing method in accordance with state and local requirements. Radon levels exceeding four pCi/L shall be mitigated by a qualified radon mitigation professional who meets state and local requirements. If there are no state or local requirements qualifying radon testing and mitigation professionals, radon testing and mitigation shall be performed by a professional certified by a national private-sector radon proficiency program.
Stretch Provision:

- Radon present at levels at or above two pCi/L in the lowest habitable level of the dwelling shall be deemed hazardous. Radon determined by an approved testing method to exceed two pCi/L shall be mitigated by qualified radon mitigation professionals in accordance with state and local requirements. If there are no state or local requirements qualifying radon testing and mitigation professionals, radon testing and mitigation shall be performed by a professional certified by a national private-sector radon proficiency program.
References:


The Federal Radon Action Plan

- Federal leadership required to accelerate action on radon risk reduction – a key Healthy Homes concern

- An example of Inter-Agency Collaboration (USDA, DOD, DOE, EPA, GSA, HHS, HUD, DOI, VA)

- A specific focus on families and low-income
Framework for Federal Action: 
*Our Areas of Focus*

- **Demonstrate Importance** of radon risk reduction
- **Provide Incentives** to encourage testing and mitigation
- **Build Demand** for testing and mitigation
Key Milestones Tracking Our Progress

Nov 2010: Held Federal Radon Summit where agencies agreed to develop the Federal Radon Action Plan

Jun 2011: Launched the Action Plan at the Healthy Homes Conference

Jan 2012: Released the Action Plan Scorecard

Aug 2012: Celebrated one-year anniversary at CDC’s National Cancer Conference in Washington DC

Feb 2013: Released the Accomplishments Report in conjunction with the unveiling of the Advancing Healthy Housing – A Strategy for Action.

Celebrating Success. Looking to the Future.

The Action Plan aims to reach about 860,000 homes, schools and day care facilities in 2013.

www.epa.gov/radon

FEBRUARY 4, 2013: FEDERAL RADON ACTION PLAN

The Risk of Radon

Radon causes an estimated 21,000 lung cancer deaths in the United States every year. It is the second leading cause of lung cancer after active smoking and the leading cause among non-smokers.

Though we’ve made progress in addressing high radon levels, because of housing construction over the last twenty years, there are more homes today in the United States with elevated radon levels than ever before.

Most low-income Americans do not have the financial resources to mitigate high radon levels in their homes and many other Americans are not yet convinced of the value of mitigating high radon levels.

Many radon-induced lung cancer deaths are preventable. Testing for and mitigating high radon levels uses time-proven, straightforward techniques. Homes can now be built to resist radon intrusion.

Protecting People and Families from Radon: A Federal Action Plan for Saving Lives

In 2011, leaders from nine federal agencies began exploring strategies that would have a significant and long-term impact on indoor radon risk reduction. Creativity, persistence and a focus on public health led senior leaders from the nine agencies to produce the first-ever comprehensive, multi-agency effort to address the leading environmental cause of cancer death in North America. The result is the Federal Radon Action Plan.

Together, the agencies committed to 33 specific actions with radon reducing potential – actions that could be completed with existing resources and take advantage of interagency collaboration to extend their reach and increase their impact.

EPA’s Deputy Administrator and the Deputy Secretary of HUD formally announced the Action Plan at the National Healthy Homes Conference in Denver, Colorado in June 2011.

The nine agencies celebrated the Action Plan’s one-year anniversary at CEQ’s National Cancer Conference in Washington, DC on August 22, 2012. At this event, EPA’s Assistant Administrator for Air and Radiation was joined by the Assistant Secretary for Health from HHS and the Deputy Secretary of HUD to showcase the actions and activities that have resulted from the plan.

Participating Agencies

- Department of Agriculture (USDA)
- Department of Defense (DOD)
- Department of Energy (DOE)
- U.S. Environmental Protection Agency (EPA)
- General Services Administration (GSA)
- Department of Health and Human Services (HHS)
- Department of Housing and Urban Development (HUD)
- Department of the Interior (DOI)
- Department of Veterans Affairs (VA)
# Status of Commitments

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**33 Total Commitments**

To access Scorecard visit [www.epa.gov/radon/action_plan.html](http://www.epa.gov/radon/action_plan.html)
Percent of Housing With Moderate Physical Problems by Race, Ethnicity and Income, 1989-2005 (American Housing Survey)
Percent of U.S. Children Aged 1-5 Years with Blood Lead Levels >= 10 μg/dL, with 95% Confidence Intervals, NHANES II, NHANES III Phases 1 and 2, and NHANES 1999-2002.

- Non-Hispanic Black
- Mexican Americans
- Non-Hispanic White

- **Lead-based Paint Poisoning Prevention Act (1971)**
- **Air & Ind Workplace Standards (1978)**
- **Phase-out gasoline & lead soldered cans (1973)**
- **Residential Lead Paint Ban (1978)**
- **Lead in Plumbing banned (1986)**
- **Lead Contamination Control Act (1988)**
  - **Virtual Elimination of Lead in Gasoline**
  - **McKinney Act**
  - **Public Housing Abatement (1989)**
- **Title X Housing & Community Development Act (1992)**
- **Federally Assisted Housing Rule 1999**
- **Residential Lead Paint Ban (1978)**
- **Lead Contamination Control Act (1988)**
  - **Virtual Elimination of Lead in Gasoline**
- **Private Housing Lead Paint Grants (1991)**
- **Lead Disclosure Rule (1996)**
- **Housing Lead Dust & Soil Std Published (1999 & 2001)**
- **Ban on lead solder in food cans (1995)**
  - **Const Work Stds (96)**
- **Federally Assisted Housing Rule 1999**
- **Renovation/Painting Rule Published (2008)**

**Blood Lead Levels (µg/dL)**

Year:
- '72
- '74
- '76
- '78
- '80
- '82
- '84
- '86
- '88
- '90
- '92
- '94
- '96
- '98
- '00
- '02
- '04

Blood Lead Levels:
- '72: 16
- '74: 14
- '76: 12
- '78: 10
- '80: 8
- '82: 6
- '84: 4
- '86: 2
- '88: 1
- '90: 0.2
- '92: 0.2
- '94: 0.2
- '96: 0.2
- '98: 0.2
- '00: 0.2
- '02: 0.2
- '04: 0.2

- **2.7%**
- **2.2%**
- **1.6%**
- **1.2%**
Radon Mitigation
(All readings were below 2 pCi/L)

JAN 2011 – JAN 2015

- Increased National Awareness
- Increased Institutional Prioritization
- Ramped Up Voluntary Action

TRANFORMATION

- 10 million homes mitigated
- 6,500 LIVES SAVED

Phase 1
FEDERAL ACTION

- Build Demand for Radon Industry
- Address Financing & Incentives
- Demonstrate Importance of Radon Risk Reduction

WE ARE HERE

Phase 2
ALLIED FEDERAL-NON PROFIT-INDUSTRY ACTION
Substandard Housing And Community Disinvestment Is:

- Not Sustainable
- Not Affordable
- Not Healthy
Conclusions

• High Costs of Health Care/Health Insurance
• Mortgage Crisis & Affordable Housing
• Economic Recovery, Radon Measurement & Mitigation

• Healthy Housing, Green Development, Climate Change
Contact Information

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