Residential Radon Epidemiology

Example - Case-Control Epidemiologic Study

Death Rates for Cancer and Heart Disease for Ages Younger than 85 Years and 85 Years and Older, 1975-2005

Why Cancer Is Potentially Dangerous

Copyright ©2009 American Cancer Society
From Jemal, A. et al.

NEHA RRNC March 2010
Residential Studies
Ten Leading Cancer Types for Estimated New Cancer Cases and Deaths, by Sex, United States, 2009


Annual Age-adjusted Cancer Incidence Rates among Males and Females for Selected Cancers, United States, 1975-2005


Annual Age-adjusted Cancer Death Rates among Males for Selected Cancers, United States, 1930-2005

NEHA RRNC March 2010
Residential Studies
Radioactivity of tobacco trichomes and insoluble cigarette smoke particles.

Martell EA

CANCER MORTALITY - 2009

<table>
<thead>
<tr>
<th>CANCER TYPE</th>
<th>ESTIMATED U.S. DEATHS/YR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Lung and Bronchus</td>
<td>159,390</td>
</tr>
<tr>
<td>2. Colon and Rectum</td>
<td>49,920</td>
</tr>
<tr>
<td>3. Breast Cancer</td>
<td>48,170</td>
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</tr>
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<td>9. Ovary</td>
<td>14,600</td>
</tr>
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<td>10. Esophagus</td>
<td>14,530</td>
</tr>
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<td>11. Urinary Bladder</td>
<td>14,330</td>
</tr>
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<td>12. Kidney and Renal Pelvis</td>
<td>12,980</td>
</tr>
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<td>13. Stomach</td>
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<tr>
<td>14. Myeloma</td>
<td>10,580</td>
</tr>
<tr>
<td>15. Melanoma</td>
<td>8,650</td>
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CA A Cancer Journal for Clinicians
Volume 59, Issue 4, Pages 225-249, 2009
Published Online: 27 May 2009
Copyright © 2009 American Cancer Society

NEHA RRNC March 2010
Residential Studies
CANCER MORTALITY - 2009

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"Statistics are people with the tears wiped away."

Irving Selikoff

Epidemiology Study Designs

- Ecological
  - Compares level of disease & exposure in groups
  - Cannot correlate exposure to sick individuals
  - Cannot control for confounders

- Cohort
  - Identify populations based on exposure
  - Follow for disease occurrence

- Case-Control
  - Identify individuals with disease & individuals without disease
  - Look at and compare exposures

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Residential Studies
Residential Radon Case-Control Around the World

European Pooling:
- 13 Studies from 9 Countries
  - Austria
  - Czech Republic
  - Finland [nationwide]
  - Finland [south]
  - France
  - Germany [eastern]
  - Germany [western]
  - Italy
  - Spain
  - Sweden [nationwide]
  - Sweden [never smokers]
  - Sweden [Stockholm]
  - United Kingdom
- Total 7,148 cases and 14,208 controls

North American Pooling:
- 7 Studies from 2 countries:
  - New Jersey
  - Winnipeg
  - Missouri I [non-smoking women]
  - Missouri II [women]
  - Iowa
  - Connecticut
  - Utah-South Idaho
- Total 3,622 cases and 4,966 controls

Basement and Living Area Radon Concentrations for U.S. Residential Radon Studies.

<table>
<thead>
<tr>
<th>Study Location</th>
<th>Geometric Mean in pCi/L</th>
<th>Basement</th>
<th>Level 1</th>
<th>Level 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Jersey</td>
<td></td>
<td>0.5</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>Missouri-I</td>
<td>2.4</td>
<td>1.2</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>Missouri-II</td>
<td>2.4</td>
<td>1.2</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>Iowa</td>
<td>4.6</td>
<td>2.5</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>Connecticut, Utah-South Idaho</td>
<td>1.5</td>
<td>0.5</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Southern Idaho</td>
<td>1.8</td>
<td>1.2</td>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>

1Summary data represent those homes that were measured with no imputed (values added to replace missing values) values.
RADON EXPOSURE ASSESSMENT CHALLENGES

- Quality Assurance/Quality Control
- Temporal and Spatial Radon Variation
- Missing Data Due to Inability to Measure Previous Homes
- Estimating Non-Residential Radon Exposure
- Measuring Radon Gas a Surrogate for Radon Progeny

National Institutes of Health

Support for this research was provided by a grant from the National Institute of Environmental Health Sciences, National Institutes of Health.

Residential Radon Gas Exposure and Lung Cancer: The Iowa Radon Lung Cancer Study


Differences Between the Other Case-Control Studies and the Iowa Study

- Performed in areas with low or average radon concentrations
- Had 30% - 60% percent missing radon data for previous 20 years which required imputation
- Did not account for where subjects spent time
- Did not link radon concentrations (within the home and outside the home) with where the subject spent time
- Measurements were limited to radon gas only
- Poor dosimetry quality control

STUDY DESIGN

- Population-based case-control study
- Geographic area: state of Iowa
- 413 female cases/614 female controls
- Study period: 10/92 to 10/97
MAJOR COMPONENTS

Rapid-reporting of cases: 94%  
Median time diagnosis to ascertainment: 20 days

- Detailed questionnaires:  
  health, diet, home characteristics, mobility
- 1 Year home $^{222}\text{Rn}$ measurements
- Histopathologic review of lung tissue:  
  96% of cases

Journal of Exposure Analysis and Environmental Epidemiology  Field et al. 1998

Case Eligibility/Ascertainment

Female Iowa resident  
No prior malignant lung cancer  
Ages 40 - 84  
Alive or deceased at initial contact  
Newly diagnosed invasive lung cancer  
without prior invasive lung cancer, histologically-confirmed  
Reside in current home $\geq$ 20 years  
No history of residential radon mitigation

Geographic Coverage

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Residential Studies
Control Eligibility/ Ascertainment

Female Iowa resident
No prior malignant lung cancer
Ages 40 - 84
Alive at initial contact
Reside in current home > 20 years
No history of residential radon mitigation

IRLCS Inclusion Criteria

20-year residency criteria in current home avoids imputation of data

Previous studies imputed 20% - 58% of data because of the inability to measure radon in previous homes

Histopathologic Review

- Blinded review by two surgical pathologists
- Consensus diagnosis based on World Health Organization 1981 (WHO) histologic type
- 72% agreement between Iowa Cancer Registry and consensus histologic type

The relative odds of misclassification for samples collected using cytology and biopsy as compared to resection was 2.4 (CI: 1.1 - 5.2) and 2.2 (CI: 1.1 - 4.2), respectively. JNCI 2004.
Morphologic Distribution of 413 Lung Cancers

<table>
<thead>
<tr>
<th>Morphology</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adenocarcinoma</td>
<td>175</td>
<td>42.4</td>
</tr>
<tr>
<td>Squamous Cell</td>
<td>82</td>
<td>19.9</td>
</tr>
<tr>
<td>Small Cell</td>
<td>74</td>
<td>17.9</td>
</tr>
<tr>
<td>Large Cell</td>
<td>32</td>
<td>7.7</td>
</tr>
<tr>
<td>Carcinoma, NOS</td>
<td>50</td>
<td>12.1</td>
</tr>
</tbody>
</table>

CONTROL SELECTION

Age 40-64: from Driver's License Tapes
Age 65-84: from HCFA Records

STUDY DEMOGRAPHICS

<table>
<thead>
<tr>
<th></th>
<th>Cases</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>413</td>
<td>614</td>
</tr>
<tr>
<td>Age in yrs. (median)</td>
<td>68</td>
<td>67</td>
</tr>
<tr>
<td>Residency in yrs. (median)</td>
<td>33</td>
<td>31</td>
</tr>
<tr>
<td>Alive at interview</td>
<td>69%</td>
<td>100%</td>
</tr>
<tr>
<td>Ever-smokers</td>
<td>86%</td>
<td>33%</td>
</tr>
<tr>
<td>Previous lung disease</td>
<td>44%</td>
<td>27%</td>
</tr>
<tr>
<td>At least H.S. Education</td>
<td>90%</td>
<td>92%</td>
</tr>
</tbody>
</table>
### HOUSING CHARACTERISTICS

<table>
<thead>
<tr>
<th></th>
<th>Cases</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of Home</td>
<td>62 years</td>
<td>56 years</td>
</tr>
<tr>
<td>Square Footage</td>
<td>1,879</td>
<td>1,990</td>
</tr>
<tr>
<td>Central AC</td>
<td>60.7%</td>
<td>64.7%</td>
</tr>
<tr>
<td>Window AC only</td>
<td>32.8%</td>
<td>29.9%</td>
</tr>
<tr>
<td>Forced air (1 Story)</td>
<td>91.8%</td>
<td>90.4%</td>
</tr>
<tr>
<td>Forced air (2 Story)</td>
<td>82.8%</td>
<td>80.4%</td>
</tr>
</tbody>
</table>

### LEVELS OF HOME

<table>
<thead>
<tr>
<th></th>
<th>Cases</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 story home</td>
<td>49.4%</td>
<td>51.5%</td>
</tr>
<tr>
<td>2 story home</td>
<td>48.0%</td>
<td>44.1%</td>
</tr>
<tr>
<td>3 story home</td>
<td>2.6%</td>
<td>4.1%</td>
</tr>
<tr>
<td>4 story home</td>
<td>0%</td>
<td>0.3%</td>
</tr>
</tbody>
</table>

### IOWA RADON LUNG CANCER STUDY

- Phase 1
- $^{222}\text{Rn}$ Gas Measurements
COMPREHENSIVE $^{222}\text{Rn}$ EXPOSURE ASSESSMENT

**Home:** Temporally and spatially weighted radon exposure

**Outside:** Temporally weighted outdoor radon exposure derived from kriged data from outdoor radon monitoring network

**Building:** Temporally weighted estimated value representing 50% of kriged 1st floor radon concentration

COMPREHENSIVE $^{222}\text{Rn}$ EXPOSURE

**Home Exposure**

**Outdoor Exposure**

**Other Building Exposure**
HOME $^{222}\text{Rn}$ EXPOSURE

REQUIRES KNOWLEDGE OF:

- Time spent at home
  (Cases 73.2% Controls 72.1 %)
- Subject mobility while at home
- Radon concentrations in various parts of the home

HOME RADON EXPOSURE

SUBJECT MOBILITY INTERVIEW
Obtains mobility patterns within/outside the home using seasonally adjusted task linkage

- Identifies temporal periods when mobility remains fairly constant
- Permits linkage of mobility information to radon measurements

SUBJECT MOBILITY INFORMATION

- Hours in-home: Bedroom, home work area, basement, upper level, kitchen/dining room
- Hours in another building: Type of activities (work, church, recreation), seasonal variation
- Hours outdoors: Type of activities (gardening, walking, work), seasonal variation
SPATIAL HOME MOBILITY

One Story Homes (N=494)
- Basement: 6.4%
- 1st Story: 93.6%

Two Story Homes (N=437)
- Basement: 3.2%
- 2nd Story: 21.8%
- 1st Story: 75.0%


PERCENT OF TIME IN HOME BY AGE

Radon Measurement
Continuous Radon Monitors
- Labor intensive
- Time consuming
- Expensive

Short-term radon monitoring
- Fast
- Cheap
- Do not allow for estimates of yearly radon variation

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Residential Studies
RADON GAS DETECTORS

- Alpha track detectors (ATDs)
  - yearly integrated mean radon measurement
  - up to 7 ATDs per home
  - second year measurements

Alpha Track Detectors
PLACEMENT OF ATDs

- Bedroom (and historic bedroom)
- 1 ATD per level of home with placement weighted by participant occupancy time
- 1 ATD in home work area

Quality Assurance/Quality Control

- Spiked Samples (5%)
- Field Duplicates (12%)
- Field Control Detectors (5%)
- Strictly Adhered to Written QA Plan
- Oversight by QA Officer

(Redfield et al., Radiation Protection Dosimetry 78(4):295-303, 1998)

Radon Measurement Devices (ATDs) Installed

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total ATDs placed</td>
<td>4,626</td>
</tr>
<tr>
<td>Mean number/home</td>
<td>4.0</td>
</tr>
<tr>
<td>Percent retrieved</td>
<td>97.2%</td>
</tr>
<tr>
<td>Duplicates placed</td>
<td>515</td>
</tr>
<tr>
<td>Percent duplicates</td>
<td>12.5%</td>
</tr>
<tr>
<td>Mean COV (S.D.)</td>
<td>6.9%(7.2)</td>
</tr>
</tbody>
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Collocated Radon Gas Measurements

Detector Accuracy and Precision “Spiked Detectors”

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Detector Accuracy and Precision “Spiped Detectors”

Detecto
OUTDOOR $^{222}$Rn EXPOSURE

REQUIRES KNOWLEDGE OF:
- Time spent outdoors (Cases 7.6%, Controls 8.5%)
- Radon concentrations outdoors

OUTDOOR $^{222}$Rn MEASUREMENTS

111 Outdoor $^{222}$Rn gas and $^{222}$Rn progeny measurements have been made in over 70 Iowa counties during 1995, 1996 and 1997. Geometric mean (GSD) = 0.8 pCi/L (1.4)

The mean outdoor kriged radon concentration within 1 mile of the home is weighted at 50%.

The mean outdoor kriged radon concentration from 1 to 20 miles away from the home is weighted at 50% with decreasing weight as you progress from 1 to 20 miles away.
OUTDOOR $^{222}$Rn EXPOSURE

1 mi. 20 mi.

COMPREHENSIVE RADON EXPOSURE

Home Exposure
Outdoor Exposure
Other Building Exposure

OTHER BUILDING $^{222}$Rn EXPOSURE

Time spent in other building
(Cases 14.2% Controls 14.4%)
Linked to
50% of kriged radon value for the
1st floor measurements (from control homes) weighted for
surrounding 20 miles

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The average of the national mean indoor $^{222}$Rn concentration (1.5 pCi/L) and national mean outdoor $^{222}$Rn concentration (0.4 pCi/L).

Working level month cumulative exposure model:

$$WLM_{5-19} = \sum_{i} \text{time}_i \times \text{radon}_i$$

where the sum is over the years 5-19 prior to enrollment and includes the following locations:

Home (individual floors, bedrooms, work area), Outside, Another Building, Away on Vacation/Business
IMPUTED VALUES

<table>
<thead>
<tr>
<th>Time Period</th>
<th>% Population</th>
<th>% Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imputed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 - 20 Years</td>
<td>100 %</td>
<td>0 %</td>
</tr>
<tr>
<td>0 - 30 Years</td>
<td>58 %</td>
<td>0 %</td>
</tr>
<tr>
<td></td>
<td>42 %</td>
<td>18 %</td>
</tr>
</tbody>
</table>

LOGISTIC REGRESSION
RISK MODEL

VARIABLES INCLUDED IN MODEL
- Age (Dx or enrollment)
- Education (yrs. attained)
- Active smoking
  - Pack-year rate
  - Year since quit smoking or never smoker
- Radon (continuous and categorical)

OTHER VARIABLES CONSIDERED
- Pre-existing lung disease
- Number of children
- Urban/rural status
- Asbestos exposure
- Family history of cancer

Design of a Case-Control Study

Exposed
Lung Cancer Cases
Exposed
Disease
Not Exposed
No Disease
Exposed
Not Exposed

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Odds Ratio

\[ \frac{\text{Odds Ratio} = \frac{a}{c} = \frac{bc}{d}}{\text{Case}} = \frac{\text{Control}}{\text{E}^+} \]

\[ \begin{array}{cc}
E^+ & a & b \\
E^- & c & d
\end{array} \]

ADJUSTED ODDS RATIO FOR ACTIVE SMOKERS

<table>
<thead>
<tr>
<th>Type of Smoker</th>
<th>Never</th>
<th>Light</th>
<th>Heavy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Odds Ratio</td>
<td>1.0</td>
<td>8.1</td>
<td>29.0</td>
</tr>
<tr>
<td>95% CI</td>
<td>--</td>
<td>5.6-11.7</td>
<td>19.1-43.9</td>
</tr>
</tbody>
</table>

Light and heavy smokers were divided by the median pack-year rate. Odds ratios adjusted for age, education, and cumulative radon exposure.

Distribution of Cases and Controls by Exposure Category

<table>
<thead>
<tr>
<th>Cumulative Radon Exposure</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-11.425</td>
<td>436</td>
</tr>
<tr>
<td>11.426-12.79</td>
<td>295</td>
</tr>
<tr>
<td>12.801-16.94</td>
<td>283</td>
</tr>
<tr>
<td>16.95+</td>
<td>1027</td>
</tr>
</tbody>
</table>

Cases (Live) 160 (37) 87 56 67 413
Controls 164 229 118 75 88 614
Total 376 205 131 155 1027

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Residential Studies
Radon-Lung Cancer Association

<table>
<thead>
<tr>
<th>WLM (Cumulative Radon Exposure)</th>
<th>p-trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases</td>
<td>Cont. Cat.</td>
</tr>
<tr>
<td><strong>All:</strong></td>
<td></td>
</tr>
<tr>
<td>OR</td>
<td>1.00</td>
</tr>
<tr>
<td>95% CI</td>
<td>0.81-2.22</td>
</tr>
<tr>
<td>Live</td>
<td>1.00</td>
</tr>
<tr>
<td>95% CI</td>
<td>0.75-2.31</td>
</tr>
</tbody>
</table>

Odds Ratios by Histologic Cancer Type

<table>
<thead>
<tr>
<th>Cases (n)</th>
<th>Cumulative Radon Exposure (WLM)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squamous (82)</td>
<td>4.23 4.47 4.73 5.00 5.27 5.54 5.81 6.08 6.35 6.62 6.89 7.16 7.43 7.70 7.97 8.24 8.51 8.78 9.05 9.32 9.59 9.86 10.13 10.40 10.67 10.94 11.21 11.48 11.75 12.02 12.29 12.56 12.83 13.10 13.37 13.64 13.91 14.18 14.45 14.72 14.99 15.26 15.53 15.80 16.07 16.34 16.61 16.88 17.15 17.42 17.69 17.96 18.23 18.50 18.77 19.04 19.31 19.58 19.85 20.12 20.39 20.66 20.93 21.20 21.47 21.74 22.01 22.28 22.55 22.82 23.09 23.36 23.63 23.90 24.17 24.44 24.71 24.98 25.25 25.52 25.79 26.06 26.33 26.60 26.87 27.14 27.41 27.68 27.95 28.22 28.49 28.76 29.03 29.30 29.57 29.84 30.11 30.38 30.65 30.92 31.19 31.46 31.73 32.00 32.27 32.54 32.81 33.08 33.35 33.62 33.89 34.16 34.43 34.70 34.97 35.24 35.51 35.78 36.05 36.32 36.59 36.86 37.13 37.40 37.67 37.94 38.21 38.48 38.75 39.02 39.29 39.56 39.83 40.10 40.37 40.64 40.91 41.18 41.45 41.72 41.99 42.26 42.53 42.80 43.07 43.34 43.61 43.88 44.15 44.42 44.69 44.96 45.23 45.50 45.77 46.04 46.31 46.58 46.85 47.12 47.39 47.66 47.93 48.20 48.47 48.74 49.01 49.28 49.55 49.82 50.09 50.36 50.63 50.90 51.17 51.44 51.71 51.98 52.25 52.52 52.79 53.06 53.33 53.60 53.87 54.14 54.41 54.68 54.95 55.22 55.49 55.76 56.03 56.30 56.57 56.84 57.11 57.38 57.65 57.92 58.19 58.46 58.73 59.00 59.27 59.54 59.81 60.08 60.35 60.62 60.89 61.16 61.43 61.70 61.97 62.24 62.51 62.78 63.05 63.32 63.59 63.86 64.13 64.40 64.67 64.94 65.21 65.48 65.75 66.02 66.29 66.56 66.83 67.10 67.37 67.64 67.91 68.18 68.45 68.72 68.99 69.26 69.53 69.80 69.97 70.24 70.51 70.78 71.05 71.32 71.59 71.86 72.13 72.40 72.67 72.94 73.21 73.48 73.75 74.02 74.29 74.56 74.83 75.10 75.37 75.64 75.91 76.18 76.45 76.72 76.99 77.26 77.53 77.80 78.07 78.34 78.61 78.88 79.15 79.42 79.69 79.96 80.23 80.50 80.77 81.04 81.31 81.58 81.85 82.12 82.39 82.66 82.93 83.20 83.47 83.74 84.01 84.28 84.55 84.82 85.09 85.36 85.63 85.90 86.17 86.44 86.71 86.98 87.25 87.52 87.79 88.06 88.33 88.60 88.87 89.14 89.41 89.68 89.95 90.22 90.49 90.76 91.03 91.30 91.57 91.84 92.11 92.38 92.65 92.92 93.19 93.46 93.73 94.00 94.27 94.54 94.81 95.08 95.35 95.62 95.89 96.16 96.43 96.70 96.97 97.24 97.51 97.78 98.05 98.32 98.59 98.86 99.13 99.40 99.67 99.94</td>
<td></td>
</tr>
</tbody>
</table>
SUMMARY

- The Iowa Radon Lung Cancer Study found a statistically significant association between residential radon exposure and lung cancer.
- The findings suggest that prolonged exposure to radon, even at 4 pCi/L, increases lung cancer risk.
- These findings suggest that radon is a major environmental carcinogen.

Have Previous Residential Radon Studies Underestimated Risk?

The evidence indicates that they have underestimated risk.

Pooled Analyses Agreement ??

10% – 18%

New Jersey, Missouri I, Canada, Iowa, Missouri II, a combined study from Connecticut, Utah and S. Idaho

Shenyang, China, Stockholm, Sweden, Swedish nationwide, Winnipeg, Canada, S. Finland, Finnish nationwide, SW England, W. Germany, Sweden, Czech Republic, Italy-Trento, Spain, Austria, France, China - Gansu Province, E. Germany
Why have the risks been under reported in residential radon studies?

**Major Reasons for Poor Exposure Assessment**
- Missing radon measurements in previous homes
- Failure to link radon concentrations with where people spent time
- Poor QA/QC
- Studies performed in low radon areas
- Inadequate consideration of temporal radon variations
- High percentage of proxy respondents

We have “demonstrated that empiric models with improved retrospective radon exposure estimates were more likely to detect an association between prolonged residential radon exposure and lung cancer.”

Therefore, estimated pooled risk estimates are likely low.


Risk estimates decrease when one fails to link radon concentrations with where the subject spends time

Random misclassification of radon exposure tends to bias studies toward finding no association between radon concentrations and lung cancer
Risk Estimates for Alternative Models
(all subjects)

Risk Estimates for Alternative Models
(live cases and controls)

RESIDENTIAL RADON EPIDEMIOLOGY - Future Activities

- World pooling of residential radon studies
- **Complete radon progeny-based study**
- Occupational exposures
- Promote awareness of radon and RRNC
- Radon related gene studies
- Explore avenues to evaluate the possible association between radon exposure and other possible adverse health outcomes, e.g., leukemia


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Residential Studies
Retrospective Radon Measurements

<table>
<thead>
<tr>
<th>Radon-222</th>
<th>4 day</th>
<th>β,γ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polonium-218</td>
<td>3 min</td>
<td>β,γ</td>
</tr>
<tr>
<td>Lead-214</td>
<td>27 min</td>
<td>α,γ</td>
</tr>
<tr>
<td>Barium-214</td>
<td>20 min</td>
<td>β,γ</td>
</tr>
<tr>
<td>Polonium-214</td>
<td>0.2 ms</td>
<td>α,γ</td>
</tr>
<tr>
<td>Lead-210</td>
<td>22 yrs</td>
<td>α,γ</td>
</tr>
<tr>
<td>Bismuth-210</td>
<td>5 day</td>
<td>β,γ</td>
</tr>
<tr>
<td>Polonium-210</td>
<td>138 day</td>
<td>α,γ</td>
</tr>
<tr>
<td>Lead-206</td>
<td>Stable</td>
<td>α,γ</td>
</tr>
</tbody>
</table>

218Po and 214Po deliver the radiologically significant dose to the respiratory epithelium.

- Long residency in glass
- Decay easy to measure

HRD schematic
HISTORIC RECONSTRUCTION DETECTOR (HRD)

- Glass-based radon progeny measurement
- Measures contemporary radon gas concentration
- Measures contemporary radon progeny deposition
- Measures retrospective deposition of radon progeny in glass surfaces via implanted Polonium-210.
- Reconstruction of airborne concentrations using a semi-empirical model

RESIDENTIAL RADON EPIDEMIOLOGY - Future Activities

- Complete radon progeny-based study
- World pooling of residential radon studies
- **Occupational exposures**
  - Promote awareness of radon and RRNC
  - Radon related gene studies
  - Explore avenues to evaluate the possible association between radon exposure and other possible adverse health outcomes, e.g., leukemia

Occupational Exposure to Radon – Very Common

- Mine workers, including uranium, hard rock, and vanadium
- Workers remediating radioactive contaminated sites, including uranium mill sites and mill tailings
- Workers at underground nuclear waste repositories
- Radon mitigation contractors and testers
- Employees of natural caves
- Phosphate fertilizer plant workers
- Oil refinery workers
- Utility tunnel workers

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Residential Studies

30
Subway tunnel workers
Construction excavators
Power plant workers, including geothermal power and coal
Employees of radon health mines
Employees of radon balneotherapy spas (waterborne 222Rn source)
Water plant operators (waterborne 222Rn source)
Fish hatchery attendants (waterborne 222Rn source)
Employees who come in contact with technologically enhanced sources of naturally occurring radioactive materials
Incidental exposure in almost any occupation from local geologic 222Rn sources
Farming related activities

RESIDENTIAL RADON EPIDEMIOLOGY - Future Activities

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Ionizing radiation can directly and indirectly damage DNA

Alpha Particle
Defects in tumor suppressor genes – p53
At risk individuals – GSTM1
(glutathione S-transferase M1)
RESIDENTIAL RADON EPIDEMIOLOGY - Future Activities

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Summary

- Residential radon epidemiology has made major advances the past 10 years.
- The residential radon studies have provided direct evidence that prolonged residential radon is one of our leading public health risks and major cause of cancer mortality.
- Radon is our leading environmental cause of cancer mortality and seventh leading cause of cancer mortality overall.
Availability of WHO Handbook

- **WHO Handbook on Indoor Radon: A Public Health Perspective:**
- **WHO Radon Webpage:**

Iowa Radon Lung Cancer Study
[http://www.cheec.uiowa.edu/misc/radon.html](http://www.cheec.uiowa.edu/misc/radon.html)

Radon Professionals Listserv
[http://list.uiowa.edu/archives/radon_professionals.html](http://list.uiowa.edu/archives/radon_professionals.html)

Please feel free to contact me with questions.

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