Radionuclide Concentrations in Food and the Environment

Kathryn Higley, PhD, CHP
Professor and Head
Nuclear Engineering & Radiation Health Physics

Presented at the 20th Annual Meeting of the Council on Ionizing Radiation Measurements and Standards
Public Perception of Ionizing Radiation
Outline

• Review sources of radiation/radionuclides
• Examine concentrations and resultant doses
• Put in context of current events
• Where to go for more information
Sources of Radiation Exposure in the US

- Radon and Thoron: 37%
- Computed Tomography: 24%
- Nuclear Medicine: 12%
- Intervventional Fluoroscopy: 7%
- Consumer products: 2%
- Outer Space: 5%
- Internal Background: 5%
- Terrestrial (Soil): 3%
- Occupational & industrial Exposure: <0.1%

~6.2 mSv
50/50 split

Source NCRP Report 160, 2009
Terrestrial Distribution of Absorbed Dose

Contributors to Gamma Exposures

Gamma-ray Ternary Map
(eU=cyan, K=magenta, eTh=yellow)

## Natural Radionuclide Content in Soil and Resultant External Dose

<table>
<thead>
<tr>
<th>Radionuclides</th>
<th>Concentration in soil (Bq kg(^{-1}))(^a)</th>
<th>Absorbed dose rate in air (nGy h(^{-1}))(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(^{40})K</td>
<td>420</td>
<td>18</td>
</tr>
<tr>
<td>(^{228})U series</td>
<td>33</td>
<td>15</td>
</tr>
<tr>
<td>(^{232})Th series</td>
<td>45</td>
<td>27</td>
</tr>
<tr>
<td>Total</td>
<td>60(^a)</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Population-weighted value

UNSCEAR, 2000, Annex B, Exposures from natural radiation sources
Altitude Effects on Cosmic Dose Rate

UNSCEAR, 2000, Annex B, Exposures from natural radiation sources
Latitude Variation in Dose Rate

UNSCEAR, 2000, Annex B, Exposures from natural radiation sources
Net effect: distribution of total annual effective doses (15 countries).
Intermission with Musings

• 8 months ago
• In the context of “Pubic Perception of Radiation”
• This would have been an extremely boring dry talk.
  • Educational
  • Largely academic interest
What could pique anyone’s interest in radioactivity in food or the environment?

Go to:
One word: Fukushima
http://www.zamg.ac.at/pict/aktuell/20110404_fuku_l-131.gif
Comprehensive Test Ban Treaty Sites

“Radiation Detected In Drinking Water In 13 More US Cities”

by Jeff McMahon

“Radiation from Japan has been detected in drinking water in 13 more American cities, and cesium-137 has been found in American milk—in Montpelier, Vermont—for the first time since the Japan nuclear disaster began, according to data released by the Environmental Protection Agency late Friday. Milk samples from Phoenix and Los Angeles contained iodine-131 at levels roughly equal to the maximum contaminant level permitted by EPA, the data shows. The Phoenix sample contained...
Japan Radiation Contaminates Food Sent Beyond Affected Area
The Japanese government reported on Sunday that it had halted some food shipments to prevent tainted samples of milk and spinach from reaching consumers.

Iodine 131 was found in milk samples in Kawa moto, a town in Fukushima prefecture, where the reactor sits, at levels five times the limit set by law. In
FDA halts imports of dairy, produce from Japan

Seafood will still be sold, but will be screened first

The Food and Drug Administration said Tuesday it will halt imports of dairy products and produce from the area of Japan where a nuclear reactor is leaking radiation.

The FDA said those foods will be detained at entry and will not be sold to the public. The agency previously said it would just step up screening of those foods.

Other foods imported from Japan, including seafood, still will be sold to the public but screened first for radiation.

On Wednesday a spike in radiation in Tokyo tap water caused new worries about food safety. Broccoli was added to the list of contaminated vegetables.

Japan’s Fukushima Dai-ichi nuclear complex has been

“There is no safe level of radionuclide exposure, whether from food, water or other sources. Period,“
### Series radionuclides in food and drinking water, mBq/kg

<table>
<thead>
<tr>
<th></th>
<th>$^{238}$U</th>
<th>$^{230}$Th</th>
<th>$^{226}$Ra</th>
<th>$^{210}$Pb</th>
<th>$^{210}$Po</th>
<th>$^{232}$Th</th>
<th>$^{228}$Ra</th>
<th>$^{228}$Th</th>
<th>$^{235}$U</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Milk Products</strong></td>
<td>1</td>
<td>0.5</td>
<td>5</td>
<td>15</td>
<td>15</td>
<td>0.3</td>
<td>5</td>
<td>0.3</td>
<td>0.05</td>
</tr>
<tr>
<td><strong>Meat Products</strong></td>
<td>2</td>
<td>2</td>
<td>15</td>
<td>80</td>
<td>60</td>
<td>1</td>
<td>10</td>
<td>1</td>
<td>0.05</td>
</tr>
<tr>
<td><strong>Grain Products</strong></td>
<td>20</td>
<td>10</td>
<td>80</td>
<td>50</td>
<td>60</td>
<td>3</td>
<td>60</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td><strong>Leafy Vegetables</strong></td>
<td>20</td>
<td>20</td>
<td>50</td>
<td>80</td>
<td>100</td>
<td>15</td>
<td>40</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td><strong>Root Vegetables &amp; Fruits</strong></td>
<td>3</td>
<td>0.5</td>
<td>30</td>
<td>30</td>
<td>40</td>
<td>0.5</td>
<td>20</td>
<td>0.5</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Fish Products</strong></td>
<td>30</td>
<td>10</td>
<td>100</td>
<td>200</td>
<td>2000</td>
<td>10</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Drinking Water</strong></td>
<td>1</td>
<td>0.1</td>
<td>0.5</td>
<td>10</td>
<td>5</td>
<td>0.05</td>
<td>0.5</td>
<td>0.05</td>
<td>0.04</td>
</tr>
</tbody>
</table>

UNSCEAR, 2000, Annex B, Exposures from natural radiation sources
Effective Dose from Ingestion of Uranium and Thorium Series Radionuclides, $\mu$Sv

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Infants</th>
<th>Children</th>
<th>Adults</th>
<th>Age – weighted</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{238}\text{U}$</td>
<td>0.23</td>
<td>0.26</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>$^{234}\text{U}$</td>
<td>0.25</td>
<td>0.28</td>
<td>0.28</td>
<td>0.28</td>
</tr>
<tr>
<td>$^{230}\text{Th}$</td>
<td>0.42</td>
<td>0.48</td>
<td>0.64</td>
<td>0.58</td>
</tr>
<tr>
<td>$^{226}\text{Ra}$</td>
<td>7.5</td>
<td>12</td>
<td>6.3</td>
<td>8</td>
</tr>
<tr>
<td>$^{210}\text{Pb}$</td>
<td>40</td>
<td>40</td>
<td>21</td>
<td>28</td>
</tr>
<tr>
<td>$^{210}\text{Po}$</td>
<td>180</td>
<td>100</td>
<td>70</td>
<td>85</td>
</tr>
<tr>
<td>$^{232}\text{Th}$</td>
<td>0.26</td>
<td>0.32</td>
<td>0.38</td>
<td>0.36</td>
</tr>
<tr>
<td>$^{228}\text{Ra}$</td>
<td>31</td>
<td>40</td>
<td>11</td>
<td>21</td>
</tr>
<tr>
<td>$^{228}\text{Th}$</td>
<td>0.38</td>
<td>0.3</td>
<td>0.22</td>
<td>0.25</td>
</tr>
<tr>
<td>$^{235}\text{U}$</td>
<td>0.01</td>
<td>0.012</td>
<td>0.012</td>
<td>0.011</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>260</td>
<td>200</td>
<td>110</td>
<td>140</td>
</tr>
</tbody>
</table>

UNSCEAR, 2000, Annex B, Exposures from natural radiation sources
## Radionuclides Routinely Measured

**FDA market basket study values, 2006**

<table>
<thead>
<tr>
<th>Nuclide</th>
<th># Results</th>
<th>Not Detected</th>
<th>Mean (Bq/kg)</th>
<th>Std Dev (Bq/kg)</th>
<th>Min (Bq/kg)</th>
<th>Max (Bq/kg)</th>
<th>Median (Bq/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{40}\text{K}$</td>
<td>3295</td>
<td>2253</td>
<td>38</td>
<td>52</td>
<td>0</td>
<td>506</td>
<td>0</td>
</tr>
<tr>
<td>$^{137}\text{Cs}$</td>
<td>3522</td>
<td>3521</td>
<td>0.002</td>
<td>0.028</td>
<td>0</td>
<td>6.7</td>
<td>0</td>
</tr>
<tr>
<td>$^{90}\text{Sr}$</td>
<td>2443</td>
<td>1937</td>
<td>0.04</td>
<td>0.094</td>
<td>0</td>
<td>2.43</td>
<td>0</td>
</tr>
</tbody>
</table>
Since Fukushima, Increased US Monitoring

Japanese Nuclear Emergency: EPA's Radiation Monitoring

This site contains information and data from March 11, 2011 to June 30, 2011. EPA has returned to routine RadNet operations. This site will continue to be available for historical and informative purposes.

For real-time air monitoring data, please visit the EPA RadNet website and Central Data Exchange. To view both current and historical laboratory data, please visit our Envirofacts database.

June 30 Statement

In response to the Japanese nuclear incident, EPA accelerated and increased sampling frequency and analysis to confirm that there were no harmful levels of radiation reaching the U.S. from Japan and to inform the public about any level of radiation detected.

RadNet Data

- Data Summaries
- EPA’s RadNet Data
  - Real-Time Monitoring Data
    - Data by Datastream

Looking for the regular EPA Radiation home page?

About Radiation

- Understanding Radiation
- Sources of Radiation Exposure
  - Radon
- Radiation Doses in Perspective

Overview of EPA's Radiation Monitoring Experience

- Monitoring Radiological Incidents
- EPA’s Radiation Response History

Common Power Plant Radionuclides

- Cesium
- Iodine
- Strontium
# US EPA RadNet Measured Data
March – June 2011

<table>
<thead>
<tr>
<th>Radio-nuclide</th>
<th>Maximum</th>
<th>Average</th>
<th>US Average</th>
<th>Units</th>
<th>Medium</th>
<th>EPA Target Risk Range Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iodine-131</td>
<td>15.6</td>
<td>3.17</td>
<td>0.725</td>
<td>Bq/L</td>
<td>Precipitation</td>
<td></td>
</tr>
<tr>
<td>Iodine-131</td>
<td>0.0285</td>
<td>0.00356</td>
<td>0.0232</td>
<td>Bq/L</td>
<td>Pasteurized milk</td>
<td>14.8 Bq/L to 0.148 Bq/L</td>
</tr>
<tr>
<td>Iodine 131</td>
<td>0.00858</td>
<td>0.0023</td>
<td>0.00559</td>
<td>Bq/L</td>
<td>Drinking Water</td>
<td></td>
</tr>
<tr>
<td>Cesium-137</td>
<td>1.35</td>
<td>0.124</td>
<td>0.0175</td>
<td>Bq/L</td>
<td>Precipitation</td>
<td></td>
</tr>
<tr>
<td>Cesium-137</td>
<td>ND</td>
<td>0</td>
<td>0.0129</td>
<td>Bq/L</td>
<td>Pasteurized milk</td>
<td></td>
</tr>
</tbody>
</table>

FROM FDA

“As of Wednesday, October 12th, FDA import investigators had performed 26,318 field examinations for radionuclide contamination. FDA had tested 1091 samples, 167 of which were seafood or seafood products. 1090 samples had no Iodine-131, Cesium-134, Cesium-137, or other gamma-ray emitting radionuclides of concern. 1 sample was found to contain detectable levels of Cesium, but was below the established Derived Intervention Level (DIL) and posed no public health concern”
FDA Derived Intervention Levels

<table>
<thead>
<tr>
<th>Radionuclide Group</th>
<th>Limits, Bq/kg</th>
<th>Limiting Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sr-90</td>
<td>160</td>
<td>15 year old</td>
</tr>
<tr>
<td>I-131</td>
<td>170</td>
<td>1 year old</td>
</tr>
<tr>
<td>Cs-134 + Cs-137</td>
<td>1200</td>
<td>Adult</td>
</tr>
<tr>
<td>Pu-238 + Pu-239 + Am-241</td>
<td>2</td>
<td>3 months</td>
</tr>
<tr>
<td>Ru-103 + Ru-106</td>
<td>[(C3 / 6800) + (C6 / 450)] &lt; 1</td>
<td>3 months</td>
</tr>
</tbody>
</table>

- The DIL for each radionuclide group is applied independently.
- Each DIL applies to the sum of the concentrations of the radionuclides in the group at the time of measurement

http://www.fda.gov/Food/FoodSafety/FoodContaminantsAdulteration/ChemicalContaminants/Radionuclides/ucm078341.htm#level98
FDA DILS

• The FDA uses the principles in the general guidance provided by ICRP in 1984 for the immediate response to a major radiation accident, recognizing that at later stages, after the local situation is stabilized and more clearly defined, the longer-term intervention for food can be modified based on more detailed evaluation of local conditions by local authorities.

• Therefore, the PAGs for the ingestion pathway at the onset of an accident are 5 mSv committed effective dose equivalent or 50 mSv committed dose equivalent to an individual tissue or organ, whichever is more limiting.
FDA DIL calculation

• DILs (Bq/kg) = [PAG (mSv)] / [f x FI (kg) x DC (mSv/Bq)]

• Where:
  • DC = Dose Coefficient; the radiation dose received per unit of radionuclide activity ingested (mSv/Bq)
  • f = Fraction of the food intake assumed to be contaminated
  • FI = Food Intake; the quantity of food consumed in an appropriate period of time (kg)

• DILs assume 10% contamination of the diet which is then multiplied by a factor of three.

• For infants, (i.e., the 3-months and 1-year age groups) 100% contamination of the infant diet is assumed

• The Protective Action Guides (PAGs) used are 5 mSv committed effective dose equivalent, or 50 mSv committed dose equivalent to individual tissues and organs, whichever is more limiting.
**International Generic Action Levels for Foodstuffs**

<table>
<thead>
<tr>
<th>Radionuclides</th>
<th>Foods destined for general consumption, kBq/kg</th>
<th>Milk, infant foods, and drinking water, kBq/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{134}\text{Cs}$, $^{137}\text{Cs}$, $^{103}\text{Ru}$, $^{106}\text{Ru}$, $^{89}\text{Sr}$</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>$^{131}\text{I}$</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>$^{90}\text{Sr}$</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>$^{241}\text{Am}$, $^{238}\text{Pu}$, $^{239}\text{Pu}$</td>
<td>0.01</td>
<td>0.001</td>
</tr>
</tbody>
</table>

(from CODEX Alimentarius Commission guidelines for radionuclides in food moving in international trade following accidental contamination.)

Calculation of Guideline Level

\[ \text{GL} = \frac{\text{IED}}{M \cdot \text{ipf} \cdot e_{\text{ing}}} \]

- Where
  - IED = Intervention Exemption Level of Dose (mSv/yr)
  - M = Mass of food consumed (kg/yr)
  - ipf = import to production factor (fraction)
  - \( e_{\text{ing}} \) = ingestion dose coefficient (mSv/Bq)

- **IED was set at 1 mSv/yr**
  - 550 kg of food is consumed per year by an adult
  - 220 kg of food and milk is consumed by an infant
  - 10% of the diet is imported (and contaminated food)
  - Guidelines apply to each of the food groups independently
Determination of Guideline Level (GL)

GL is defined as “The maximum level of a substance in a food or feed commodity which is recommended by the CAC to be acceptable for commodities moving in international trade.

When the GL is exceeded, governments should decide whether and under what circumstances the food should be distributed within their territory or jurisdiction”.
Anecdotal Radioactivity Reported in Japanese Foodstuffs

- Spinach – 15 k Bq/kg $^{131}$I (~15 x adult GL)
- Milk -1.510 kBq/kg $^{131}$I (~15 x infant limit)
- Rice grains 0.500 kBq/kg $^{137}$Cs (~1/2 adult limit)
- Tea 2.720 kBq/kg $^{137}$Cs (~3 x adult limit)
- Saitama products had between 0.800 and 1.530 kBq/kg $^{137}$Cs (~1- 1.5 adult limit)

- These are single measurements
- Not representative of sustained consumption levels

## Radiation Doses and Expected Effects

<table>
<thead>
<tr>
<th>Dose</th>
<th>Time span</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-0.1 Sv</td>
<td>Acute or chronic</td>
<td>No observable effect</td>
</tr>
<tr>
<td>0.1-0.5 Sv</td>
<td>Acute or chronic</td>
<td>No observable effect, possible cancer risk</td>
</tr>
<tr>
<td>0.5-1 Sv</td>
<td>Chronic</td>
<td>Increased cancer risk</td>
</tr>
<tr>
<td>1-2 Sv</td>
<td>Acute</td>
<td>May see changes in blood cells, but the blood system quickly recovers</td>
</tr>
<tr>
<td>1–2 Sv</td>
<td>Chronic</td>
<td>Increased cancer risk.</td>
</tr>
<tr>
<td>2–3 Sv</td>
<td>Acute</td>
<td>Nausea and vomiting within 24-48 hours. Medical attention should be sought</td>
</tr>
<tr>
<td>3–5 Sv</td>
<td>Acute</td>
<td>Nausea, vomiting, and diarrhea within hours. Half of people exposed at high level will die if they receive no medical attention.</td>
</tr>
<tr>
<td>5-12 Sv</td>
<td>Acute</td>
<td>Likely lead to death within a few days</td>
</tr>
<tr>
<td>&gt;100 Sv</td>
<td>Acute</td>
<td>Death within a few hours.</td>
</tr>
</tbody>
</table>
### Radiation Risks in Japan

<table>
<thead>
<tr>
<th>Short term whole body dose, Gy</th>
<th>Acute Symptoms (nausea and vomiting within 4 hr), (%)</th>
<th>Death (acute) even with medical intervention, %</th>
<th>Excess Lifetime Risk of Fatal Cancer due to Short-term Radiation Exposure, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>0</td>
<td>0</td>
<td>0.8</td>
</tr>
<tr>
<td>0.5</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>5-30</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>1.5</td>
<td>40</td>
<td>&lt;5</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>75</td>
<td>15-30</td>
<td>24</td>
</tr>
<tr>
<td>6</td>
<td>100</td>
<td>50</td>
<td>&gt;40</td>
</tr>
<tr>
<td>10</td>
<td>&gt;90</td>
<td></td>
<td>&gt;50</td>
</tr>
</tbody>
</table>

Short-term is radiation exposure during the initial incident. Lifetime risk of fatal cancer is approximately 24%. Applies to individuals surviving the acute radiation syndrome.
First-Year Dose Estimate
Dose Commencing March 16, 2011 for 365 Days

Estimated First Year Dose (mrem)
- > 2000
- 1000 - 2000
- 500 - 1000
- 100 - 500
- < 100

Map created on 04092011 1300 JST
Name: CMHT A 1stYrDoseEst 08Apr2011

UNCLASSIFIED
Nuclear Incident Team DOE NIT
Contact (202) 586 - 8100
From the atlas of caesium deposition on europe
Summary and Conclusions

• Radionuclides are present in our environment
  • Naturally
  • Not-so naturally

• Systems in place to
  • Measure them
  • Limit total dose
Great Sources of Data and Information

- Ongoing monitoring
  - EPA RADNET
  - FDA
- Overviews
  - UNSCEAR
  - IAEA
  - Other
  - USGS
Thank you – Questions?