POLONIUM-210 AND DRINKING WATER: OCCURRENCE IN MINNESOTA AND HEALTH RISK IMPLICATIONS

James Jacobus, Ph.D.  
Minnesota Department of Health

October 26, 2015
Special Note

- MDH has not developed a specific policy or interpretation of the exposures and risks to date

- Po-210 occurrence in groundwater is an ongoing project under the Minnesota Department of Health’s Contaminants of Emerging Concern program
Acknowledgements

MN Department of Health:
• James Lundy, Source Water Protection
• Anna Schliep, Drinking Water Protection
• Karla Peterson, Drinking Water Protection
• Jeff Brenner and Jessie Fillmore, MDH Public Health Laboratory

Po-210 and Pb-210 Analysis:
• Pace Analytical, Inc.

Wonderful colleagues:
• Mike Schultz, University of Iowa
• Lowell Ralston, USEPA
• Paul Stackelberg, USGS
Focus

- Polonium-210 (Po-210) and other Naturally-occurring radionuclides (NORM) in MN drinking water sources

- Cancer is the major health risk, low level exposures

- Groundwater used for drinking water

- Minnesota and northern Midwestern states are known for elevated radionuclides in soil and groundwater
Assessment of radionuclides in drinking water requires fundamentals of chemical toxicology and radiation biology.
Background Exposure

• Average annual exposure range is 300-600 mrem / 3-6 mSv

• Medical diagnostics such as CT/x-rays and radiation therapy can greatly increase an individual’s annual radiation exposure
  • Fastest growing source of radiation exposure at the population level in the US

• Increasing use of groundwater resources can also be a source of increasing exposure to environmental radiation sources
Groundwater Use Increasing

Municipal Water Use in Seven-County Twin Cities Metropolitan Area, Minnesota

- % Groundwater
- % Surface Water

Metro Council, Minnesota
Cumulative Counts

• Small doses of radiation (mSv), over the course of a lifetime, cumulatively increase risk of cancer

• Those with longer to live (children) encumber greater risk from equivalent dose exposure compared to adults

• Therefore, limiting exposure where possible is important for public health

• Limiting most potent exposures even more critical ($\alpha$)
Mechanism of Toxicity: Breaking DNA

Sparsely Ionizing (wave)

Densely Ionizing (particle)

Single strand break; easy fix

Double strand break; which end is up??
Why Focus on Po-210?

• Potent alpha emitter and known human carcinogen
  • Biological half-life of ~50 days
  • Readily taken up by GI tract, especially in children
  • Partitions to organs and tissues, rather than bone

• Scant data on Po-210 in drinking or ground water

• Radium-226, ‘parent’ of Po-210, elevated in Minnesota

• Gross alpha elevations could be due to Po-210 levels

• EPA has expressed concern over Po-210, but no new comprehensive study completed since addition to UCMR in 2000
Relative Potency of Selected Radionuclides

Groundwater Radionuclide Cancer Risk Potency
Relative to Radium-226

Cancer Morbidity Risk
Relative to Radium-226

Polonium-210
Lead-210
Radium-226
Radium-228
Pilot Study Design, Po-210 and Pb-210

- Select sampling sites based on hierarchy of gross alpha levels known from compliance monitoring

- 32 source water samples spread across various aquifers
  - 4 entry point (post-treatment) samples
  - Split sampling at five sites with USGS to examine interlab var.

- Paired gross alpha time course analysis with Po-210

- 10 samples were also analyzed for lead-210
Minnesota Well Code

• Wells in Minnesota cannot be open to more than one aquifer

• All wells in this study draw water from a single aquifer

• Wells in other states are often open to all aquifers readily accessible in the boring, mixing water types
Po-210, By Aquifer

Aquifer acronyms: CTCW (Tunnel City-Wonewoc), CJDN (Jordan), CMSH (Mt. Simon-Hinckley), CMTS (Mt. Simon), DCOG (Cedar Valley-Galena), DCOM (Cedar Valley-Maquoketa), PMFL (Fond du Lac Formation), PMHN (Mt. Simon-Hinckley), PMSX (Sioux Quartzite), OSTP (St. Peter), QBA (Quaternary buried artesian aquifer)
## Po-210 and Pb-210 Results

<table>
<thead>
<tr>
<th>Well #</th>
<th>Po-210 (pCi/L)</th>
<th>Pb-210 (pCi/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>430604</td>
<td>4.99 (±0.75)</td>
<td>0.551 (±0.31)</td>
</tr>
<tr>
<td>415943</td>
<td>1.33 (±0.09)</td>
<td>0.326 (±0.18)</td>
</tr>
<tr>
<td>241335</td>
<td>1.23 (±0.21)</td>
<td>0.702 (±0.32)</td>
</tr>
<tr>
<td>151559</td>
<td>0.528 (±0.13)</td>
<td>--</td>
</tr>
<tr>
<td>645355</td>
<td>0.371 (±0.09)</td>
<td>0.631 (±0.26)</td>
</tr>
<tr>
<td>Entry Point #3</td>
<td>0.334 (±0.09)</td>
<td>2.870 (±0.41)</td>
</tr>
<tr>
<td>206456</td>
<td>0.308 (±0.09)</td>
<td>0.120 (±0.17)</td>
</tr>
<tr>
<td>Entry Point #1</td>
<td>0.232 (± 0.08)</td>
<td>1.52 (± 0.28)</td>
</tr>
</tbody>
</table>
Gross Alpha trends over time

Absolute Gross Alpha Activity Time Course in high Po-210 Samples

- Po-210: 4.99 pCi/L
- Po-210: 1.33 pCi/L
Correlation with Radium-226 (Historical data)

Historical Ra-226 Activity Correlated to Po-210 Activity

\[ y = 0.1003x - 0.2572 \]

\[ R^2 = 0.3215 \]
Ra-226/Ra-228 ratio and Po-210

Historical Ra-228/Ra-226 Ratio and Po-210 Activity

\[ y = 0.0572x + 0.3713 \]
\[ R^2 = 0.0053 \]
Major Findings

• Po-210 is found at low levels in many aquifers, with highest levels found in Mt. Simon

• Highest levels found in relatively shallow Mt. Simon wells

• Two post-treatment samples contained highest activity of Pb-210

• Po-210 was found in three source wells above 1 pCi/L, with a maximum detection of 5 pCi/L
Po-210 Health Risk Assessment

- Po-210 radiation doses, delivered over a lifetime, may be contributing extra cancer morbidity risk between 1:100,000 (within the acceptable risk range) and 1:2,000 (outside of range)

- Gross alpha screening level of 15 pCi/L not low enough to account for Po-210 health risks

- Cumulative nature of radiation exposures throughout life warrants identification and reduction of Po-210 exposure in possible drinking water sources
Future Steps

• As neither gross alpha nor radium were good predictors of Po-210 in groundwater, continued monitoring efforts are needed to understand risks and exposures in Minnesota.

• Does current treatment reduce Po-210?

• Is radon supporting Pb-210 in treatment plant effluent?

• Can domestic wells contain Po-210 >1 pCi/L?
Questions and Discussion
Acknowledgements

MN Department of Health:
• James Lundy, Source Water Protection
• Anna Schliep, Drinking Water Protection
• Karla Peterson, Drinking Water Protection
• Jeff Brenner and Jessie Fillmore, MDH Public Health Laboratory

Po-210 and Pb-210 Analysis:
• Pace Analytical, Inc.

Wonderful colleagues:
• Mike Schultz, University of Iowa
• Lowell Ralston, USEPA
• Paul Stackelberg, USGS