Naturally Occurring Radionuclides in Drinking Water are an Underestimated Public Health Risk

James A. Jacobus, Minnesota Department of Health

Abstract ID: RP099

Overview

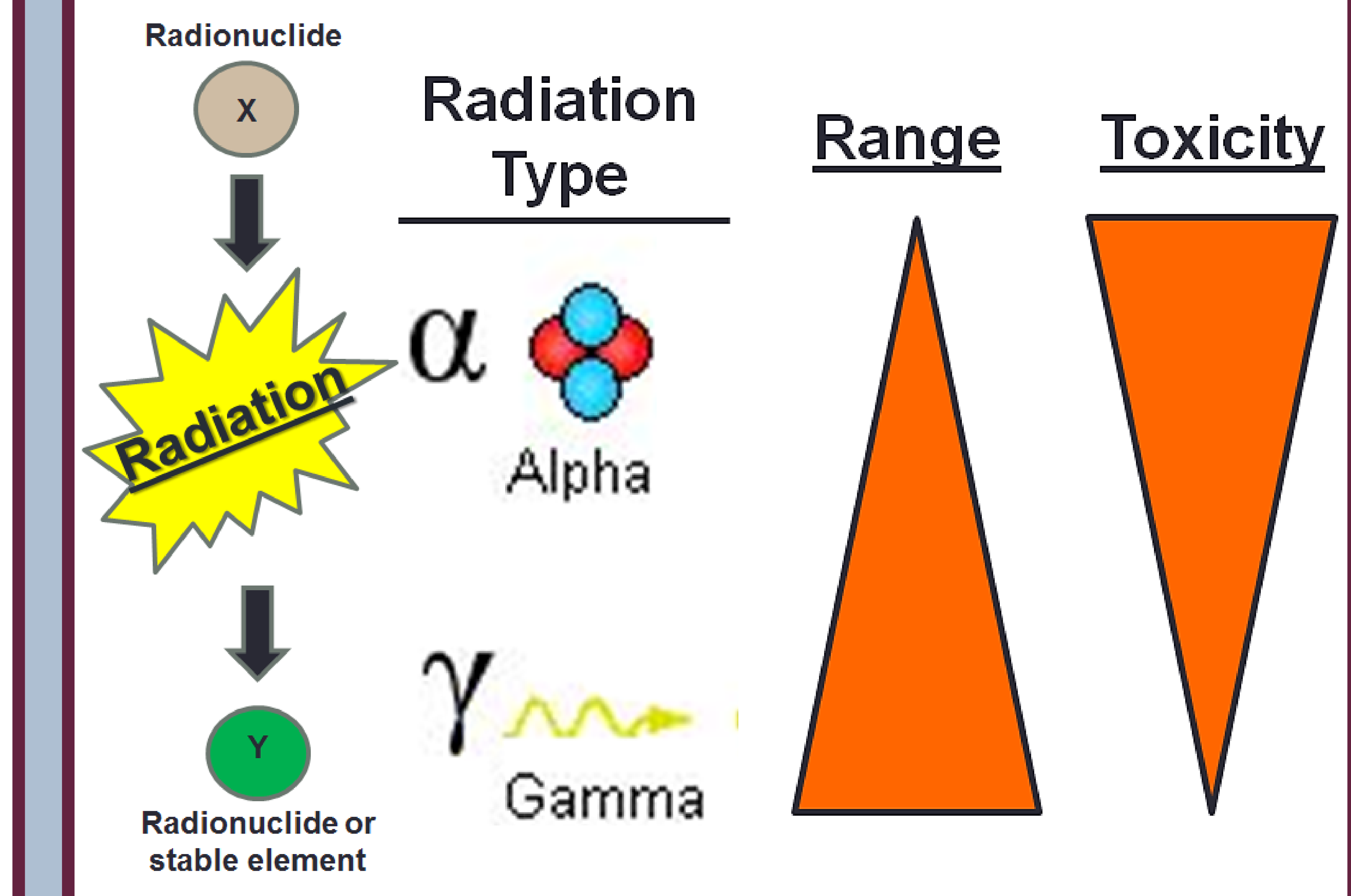
In Minnesota, many communities rely on deep aquifers that contain naturally occurring radioactive daughters of the uranium-238 decay series. As opposed to the high-profile, low frequency exposure to manmade radionuclides, exposure to naturally occurring radionuclides throughout our environment is very common. When ingested, these radionuclides deposit ionizing radiation inside the body. Alpha-emitting radionuclides, such as polonium-210 and radium-226, pose the highest health risk from ingestion and inhalation, while being essentially harmless outside the body. Therefore, in drinking water, alpha particle ingestion poses considerable health risks that deserve careful consideration.

Two federal drinking water standards currently regulate alpha-emitting radionuclides. Both MCLs use the upper end of the acceptable risk range - a 1:10,000 cancer risk[1]. Critically, the gross alpha MCL is a crude assessment that only quantifies alpha particle radiation, and not the specific source radionuclides from which these alpha particles originate. Specific alpha-emitting radionuclides need to be identified to understand health risks, as residence time in the body, dose, and tissue-specific radiation effects vary greatly between different radioactive elements.

To ensure adequate protection of public health, specific occurrence information must be gathered on highly toxic radionuclides that could be producing alpha particles in drinking water[2]. Polonium-210 is the highest priority, as this radionuclide has the greatest potency and its occurrence in Minnesota's drinking water is unknown despite the confirmed presence of other uranium-related decay products. A pilot study to determine polonium-210 levels in groundwater began in 2014.

Alpha Particle Toxicity

- Ingestion or Inhalation Required
- Tissue-specific targeting based on radionuclide
- Concentrated Damage
- Clustered DNA Breaks Difficult to Repair
- 20 times more potent than gamma/x-rays
- Naturally occurring alpha emitters most prevalent

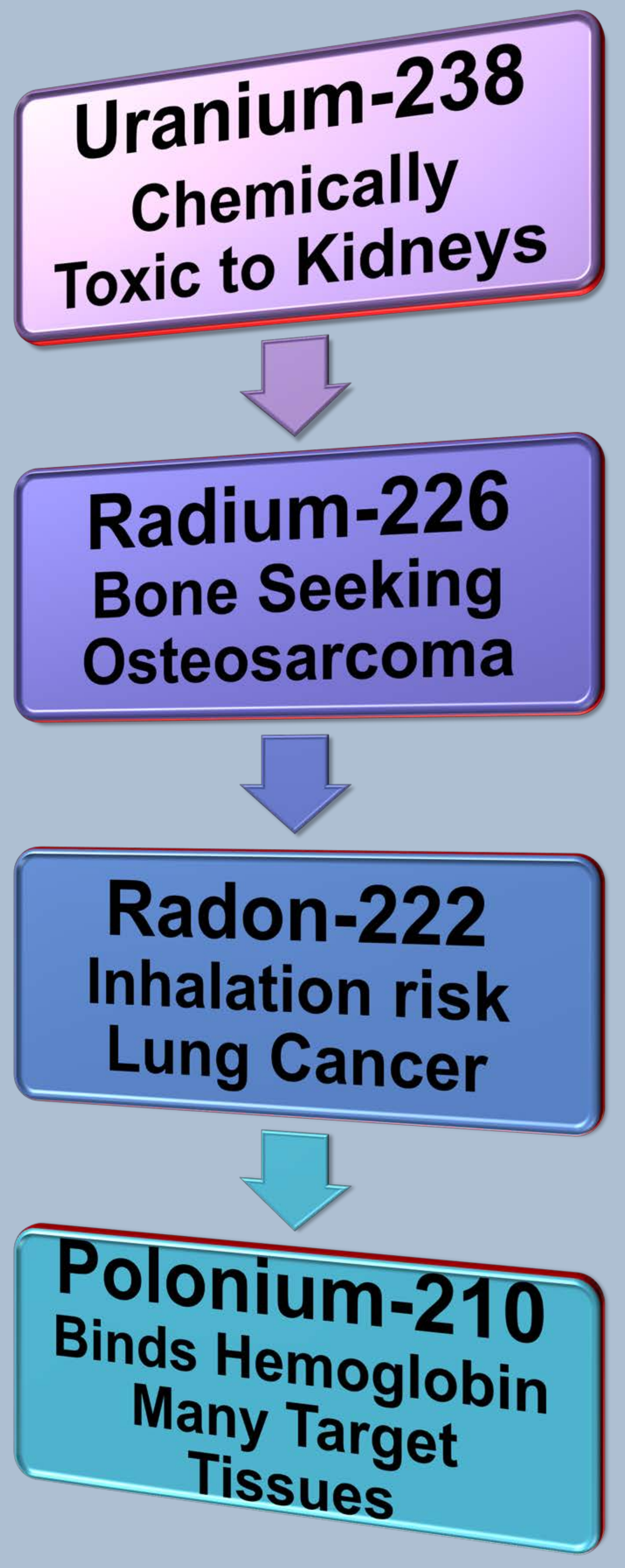


Drinking Water Regulations

- Only Community Water Supplies are regulated
- Activity, in picocuries per liter (pCi/L), concentration, and dose are all used as regulatory units
- Maximum Contaminant Level Goal (MCLG) for all radionuclides is zero – all known carcinogens
- Maximum Contaminant Level (MCL) guidance has been set for some specific radionuclides, but most are regulated as a group, alpha emitters.
    - Gross Alpha MCL: 15 pCi/L
    - Ra-226/228 MCL: 5 pCi/L
    - Uranium-234/235/238 MCL: 30 µg/L
    - Anthropogenic radionuclides emitting long range gamma/x-ray radiation also have a group-based MCL relying on human dose rather than (radio) activity in water

Radioactive Decay

- Unstable atoms (radionuclides) release radiation (decay) and form new elements
- Uranium/Thorium decay creates a variety of toxic radionuclides in some aquifers
- Distinct elements = Varied Toxicities



Only selected radionuclides shown from the U-238 decay series.

Risks/Uncertainties

- Radionuclide MCLs have been set at a 1:10,000 cancer risk for lifetime consumption based on dosimetry models. Naturally occurring material guidance/regulatory values typically represent an order of magnitude (or two) greater risk than synthetic chemical risk assessment.
- Developmental toxicity has not been examined for radium, polonium, and many other radionuclides. The developing organism is extremely sensitive to radiation exposure, and this gap constitutes a large uncertainty, currently ignored, when considering population-wide exposures from community water supplies.
- The Gross Alpha MCL may not be protective for polonium-210 (Po-210), which has a 1:10,000 cancer risk <15 pCi/L and is poorly detected by the gross alpha analytical method

Occurrence Data Lacking

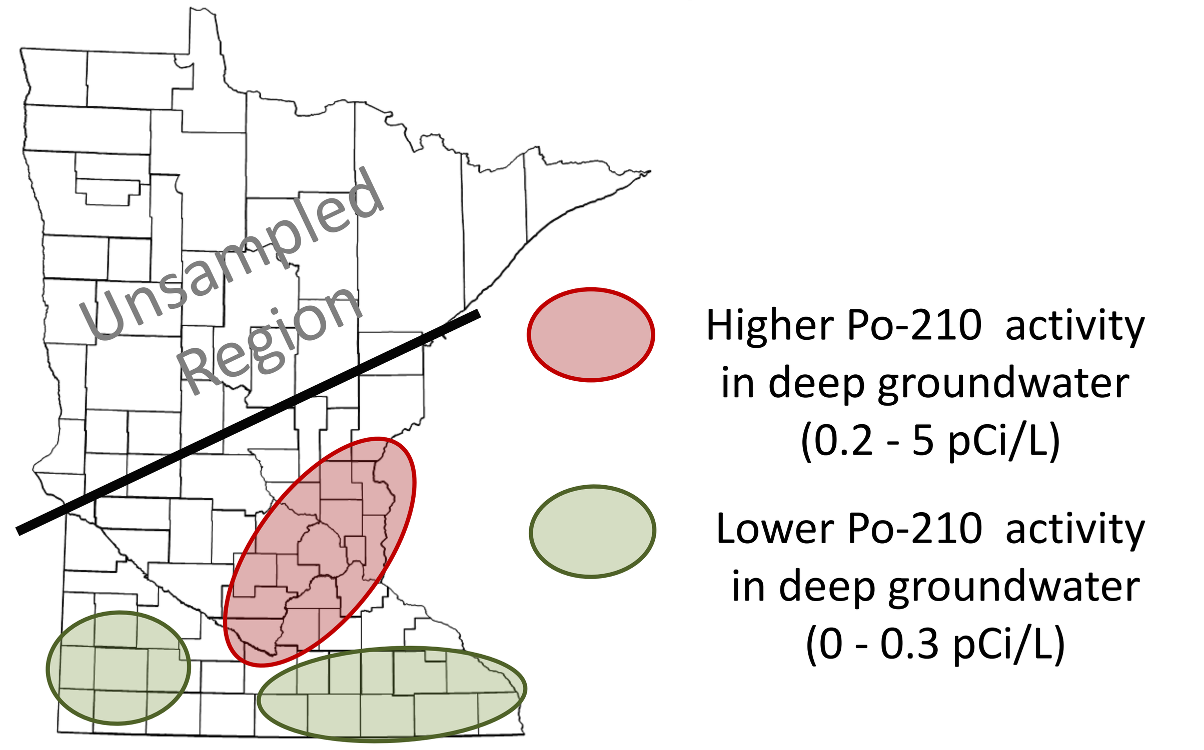
- Many toxicologically important radionuclides are difficult to detect in environmental samples.
- In 2000, when the Radionuclide Rule was finalized, the detection of individual alpha emitters was considered too arduous, outside the reach of most state laboratories
- Polonium-210 and Lead-210 (Pb-210) were singled out for environmental assessment on the Unregulated Contaminant Monitoring Rule, but analytical hurdles could not be overcome and no data were gathered. Focus to date on Radium has resulted in very good occurrence data for this radionuclide
- Occurrence of Po-210 and Pb-210 in important groundwater resources of many states is largely unknown, including Minnesota
- Po-210 occurrence study is underway in MN

References

1. Radionuclides Notice of Data Availability Technical Support Document. USEPA, 2000. Office of Ground Water and Drinking Water.
2. Weinhold, B. Unknown Quantity: Regulating Radionuclides in Tap Water. 2012. *EHP* 120; 9: A350-A356.

Polonium-210 Pilot Study

- Many community water supply groundwater wells in Minnesota contain elevated total gross alpha activity
- The occurrence of polonium-210 is unknown, despite the confirmed presence of its parent radionuclides
- Preliminary sampling results (n=30) demonstrate the presence of polonium-210 in groundwater, with a maximum concentration of 5 pCi/L



Conclusions and Future Directions

- The alpha emitter Po-210 occurs in MN groundwater
- Initial results show that Po-210 activity exceeds 1 pCi/L in some wells, with a maximum detection of 5 pCi/L in the pilot study
- Po-210 concentration is not accurately predicted by gross alpha activity, but gross alpha is an indicator
- The 1:10,000 cancer risk level allowed for total alpha exposure may be exceeded by just Po-210 ingestion
- Po-210 removal efficiency by current treatment processes in MN is unknown and needs assessment
- Careful hydrogeologic analysis of high Po-210 wells may identify important occurrence drivers in MN
- Lead-210 occurrence, now that Po-210 is confirmed, needs assessment due to its potency/toxicity and relationship to Po-210 in the U-238 decay series.