Produced Water Radioactivity

Regulation Lax as Gas Wells’ Tainted Water Hits Rivers, Ian Urbina, NYT, 2/26/11

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Summary of Conclusions

- The total alpha measurements should reflect mostly radon (Rn) gas, dissolved in produced frac water (where available, other $\alpha$-radioactivity was subtracted)

- The radium $^{228}_{88} \text{Ra}$ and $^{226}_{88} \text{Ra}$ isotopes have $T_{1/2}$ of 5.79 and 1,602 years, respectively

- The uranium $^{238}_{92} \text{U}$ and $^{235}_{92} \text{U}$ isotopes have $T_{1/2}$ of 4.5 and 0.7 billion years, respectively

- The radon $^{220}_{86} \text{Rn}$ and $^{222}_{86} \text{Rn}$ isotopes have $T_{1/2}$ of 55.6 sec and 3.82 days, respectively
Summary of Conclusions

- Chemical properties of radium mostly resemble those of barium, its high concentration is due to the ion exchange of formation minerals and water with the barium-rich drilling mud.

- Airborne (not water-dissolved) radon is responsible for the majority of the public exposure to ionizing radiation; it is often the single largest contributor to an individual’s background radiation dose.

- Airborne radon is the second most frequent cause of lung cancer, after cigarette smoking, causing 21,000 lung cancer deaths per year in the United States.
Radioactive decay chains

Leaching of radium

- Radium is less strongly sorbed to the silicate surface than its thorium or uranium parents and has the potential for desorption from the aquifer matrix to groundwater when the Th-230 decays.

- Potential exists for the newly formed Ra-226 ions to be physically ejected into solution from the rock matrix upon their creation (alpha recoil).

- The bond to the matrix can be weakened by the emission energy, increasing the potential for the Ra-226 to leach to groundwater because of increased competition for cation exchange sites on the rock matrix from other ions in solution.
MCLs and scales

The Maximum Contaminant Levels are:

- Radon: 300 picocurie/L (pCi/L) = 0.3 nanocurie/L (nCi/L), or 300 radioactive decays per second in 27 L of water. The Alternative MCL (AMCL) is 4,000 pCi/L
- Radium: 5 pCi/L
- Uranium 5 pCi/L

Radioactivities were scaled as follows:

- Total $\alpha$ and Rn from 0 to 45 nCi/L
- Ra-226 and 228 from 0 to 18 nCi/L
- U-235 and 238 from 0 to 500 pCi/L
Total $\alpha$-radiation

Data source: NYT spreadsheet from Ian Urbina, 2/27/11
Alpha-radiation is multifractal

- The measured $\alpha$-emissions were ranked with respect to level: Rank 1 is given to the highest emission in the sample.
- The ranked distribution of $\alpha$-emission levels plots as a parabola on a log-log scale.
- This means that the $\alpha$-emissions are a power function of rank, whose negative exponent decreases with the increasing rank.
- This means that at any emission level there is increasingly more samples with smaller emissions.
- Such a distribution is multifractal: there is no physically meaningful mean and standard deviation.
Total $\alpha$-radiation

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Radon or total $\alpha$-radiation

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Ra-226 $\alpha$-radiation

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Ra-228 $\alpha$-radiation

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Ra-228 $\alpha$-radiation

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U-235 $\alpha$-radiation

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U-235 $\alpha$-radiation

Data source: NYT spreadsheet from Ian Urbina, 2/27/11
U-238 α-radiation

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U-238 $\alpha$-radiation

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