Produced Water Radioactivity

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

Tad Patzek, (Petroleum), UT Austin

February 28, 2011, PGE

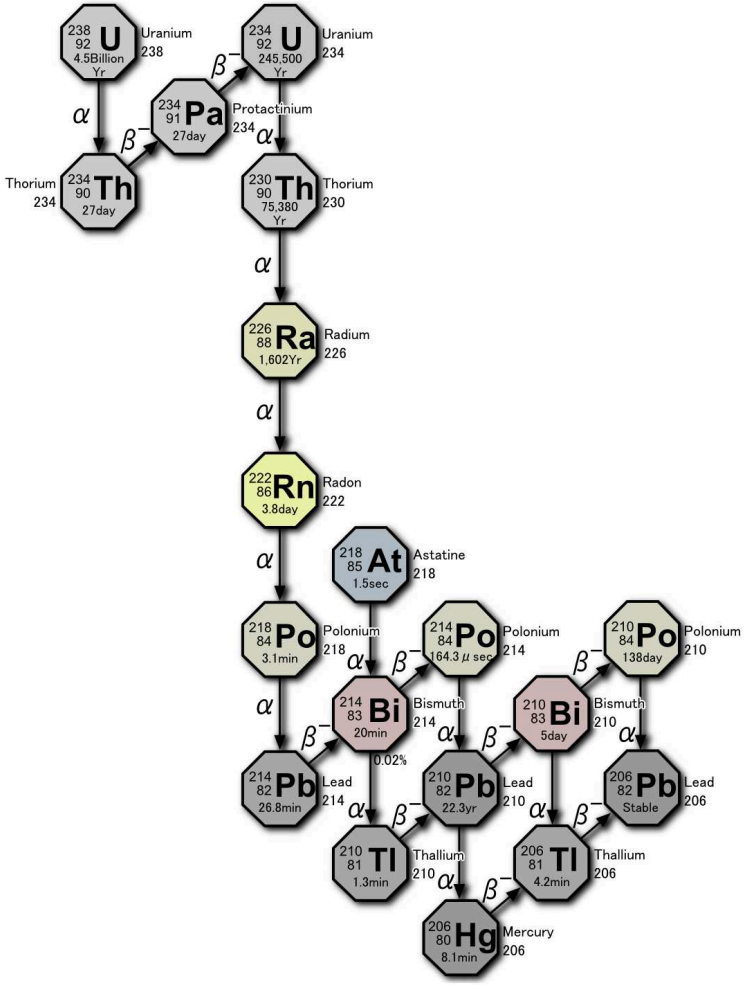
Summary of Conclusions

- The total alpha measurements should reflect mostly radon (Rn) gas, dissolved in produced frac water (where available, other α-radioactivity was subtracted)
- The radium $^{228}_{88}$Ra and $^{226}_{88}$Ra isotopes have $T_{1/2}$ of 5.79 and 1,602 years, respectively
- The uranium $^{238}_{92}$U and $^{235}_{92}$U isotopes have $T_{1/2}$ of 4.5 and 0.7 billion years, respectively
- The radon $^{220}_{86}$Rn and $^{222}_{86}$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



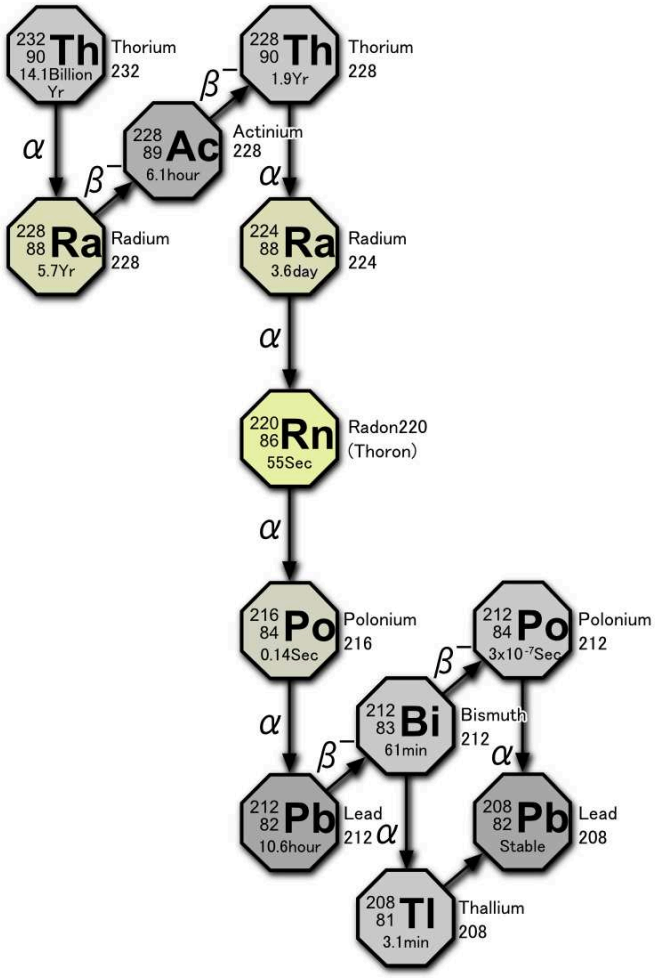


Image source: Wikipedia

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

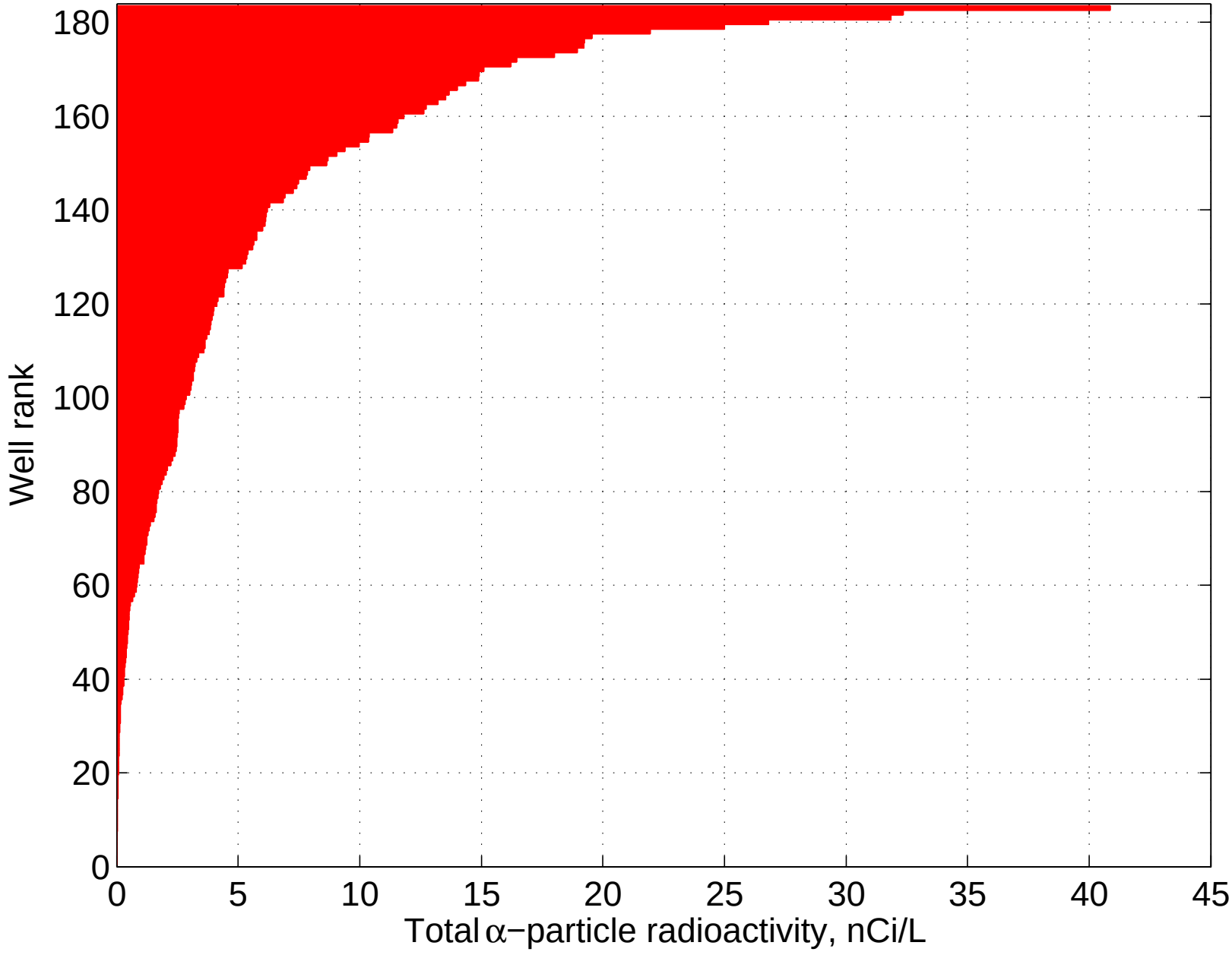
The Maximum Contaminant Levels are:

- 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 α 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 α-radiation

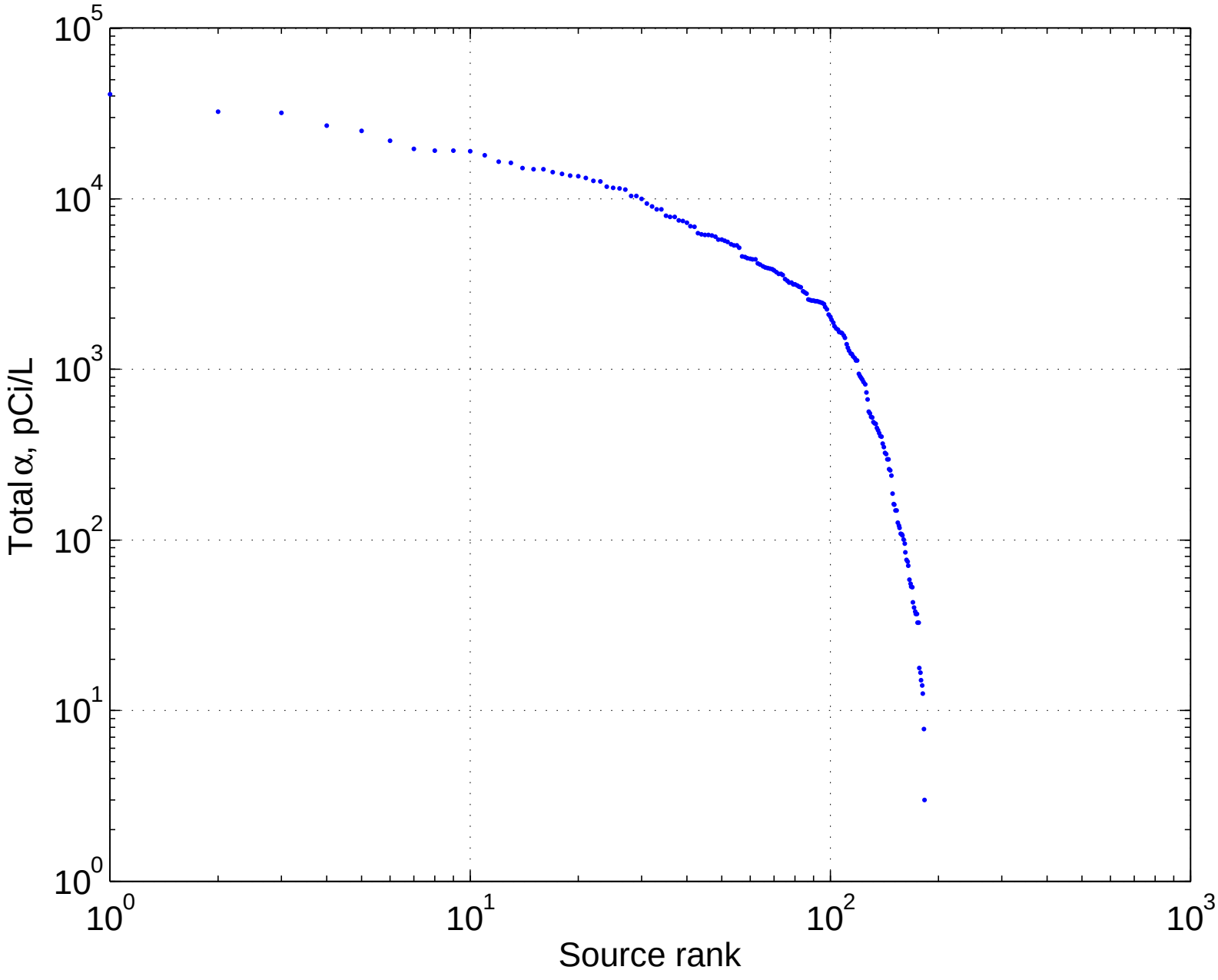


Data source: NYT spreadsheet from Ian Urbina, 2/27/11

Alpha-radiation is multifractal

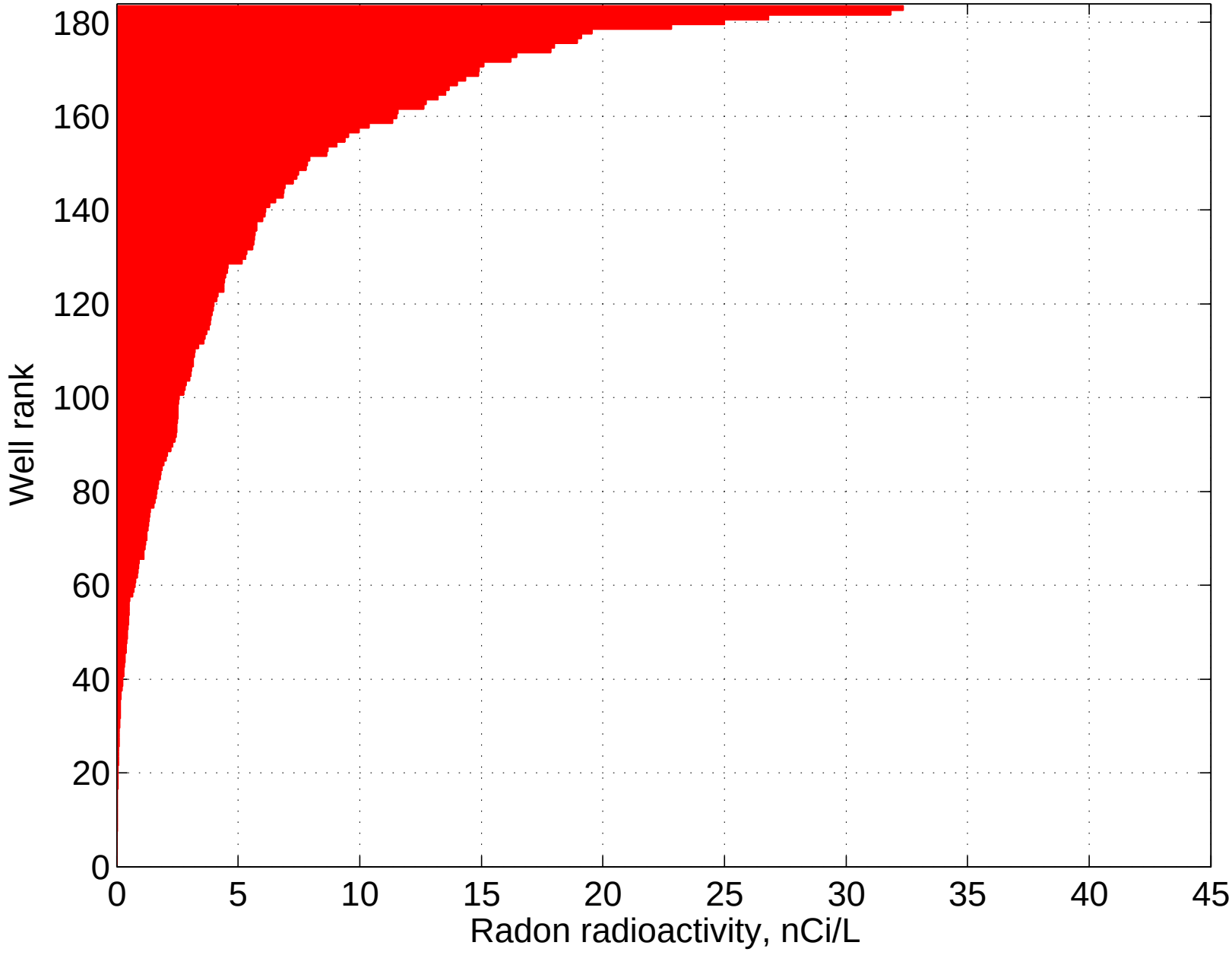
- The measured α-emissions were ranked with respect to level: Rank 1 is given to the highest emission in the sample
- The ranked distribution of α-emission levels plots as a parabola on a log-log scale
- This means that the α-emissions are a power function of rank, whose negative exponent decreases with 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 α-radiation



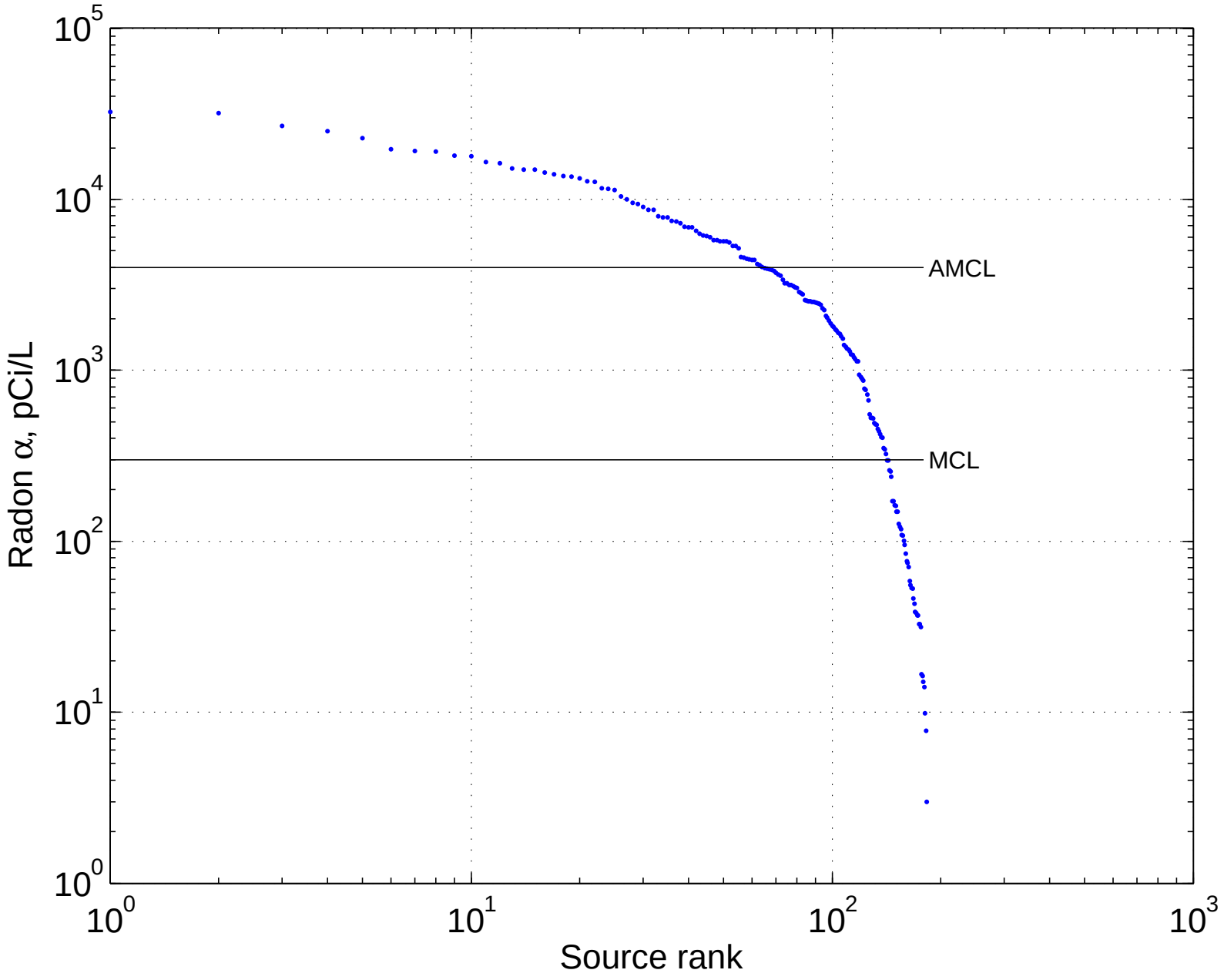
Data source: NYT spreadsheet from Ian Urbina, 2/27/11

Radon or total α-radiation



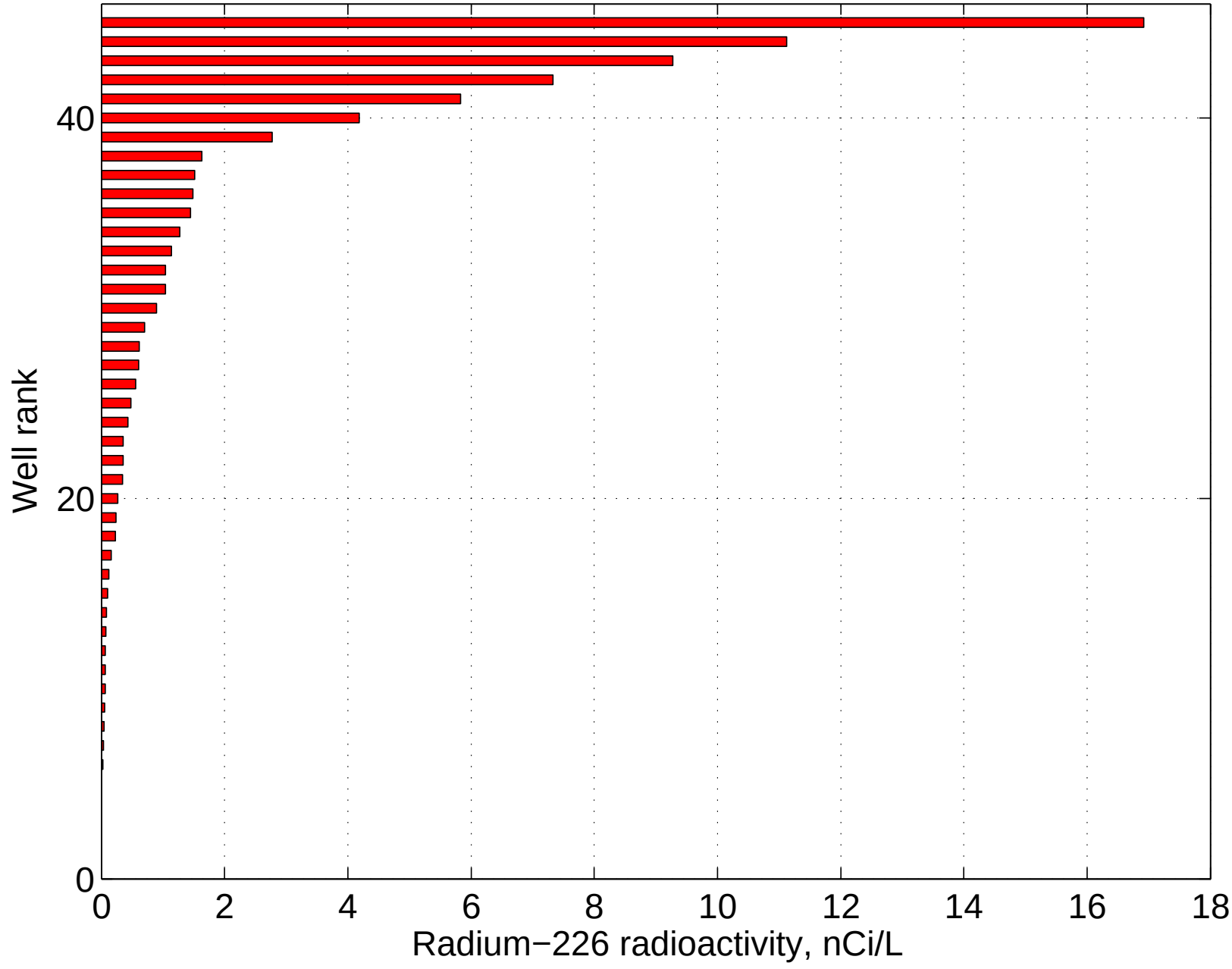
Data source: NYT spreadsheet from Ian Urbina, 2/27/11

Radon or total α-radiation



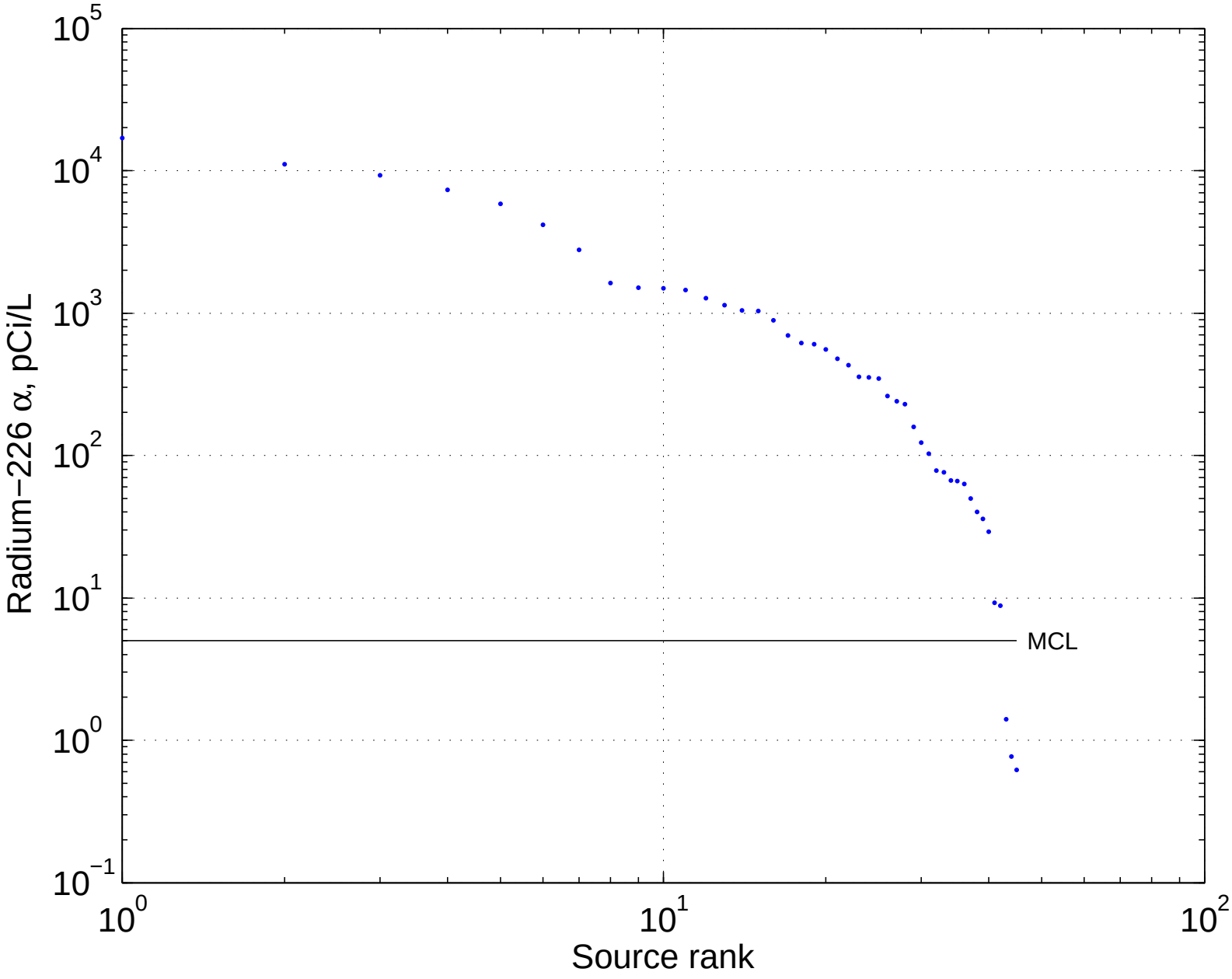
Data source: NYT spreadsheet from Ian Urbina, 2/27/11

Ra-226 α-radiation



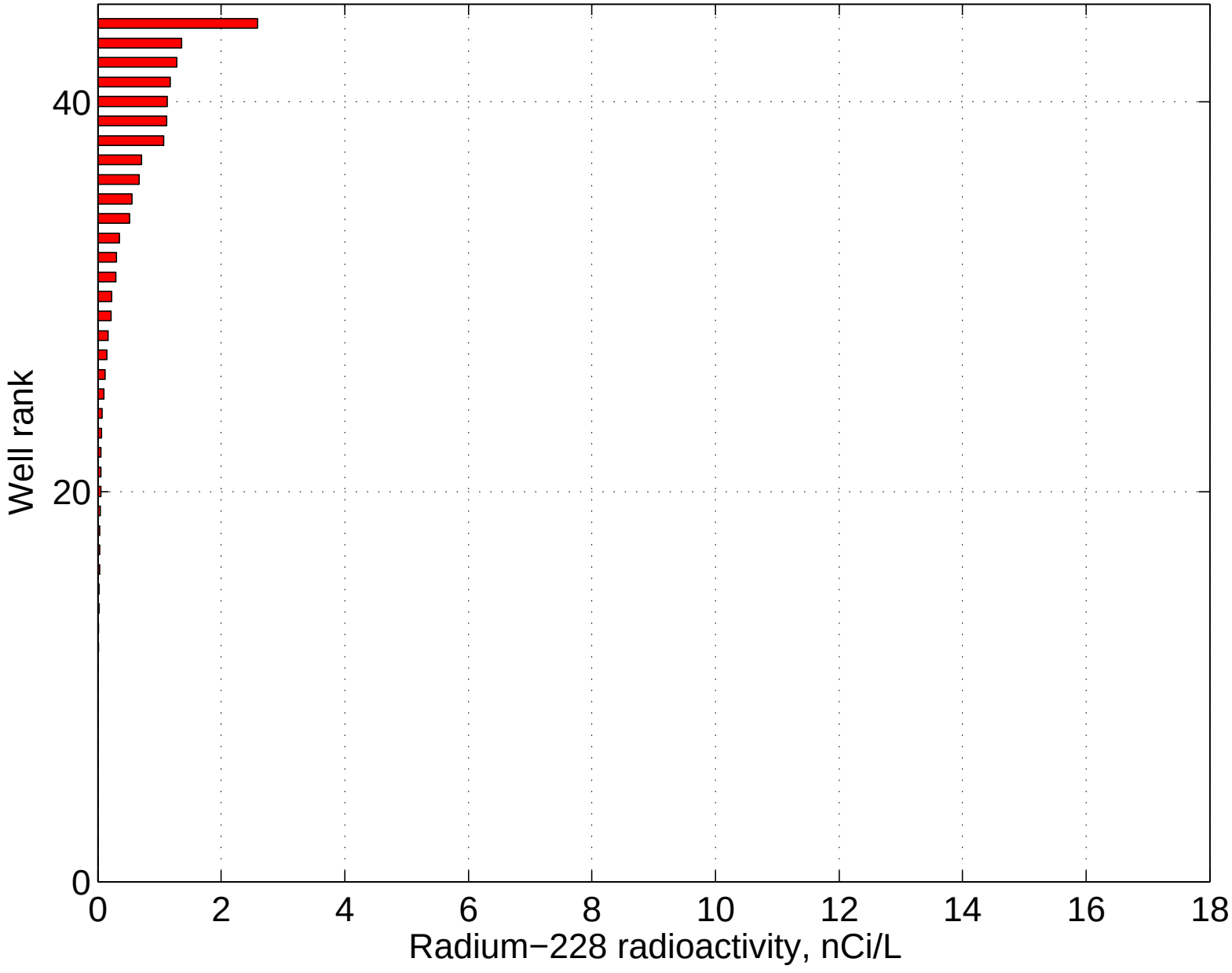
Data source: NYT spreadsheet from Ian Urbina, 2/27/11

Ra-226 α-radiation



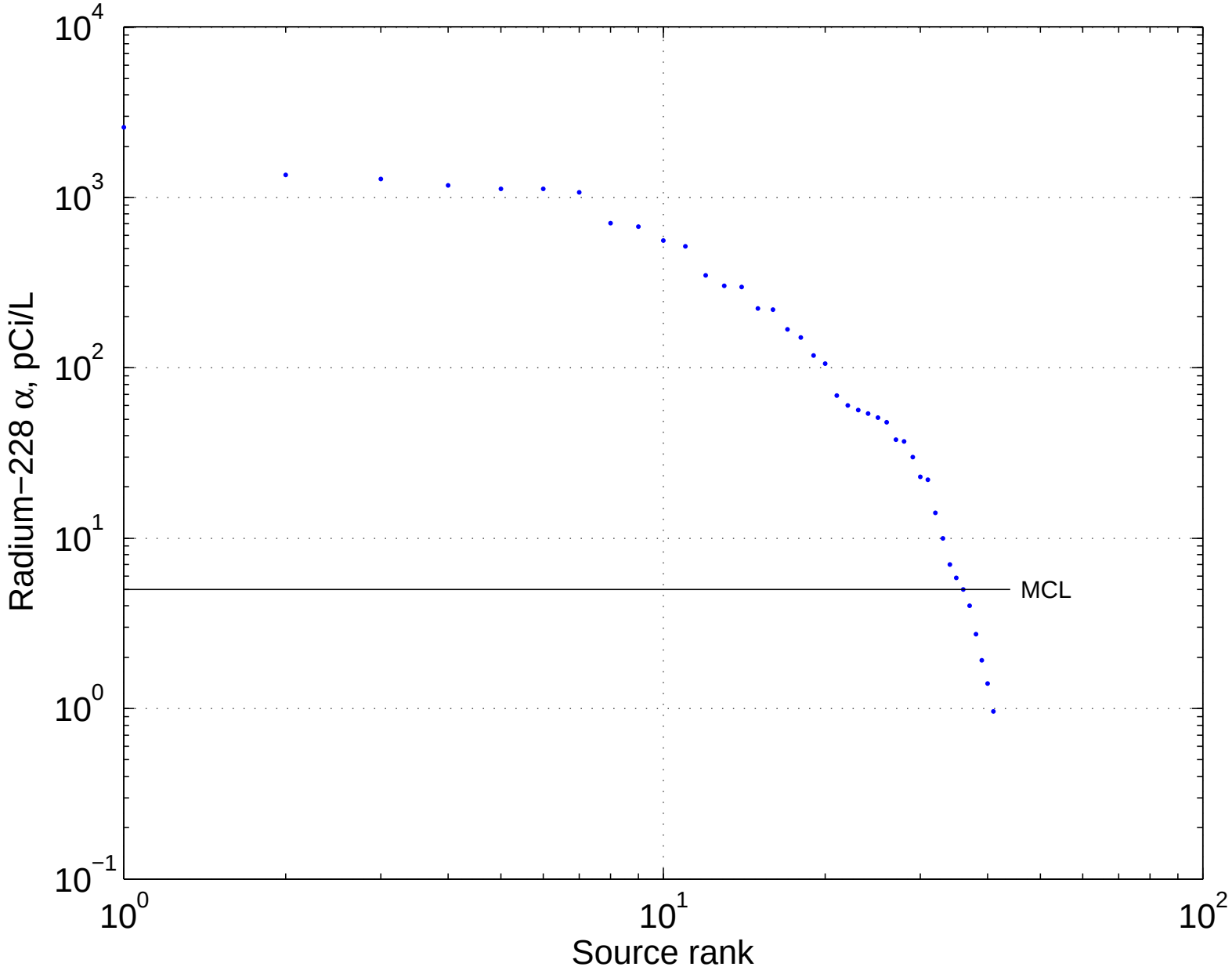
Data source: NYT spreadsheet from Ian Urbina, 2/27/11

Ra-228 α-radiation



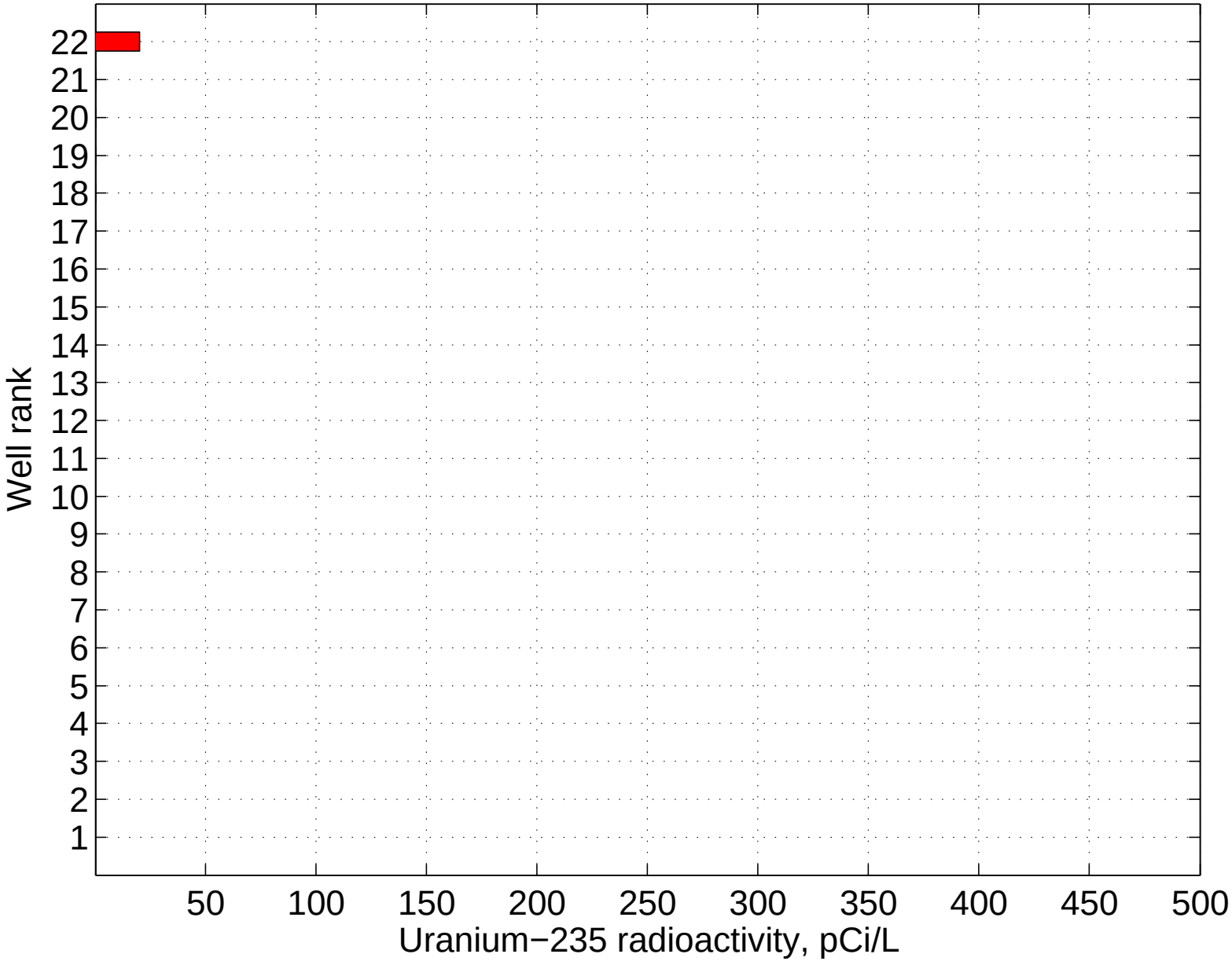
Data source: NYT spreadsheet from Ian Urbina, 2/27/11

Ra-228 α-radiation



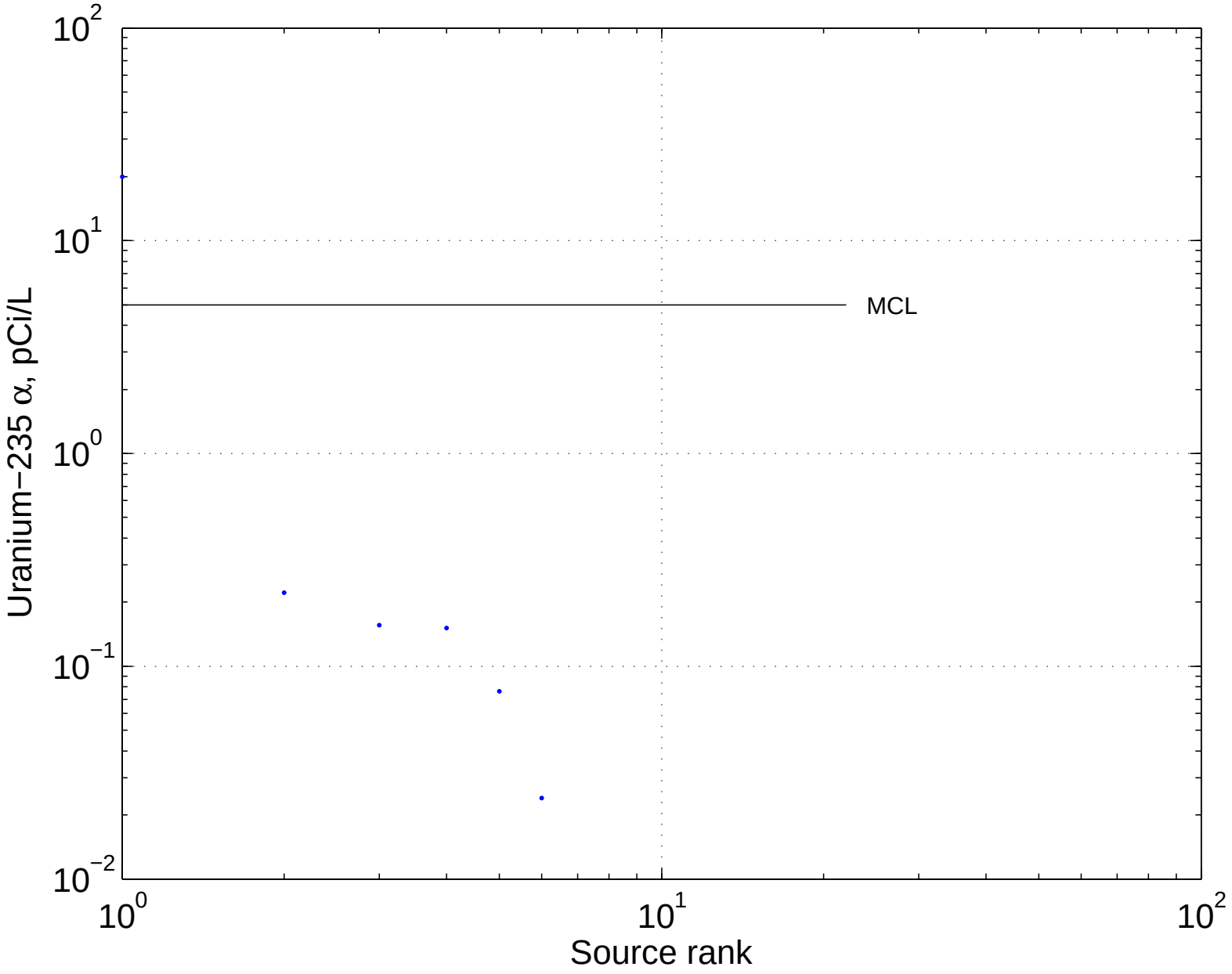
Data source: NYT spreadsheet from Ian Urbina, 2/27/11

U-235 α-radiation



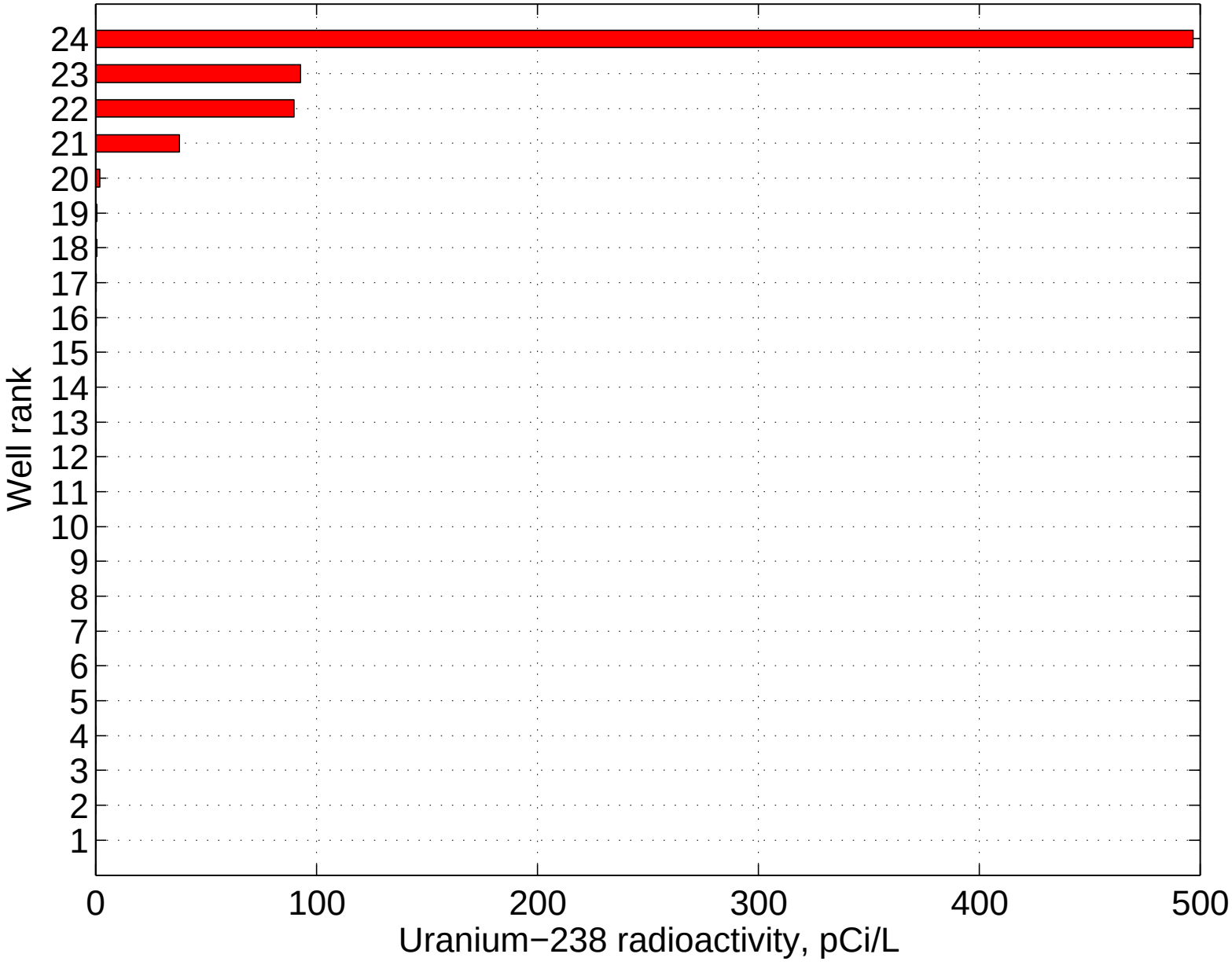
Data source: NYT spreadsheet from Ian Urbina, 2/27/11

U-235 α-radiation



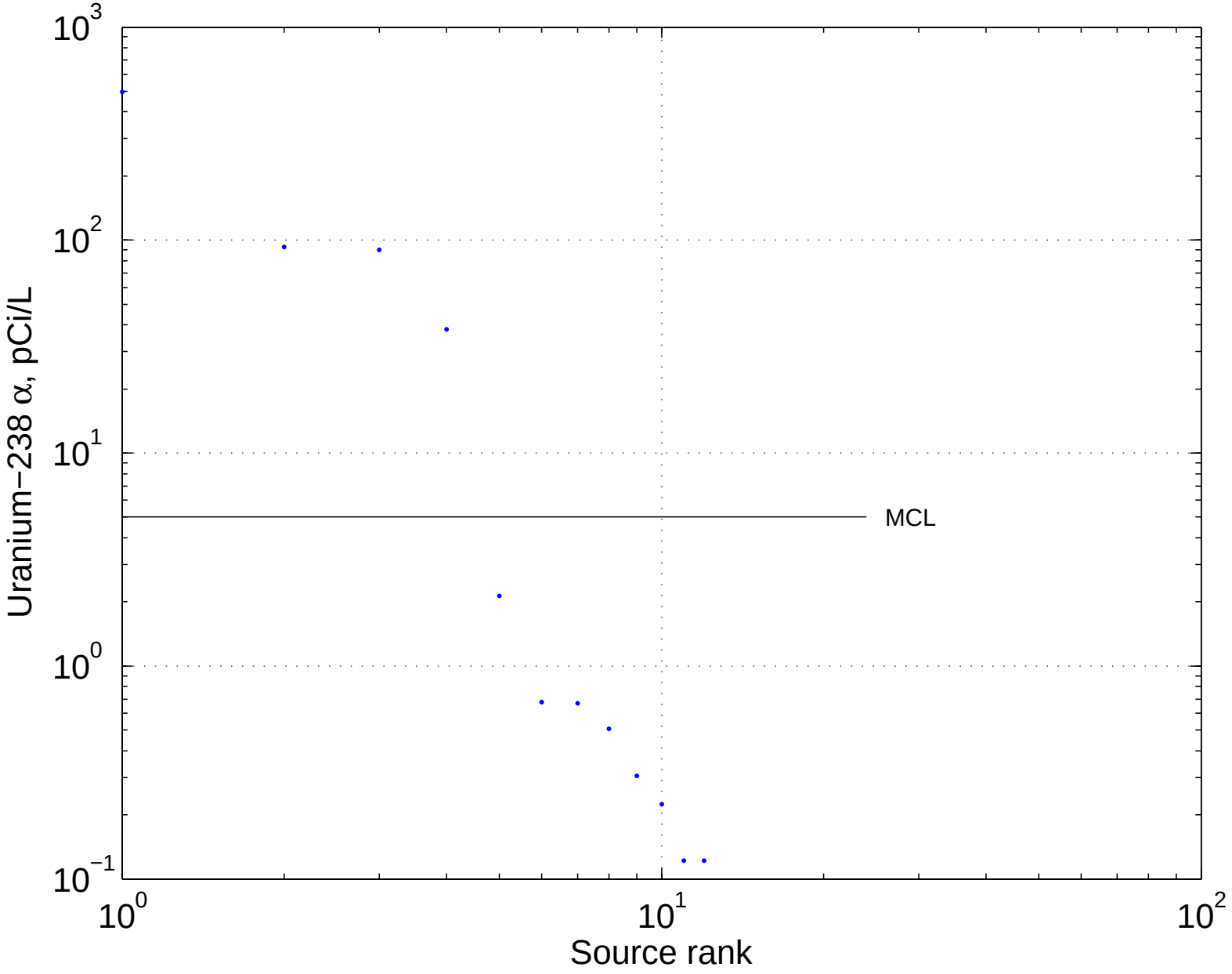
Data source: NYT spreadsheet from Ian Urbina, 2/27/11

U-238 α-radiation



Data source: NYT spreadsheet from Ian Urbina, 2/27/11

U-238 α-radiation



Data source: NYT spreadsheet from Ian Urbina, 2/27/11