Don’t be fooled by low Ra-226 and much higher Pb-214 and Bi-214 activities in water and leachate samples

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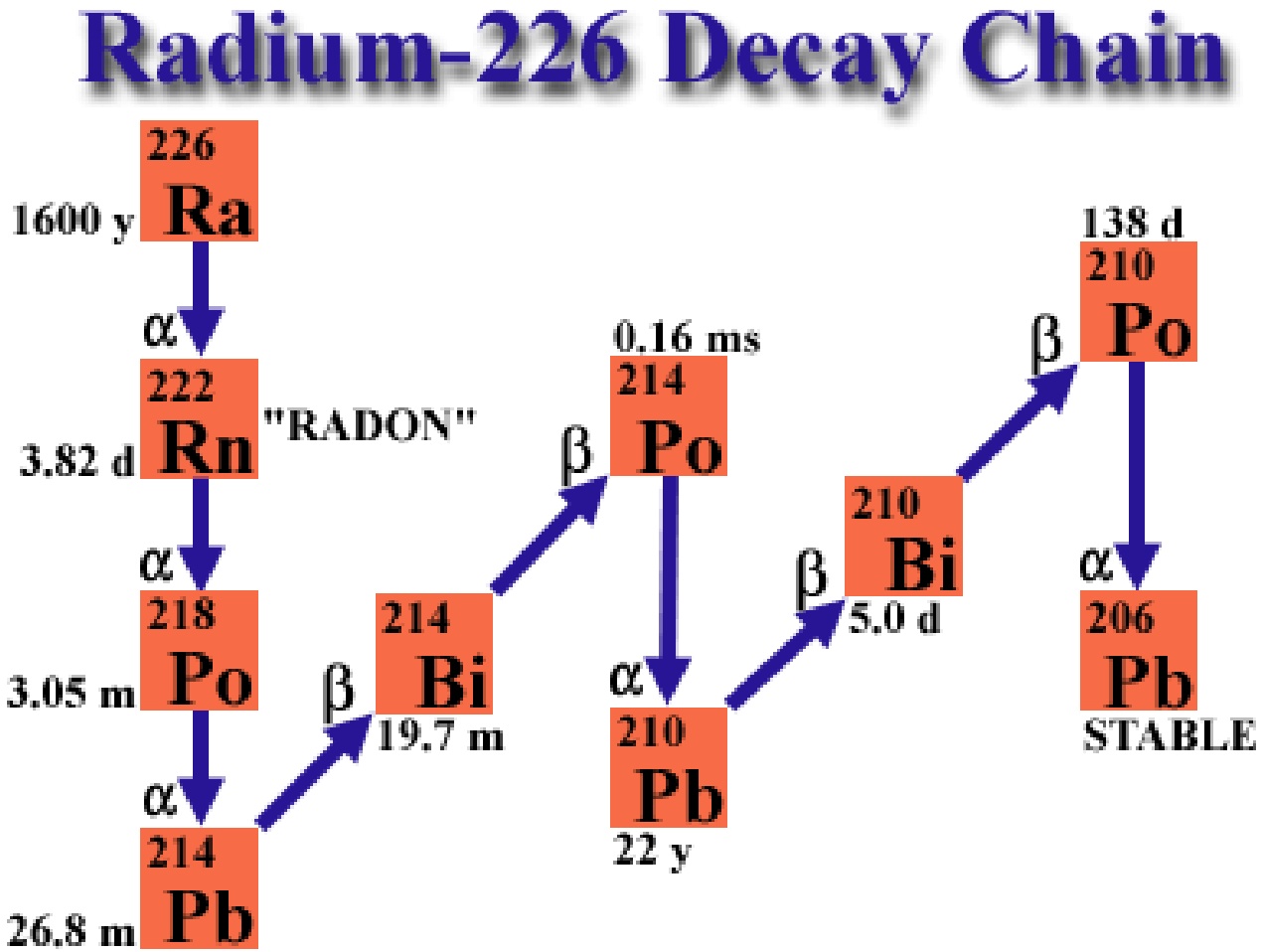
The radon-226 decay chain, and the longer uranium-238 decay chain to which it belongs, have been known for many decades

How can there be anything new to present?



In testing water or leachate or other samples, particularly by gamma spectroscopy, Bi-214 serves as a proxy for Rn-222. Whether intended or not, this proxy relationship exists for sealed samples held at least a few hours because:

- **Pb-214 and Bi-214 have such short half-lives (20-30 minutes) that they will be essentially gone due to decay within about 5 hours if not replenished by Rn-222.**
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- **Thus, activities of Pb-214 and Bi-214 cannot diverge, except within narrow limits, from the activity of Rn-222 in a sealed container.**
- **This is readily understood as secular (secondary) equilibrium**

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- **Need to know that Bi-214 activity doesn't substantially exceed Ra-226 activity in the sample**

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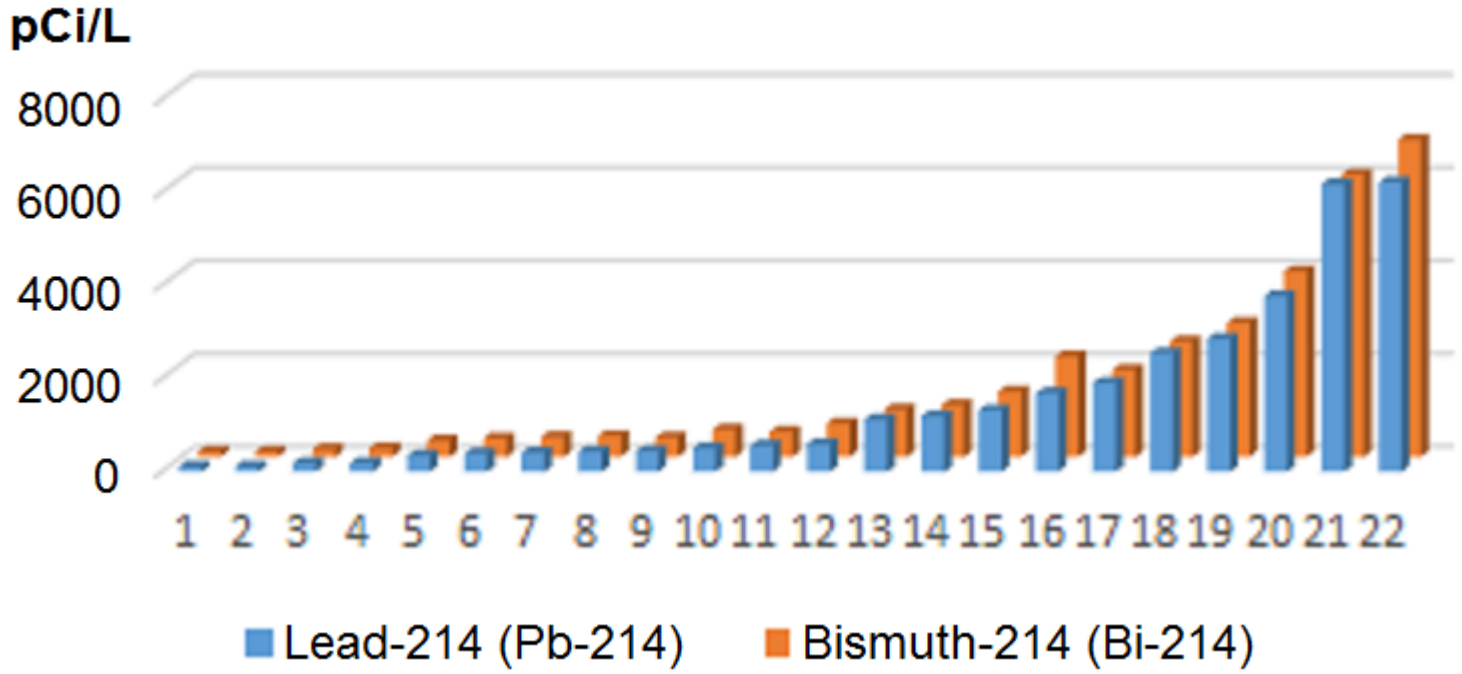
- **But if independent measurement of Ra-226 activity is needed, it defeats the purpose of using Bi-214 as a proxy!**

This talk covers the logic that applies when Bi-214 activity substantially exceeds Ra-226 activity in a sealed sample.

This work emerged from a review of leachate data from a landfill in New York State, where 106 samples showed low Ra-226 (generally >5 pCi/L) and Pb-214 and Bi-214 results averaging 16 pCi/L and ranging up to 6000 pCi/L.

Of these 106 samples, the 22 that exceeded 100 pCi/L Pb-214 and Bi-214 are plotted here from lowest to highest.

Other, smaller data sets from NY (leachate), Ohio & Oregon (well water) have also shown sporadically high Pb-214 and Bi-214 relative to Ra-226.



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Of these 106 samples, the same 22 that exceeded 100 pCi/L Pb-214 and Bi-214 are plotted here by test date (showing no clear time trend).

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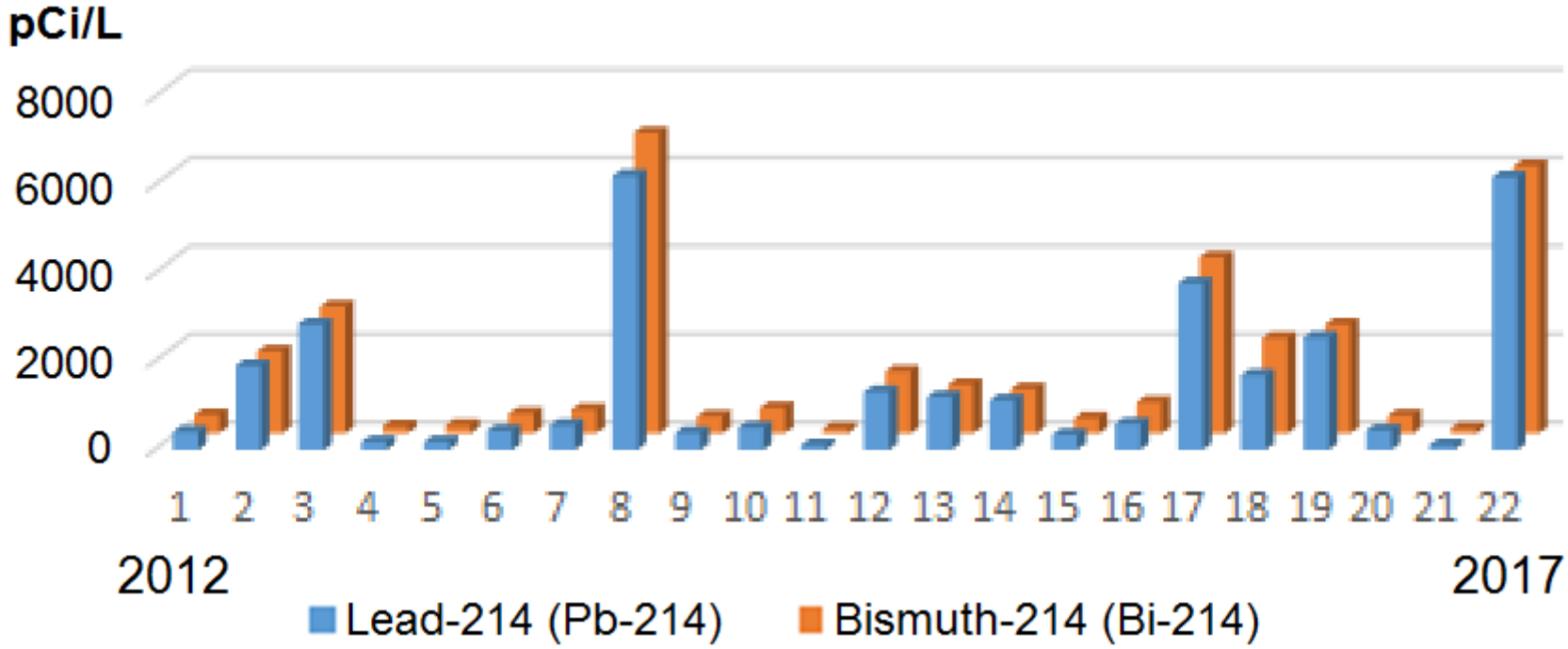

How can such results be interpreted? (For example, 6000 pCi/L Pb-214 and Bi-214, and only 5 pCi/L Ra-226?)

- For example, if sample was held 21 days, then the sample's 5 pCi/L of Ra-226 can account for ingrowth of 5 pCi/L Pb-214 and 5 pCi/L Bi-214 when the sealed sample is opened.
- This leaves 5995 pCi/L Pb-214 and also 5995 pCi/L Bi-214 unaccounted for. Both must come from Pb-214 and Bi-214 replenishment (ingrowth) from Rn-222 in the sealed sample – as already explained. Rn-222 is the known parent.

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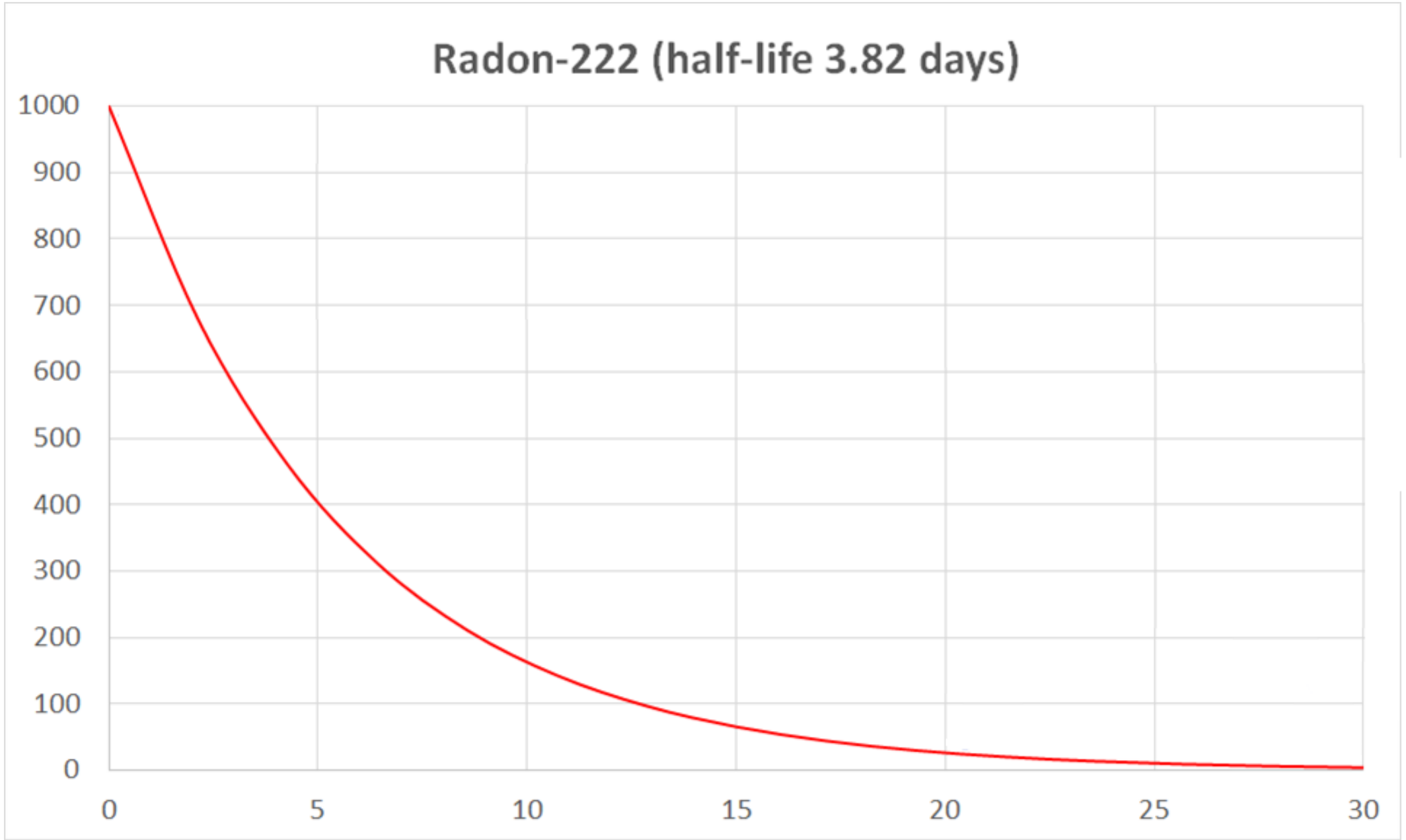
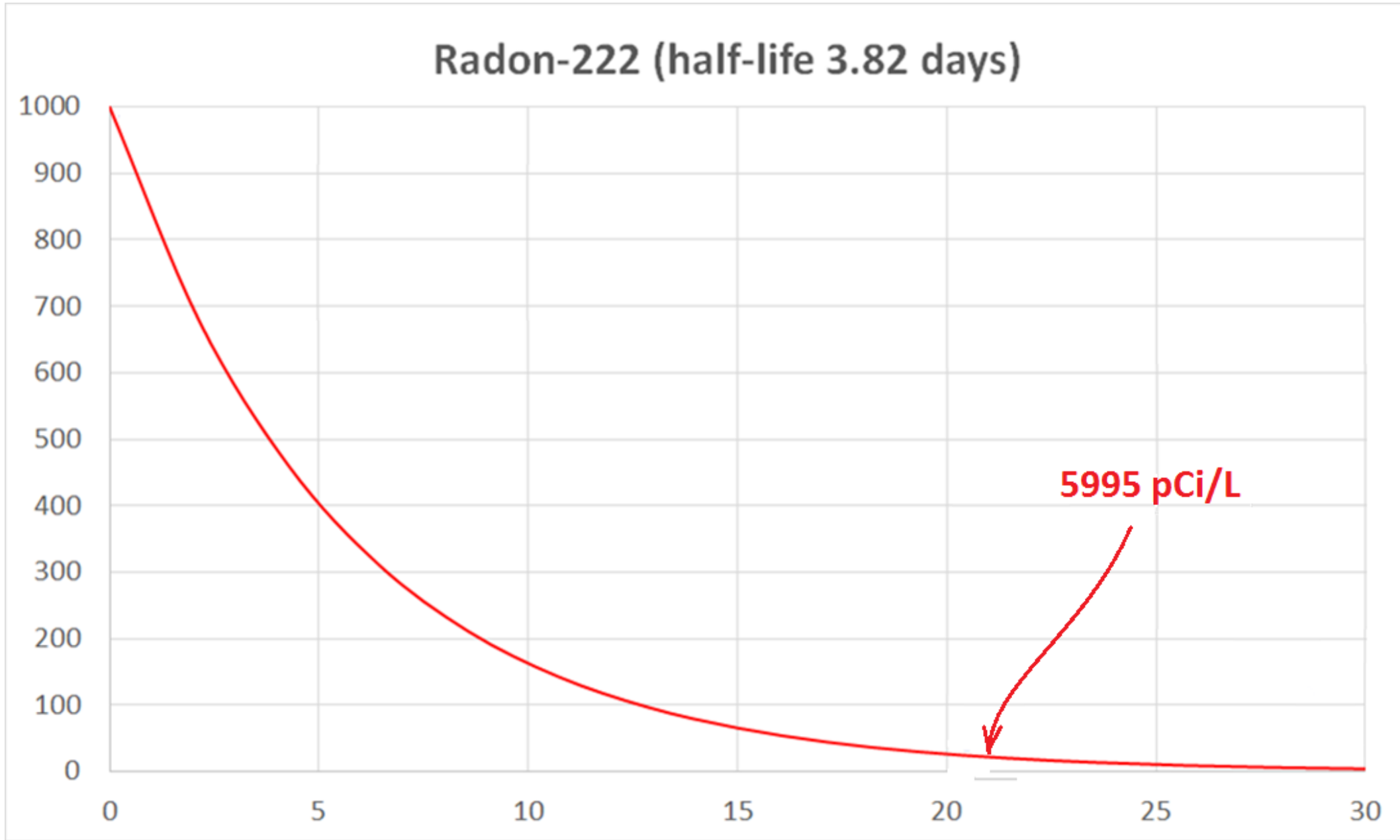
- Does this indicate 5995 pCi/L Rn-222? Yes, at time of testing, but <u>much higher than 5995 pCi/L at time of sample collection</u>.
- Looking back up the Rn-222 decay curve shows 270,811 pCi/L


Radon-222 (half-life 3.82 days)
1000
900
800
700
600
500
400
300
200
100
0
0
5
10
15
20
25
30
days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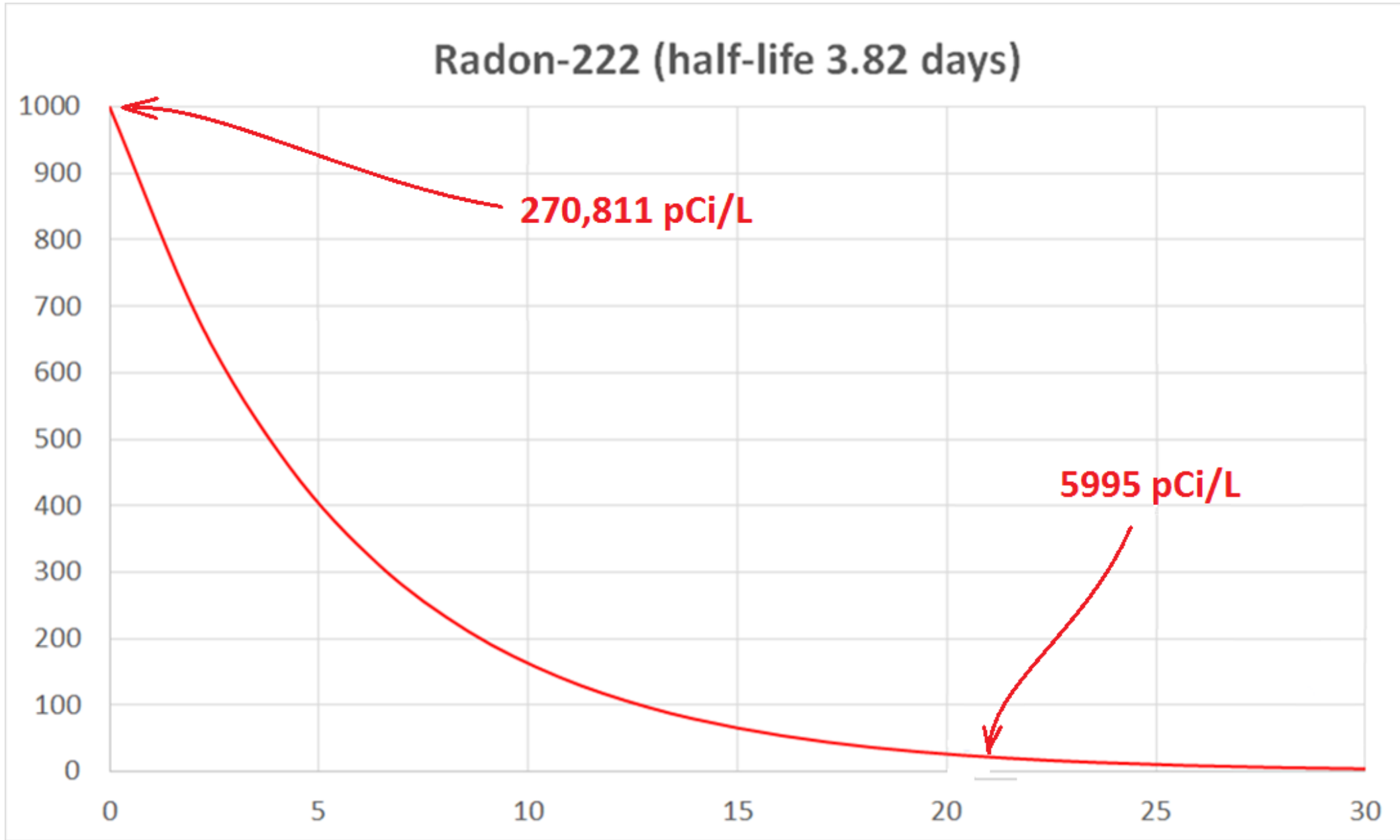
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Rn-222 activity at the time of sample testing, as determined from Pb-214 and Bi-214 results, needs to be multiplied by a factor F that depends on the holding period (such as F = 2 for a 3.82-day holding time) in order to account for unreplenished Rn-222 decay within the sample. Specifically,

$$F = \exp(-\ln(2)\, \Delta t / T_{1/2})$$

where the holding period Δt is expressed as a negative number because it runs backward in time from sample testing to sample collection.

F *times* the Rn-222 activity at the time of sample testing is the Rn-222 activity at the time of sample collection.

Holding time	Factor
delta t (days)	F
-40	1419.536
-30	231.265
-21	45.17279
-8	4.270014
-4	2.066401
-3.82	2
-1	1.198957
0	1
1	0.834058
3.82	0.5
4	0.483933
8	0.234191
21	0.022137
30	0.004324
40	0.000704

Is 270,811 pCi/L plausible? **Yes, physically plausible. Radon's mobility, as a gas, can certainly move it away from its parent radium, and 270,811 pCi/L is nowhere near radon's aqueous solubility limit.**

Radon springs and other sources of upwelling radon-rich groundwater are known to have similarly high radon concentrations.

Testing error? **Possibly some error in radium results, but an error of 5 versus 6000 pCi/L doesn't appear plausible.**

Is follow-up radon testing warranted? YES.

There's no plausible error in the independent Pb-214 and Bi-214 results. Cf. Tucker, Donakowski, and Hays, "Comparison of Activity Determination of Radium 226 in FUSRAP Soil using Various Energy Lines," WM2012 Conference, Feb.-March 2012, Phoenix, AZ:

"To check laboratory performance, Pb-214 results were compared to Bi-214 results. Because Bi-214 is a daughter of the short lived Pb-214, the two radionuclides should have essentially identical activities. In order to check this…, activities of the two radionuclides for each of the samples were plotted against each other. The plot of Bi-214 vs. Pb-214 in Figure 4 shows very good agreement with a slope of 0.9802 and a correlation coefficient of 0.997, which is to be expected."

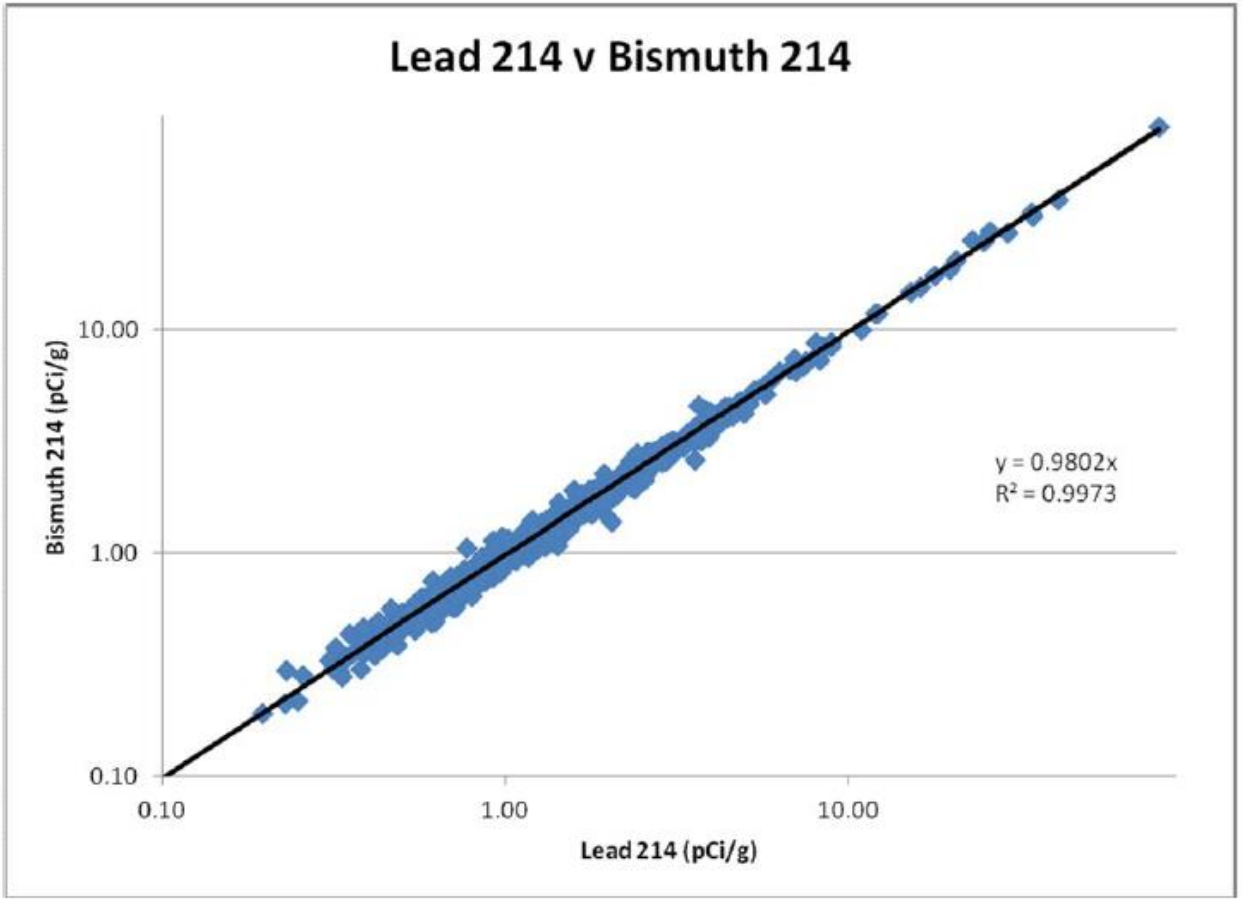

Fig 4. Pb-214 vs. Bi-214

If testing/reporting for a client, and results show low Ra-226 activity and much higher Pb-214 and Bi-214 activities:

- **Don’t discard results as impossible or uninterpretable. This would be unprotective and possibly unethical if human exposure is involved (e.g., well water)**

- **Recommend follow-up radon testing? Keep in mind that radon in the tested medium (e.g., well water) may vary over time due to variations in groundwater and groundwater pathways**

QUESTIONS?

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