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*Concentrating on Curie-ous Cows*

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Caoimhín P. Connell

Forensic Industrial Hygienist



***In the residential radon industry, the commonly used unit for radon, pCi/L is largely meaningless and, contrary to common belief, cannot be used as a “concentration” of radon.***

IN MY POST [“EXPRESS Yourself,”](#) I noted that units commonly used to express *concentration* are not units of concentration at all (such as CFU/m<sup>3</sup> and pCi/L, and so forth). A reader, Mr. JS, sent an off-line question asking for clarification - This discussion is a little lengthy but is intended to clarify why the commonly use unit, pCi/L is not a unit of concentration.

Thousands of citizens across North America and Western Europe have encountered the exotic unit of “pico Curies per liter of air” (pCi/L) when they have received results of “radon testing” in their home.

In about 100% of those cases, they have erroneously been told that the value expressed as “pCi/L” tells them how much radon gas is in their home. And yet, nothing could be further from the truth. Furthermore, similar to the units “spores/m<sup>3</sup>.” when used by the untrained individuals who are usually employing such units, the notion that, say 10 pCi/L indicates twice as much radon as 5 pCi/L, is simply false. In fact, when someone receives

their “radon test” results, they have no idea how much radon is in their house since the concentration of radon was never determined by the “test.”

## **Concentration**

So we first have to ask what, then, *is* concentration? Interestingly, my Concise Oxford English Dictionary (Ninth Edition), gave a very poor example of “*concentration*” as used in the scientific realm and merely stated it was “*the amount of solute per unit volume of solution.*” Although accurate, the definition is too limited and would not apply, for example, to the concentration of sand mixed with powdered salt, or the concentration of Aflatoxin B1 in a jar of peanut butter.

So, I’m going to take the liberty of proposing a better definition of *concentration* as follows: “*Concentration is the amount of a specified thing in relationship to the whole in which it occurs.*”

There – Now we can conceptualize with meaning the following statements as *concentrations*:

- 10% of the coins in my pocket are dimes.
- The average concentration of CO<sub>2</sub> in the Earth’s atmosphere is about 400 parts of CO<sub>2</sub> per one million parts of air (400 ppm CO<sub>2</sub>).
- There is 5 milligrams of powdered salt in that one kilogram pile of sand (5 mg/kg).
- There is 0.003 ounces of Aflatoxin per ton of peanut butter (0.003 oz/ton).

Even more esoteric units such as the air in my tires expressed as “pounds per square inch” *may* be a unit of concentration, since I can directly convert that value to mass per unit volume using  $PV=nRt$  to derive the mass of, say, nitrogen in the unit volume of the tire space.

However, merely having the word “per” in an expression does not make the unit a concentration as exemplified with the following:

- Miles per gallon
- Feet per second
- Points per game
- pCi/L

Now imagine you are a farmer with a barn that measures 73 feet by 74 feet by 20 feet high (4,000 cubic meters of air), into which you place 40 cows. Being a bored farmer, you note that during the spring and fall an average of about 8 cows in the group will sneeze every day, but in the summer and winter you only hear about four sneezes per day, even though you always have the same number of cows. With legitimacy can you express the summer and winter sneezing activity as “0.001 sneezes per cubic meter of air”?

Of course not, for a variety of reasons, not least of all “sneezing” is a verb, not a noun, and a sneeze is not a quantity (you could have big sneezes, little sneezes and snuffle sneezes).



Similarly, the “sneezes per day” will still occur if you put the same 40 cows in a structure half the original size or triple the original size. And the sneezes only occur within a limited portion of the given volume, not the volume as a whole. And finally, you certainly can’t convert “sneezes per cubic meter of air” to determine the number of cattle in an enclosure.

## ***EPA Radon Industry***

And yet, this is exactly what the EPA is doing when “radon testers” run around, use EPA “testing” protocols and tell people there is “X pCi/L” of radon in their houses. A Curie is used to refer to a verb – a disintegration. That is, an atom has “sneezed” and the product could be corpuscular or a quantum of energy. That atomic sneeze may only be able to give a lower probable number of concentration needed to result in the verb. Thus in the case of the cows, four sneezes per day imply at *least* one cow is present; but that is as far as one can take the value to interpret the number of cows.

Effectively radon “testers” use a variety of devices that “listen” for atomic sneezes and try to translate those sneezes into “*concentration of atomic cows per cubic liter of air.*”

Without changing the number cattle in the barn, imagine adding some oxen, some buffaloes, and some elk into the population. Since these animals also sneeze, if one only counts the sneezes, then one will arrive at an artificially high concentration of cattle since we *cannot* differentiate the “cow sneeze” from the “ox sneeze.”

So, when looking at “radon results” one needs to remember, radon, *per se*, poses absolutely no toxicological risk to humans. Radon is biologically inert, and being a noble gas, it doesn’t even react with anything in the body. Effectively, radon inhaled = radon exhaled. The underpinning etiological entities associated with lung cancer risk is the progeny of the uranium decay products called the Short Lived Radon Daughters (SLRDs) – the radon itself is merely the vehicle by which the SLRDs can become formed in the interior space. No one cares what the radon levels are – one is only interested in the concentrations of the SLRDs. Therefore, some devices actually estimate the concentration of the radon – while completely ignoring the concentration of the etiological agents of interest – the SLRDs, and some devices measure all ionizing pairs even if it has nothing to do with radon, or the SLRDs.

One such device used by “radon testers” is based on the discharge of an electret which cannot differentiate types of radiation or the source of those emissions, and for many devices, the reported radon concentration could come from a property with virtually no radon, but built on orthoclase feldspar and at an elevation of 9,000 feet, and the elevated “radon” concentration is a result of the combined effects of the beta emissions from the K40 found in the granite and the cosmic radiation pouring into an ionizing chamber.

Or, let’s look at the common membrane charcoal canister, for example. Imagine two identical homes, side-by-side, occupied by identical twins. The two homes are identical in every respect. The lifestyles of the identical twins are identical. Each home has a magical steady-state radon concentration of, say, 100 atoms of radon per liter of air.



One of the twins likes to burn scented jar candles and incense, and likes to run a Casablanca type ceiling fan in the main room and a bedroom – the other twin hates candles, hates Casablanca fans, and hates incense.

“Joe the Radon Guy” goes into the two houses and, using charcoal canisters, he reports that each of the two houses both have 50 pCi/l, and therefore, recommends a radon reduction system for both structures since, “Joe the Radon Guy” doesn’t actually know much about radon, and according to his data both structures pose the same risk since both contain the same “concentration” of radon (50 pCi/l).

But is that correct? The Twins read my page “[Radon – Facts and Fiction](#)” and decide to hire an Health Physicist (HP) to perform “real” radon measurements. The HP explains to the Twins that risk estimates used by the EPA and National Research Council (NRC), are not pCi/l, but rather, “*Working Level Months*” (WLM).

The HP explains that one “*Working Level*” is actually defined as any combination of short lived daughters in one liter of air which will ultimately release 1.3E5 MeV (million electron volts) of alpha by decay through polonium 214. Therefore a known concentration of radon has a specific “potential alpha energy concentration” (PAEC).

The Twins are smart and know that based on Joe the Radon Guy’s tests the HP will probably find half a Working Level in the homes. But will he?

## **SLRDs**

Before we find out, we need to introduce a new term - “*Equilibrium*” which is said to be reached when the maximum concentration of SLRDs has been attained for any given concentration of radon gas in a given volume of air. The ratio of the activity of the SLRDs to the activity of the radon gas is called the *Equilibration Ratio* (ER).

Typically, in an average home, ERs probably range from 0.3 to 0.7 but an ER of exactly 1.0 is never seen because radon daughters are removed from buildings at different rates and some SLRDs will plate-out while the radon remains airborne, and newly infiltrated radon has not yet decayed.

The “radon guy” doesn’t know it, but his lab uses an automatic ER arbitrarily given by the EPA as 0.5. Therefore, assuming an ER of 0.5, the “radon guy” would have (erroneously) defined the Working Level as about 200 pCi/l and not 100 as previously stated.

Remember, the Twin that likes candles, and incense and ceiling fans? The HP determines the ER in his home is 0.05. The HP determines the ER in the other home is 0.9. The HP determines the WL in the candles/fans home is 0.02 WL and the WL in the home with no candles has a WL of 0.45. Now, based on that, the HP explains that the two homes do indeed, have the exact same radon concentration, but one home needs a “radon” mitigation system” (WL = 0.45), and one home already mitigates the SLRDs in the form of ultrafine particles produced by the candles and ceiling fans, which effectively remove the “unattached fraction” of SLRDs from the environment.



Therefore, from this, we learn that with one type of radon measuring system, if one has two readings from two different houses, of, say, 10 pCi/l and 20 pCi/l, one cannot conclude that the radon concentration in one home is twice as high as the other home; and, with another measurement system, we learn that two identical homes can have the exact same radon concentrations, but pose completely different risks.

Mr. JS asks:

I ask this because not all decays are equal. Some emit more energetic particles and gamma rays than others.

This is true, Mr. JS, and this starts to get into the concept of “dose” for which a full response would be too lengthy to give here. However, suffice to say, that none of the units used in the residential radon industry can be used to calculate radiation dose, or risk, or concentrations.

Mr. JS asks:

BTW, I still can't get my head around the EPA units of measure for radon exposure. Their units are somewhat convoluted. Know of any way to convert their units into real units?

I hope the preceding discussion has helped you to understand that there is no way to use the EPA residential radon methodologies or the units thus derived to any great realistic extent. Essentially it is an industry without foundation using units of expression without meaning.

