Monitoring and Compliance

Radiological Lab Results Don't Have to Be Confusing

The latest news about radiologicals may have water utilities taking a second look at their historical compliance sampling results. A lack of experience addressing the subject could cause confusion about what the results mean for drinking

water safety. By John Consolvo and John M. Sukosky

LTHOUGH SEVERAL radionuclides are regulated in drinking water, radiochemistry might be a foreign concept for many water utility professionals. Routinely concerned with chemical and biological contaminants, water utility personnel are familiar with chemistry results in units of mg/L or biological results in colony-forming units/ mL. For utilities whose initial Radionuclides Rule monitoring indicated levels of radiological parameters that weren't of concern, current sampling intervals are infrequent-perhaps every three years. Further, such results are probably reviewed, reported to the appropriate regulatory authority, filed away, and forgotten.

What is a pCi/L? Why does every reported result have associated values for a detection limit and uncertainty? Why are some results negative? These questions and more are answered here. For additional guidance, read the Radionuclides Rule and helpful guidelines published by the US Environmental Protection Agency (USEPA) at http://water.epa.gov/ lawsregs/rulesregs/sdwa/radionuclides/ regulation.cfm.

UNITS OF MEASURE

Although water utilities are concerned with the amount per volume (concentration) of radiochemical and nonradiochemical contaminants, we think of chemical contaminant concentration in terms of mass, such as mg in a liter of water (mg/L). The activities at which radionuclides are regulated may be much less than measurable levels in mass/volume units. For example, iodine-131, a beta emitter, exceeds the 4 mrem/yr maximum contaminant level (MCL) at an activity of 3 pCi/L. The mass equivalent concentration of this activity is about



 10^{-15} mg/L iodine. So far, no analytical chemistry method can make such low-level measurements.

For radiochemical parameters, the mass amount of a radionuclide isn't as important as the amount of energy released through radioactive decay. This release of energy-as alpha, beta, or gamma radiation-is measured in units of activity, which measures the decay rate of a radioactive atom per unit of time. The analytical measurement is made by determining the rate of decay in disintegrations per minute (dpm). Disintegrations are converted to activity; drinking water regulations are based on the Curie (Ci) unit of activity. In environmental samples, radioactivity is very small, so the most frequently used unit is the pCi (10⁻¹² Ci). More specifically, regulations are based on activity concentration or activity per volume (activity/L, or pCi/L).

South Carolina's Environmental Surveillance Oversight Program regularly conducts radiological monitoring of surface water on and adjacent to the Savannah River Site, a nuclear reservation owned by the US Department of Energy. The program's primary purpose is to provide downstream drinking water customers with advance notice of any radiological release.

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SAMPLE RESULTS

In addition to different reporting units, two pieces of ancillary data are associated with each sample's results that are similar to but differ from terms we already know: detection limit (or level) and measurement uncertainty.

Unlike general analytical chemistry results, which are typically reported down to a minimum reporting level (a value greater than its minimum method detection limit), radiochemistry results are reported raw. In other words, the concentration determined is reported unqualified even if this concentration is less than the detection limit. Although the reported result is used to determine compliance, the detection limit and uncertainty provide further information to give a broader perspective.

DETECTION LIMITS

As shown in the figure above, there are

two detection-capability concepts associated with radionuclide analyses.

Theoretical Detection Limits. Theoretical detection limits are *a priori* (before the fact) calculations that determine, prior to actual sample analysis, whether a particular measurement system can detect activity to a specific level. Given a sample's anticipated characteristics, *a priori* calculations can be used to determine the counting time required to meet a predetermined minimum detection limit.

Lower Limit of Detection (LLD). The LLD is the smallest activity or concentration of radioactive material in a sample that will yield a net count (above system background) that can be detected with 95 percent probability. LLD is an *a priori* calculation that represents the measurement capabilities of a system.

Required Detection Limit (RDL). The RDL is the minimum level to which an

Detection Limits

Theoretical detection limits determine if a particular measurement system can detect activity to a specific level; functional detection limits determine the minimum detection limit for a specific analysis.

analytical method must be able to report to measure radionuclides at the regulated action levels or MCLs. Table 1 on page 16 shows Radionuclides Rule parameter RDLs. The calculated LLD must indicate the RDL will be met. If not, the sample amount or counting time may need to be increased. More specifically, RDL is the concentration that can be counted with a precision of ±100 percent at the 95 percent confidence level (1.96 σ , where σ is the standard deviation in the net counting rate of the sample).

Functional Detection Limits. Functional detection limits are *a posteriori* (after the fact) calculations that, following an actual sample analysis, determine the minimum detection limit specifically for that analysis.

Minimum Detectable Activity (MDA). The MDA is the smallest activity or concentration of radioactive material in a sample that will yield a net count (above sample background) that can be detected with 95 percent probability. MDA is an *a posteriori* calculation that represents the limit for a particular sample count.

Other terms that may be used in a data report instead of MDA are minimum detectable concentration, minimum detection limit, and minimum reporting limit.

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 Table 1. Parameter RDLs

The Radionuclides Rule prescribes RDL parameters.

	Measurement
Gross Alpha	3 pCi/L
Gross Beta	4 pCi/L
Radium 226	1 pCi/L
Radium 228	1 pCi/L

ANALYTICAL METHODS

Different labs and analytical methods may use different detection limit terms that mean the same thing. However expressed, the minimum detection limit on your data report is the detection limit specific to the associated sample result (i.e., it's an a posteriori determination calculated specifically for the sample to which it is attached). This value changes from sample to sample and is affected by sample size, amount of time the sample is analyzed (counted), sample background, and other factors. The calculated value of the detection limit for each sample helps a data user determine the significance of the reported result.

A related concept that may be more familiar to laboratory personnel in the water treatment sector is the method detection limit. According to USEPA, the method detection limit is "the minimum concentration of a substance that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero and is determined by analyzing a sample in a given matrix containing the analyte." As defined here, the method detection limit isn't applied to the analysis of samples for radionuclides. However, because the required detection limit for analysis of radiochemical parameters is specific to a method's capability, it might also be referred to as a method detection limit. But remember, it isn't the same as the method detection limit associated with chemical contaminant analytical methods.

Table 2. Sample Gross Alpha Report

Determining the detection limit and uncertainty of each parameter helps data users interpret the results.

Parameter	Result (pCi/L)	Uncertainty (±)	MDA (pCi/L)	MCL (pCi/L)
Gross Alpha	5	2	2	15

UNCERTAINTY REPORT

Along with a result and detection limit, each result's uncertainty is reported. Various sources of uncertainty are associated with every analytical measurement, and each contributes to overall uncertainty in a reported result. In analysis of samples with low levels of radioactivity (water samples typically fit this description), the counting error of an analytical instrument's detector is usually the greatest contributor to overall uncertainty; this source of uncertainty is most often reported with the final result. Detector uncertainty is partly due to statistical effects in the emission of radiations and partly due to statistical effects in the detection process.

The counting error is determined with a mathematical equation that, as the detection limit, accounts for several variables associated with each measurement. The counting error is determined at two standard deviations, which means there's a 95 percent probability that the reported plus-minus range contains the actual value of the true activity.

NEGATIVE RADIOACTIVITY

Reported sample results are sometimes negative values. When a sample has little radioactivity, the analytical results should have a normal distribution of positive and negative results around zero. When a sample result is subtracted from that of the system's background and the sample value is less than that background, the result is a negative value. A negative result simply indicates that the radionuclide activity in the sample is low—so low that it approaches that of the analytical instrument's system background.

PERSPECTIVE

Knowing the detection limit and uncertainty associated with each result helps provide perspective to data users. Using the sample report for the gross alpha result in Table 2, it's easy to see the 2 pCi/L MDA meets the required detection limit of 3 pCi/L (Table 1) for gross alpha. The reported result is 5 pCi/L, and the uncertainty in this result is 2 pCi/L. Therefore, there's a 95 percent probability that the actual amount of activity in the sample is 3-7 pCi/L. The reported result is used to determine compliance, without considering uncertainty. However, knowing the detection limit and the uncertainty allows for a more thorough assessment of a sample's radioactivity. $\langle \rangle$

RESOURCES

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