What Radiation Detection Instrument Do I Choose to Meet My Needs?

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Judson Kenoyer, CHP, CIH

It is not a simple question or process to go through to determine the type of radiation detection instrument you should choose to meet your specific needs. But, if you follow a simple, step-by-step process as described below, you can come up with the answer.

Two basic questions need to be answered:

- Are you going to use the instrument for exposure rate measurements?
- Are you going to use the instrument for measurement of contamination?

From there, you can go through a number of other questions to determine the type of instrument you need to choose. The attached table (Table 1) describes the entire process. The rest of this text helps you work through the process.

Exposure Rate Measurements

If you are going to be performing exposure rate measurements (i.e., measuring gamma or x-rays), you will need to decide if you are making low-level exposure rate measurements (i.e., micro-R/hour to milli-R/hr readings) or high-level exposure rate measurements (i.e., several mR/hr to R/hr measurements). Low-level measurements (e.g., those at or below 2 mR/hr) are normally made with Micro-R meters, pressurized ion chambers, sodium iodide (NaI) detectors, or plastic scintillators. High-level measurements are made with ion chambers, pressurized ion chambers, or Geiger Mueller (GM) detectors. Any of these detectors would need to be calibrated to make exposure rate measurements with the readings calibrated against known or calculated levels of exposure from a Cs-137 source at different distances between the detector and the source using documented procedures based on the ANSI N323 standard.

Contamination Measurements

The choice of instruments to use for contamination measurements is more complicated than those for exposure rate instruments; there are more decisions to make. It depends on what types of radiations are being emitted from the source(s). For this discussion, we are assuming that the sources being measured are limited to alpha, beta, gamma/x-ray, or a mix of them. Instruments used to measure contamination are calibrated using sources that are traceable to the National Institute of Standards and Technology (NIST). A counting efficiency is calculated for each different radionuclide for which the detector is calibrated. The counts per minute (cpm) as measured by the detector and a count rate meter is divided by the disintegrations per minute (dpm) as reported by NIST for the source. This is the fractional counting efficiency of the detector. The detector is normally positioned a fraction of an inch (i.e., 1/8 or ¼ of an inch) above the known source in a reproducible geometry for these measurements.

For alpha-emitters, Zinc Sulfide (ZnS) detectors are quite often used to measure for contamination. Proportional counters can also be used to measure alpha contamination. In fact, they are often used when mixed alpha-beta contamination is present because they can differentiate between the two and measure them simultaneously. They are sometimes used in floor monitors and/or large hand-held detectors when large areas of floors or walls need to be evaluated. Plastic scintillators and semiconductor detectors can also be used to measure for alpha contamination. GM detectors can be used to measure alpha contamination but the counting efficiency will be fairly low, on the order of 10% because the alpha particle has to penetrate the beta detector window and the range in air is limited also.

For beta-emitters, the most used type of detector is the GM detector. Counting efficiencies for pancake probes range from a few percent for maximum beta energies (B_{max}) of 150-200 keV (e.g., from C-14, S-35), to around 15% for medium-range betas of 200-300 keV (e.g., from P-33, Ca-45), to approximately 25% for I-131(B_{max} = 606 keV), 32% for P-32 (B_{max} = 1.71 MeV), and 35-40% for Sr-90/Y-90 (B_{max} = 544 keV and 2.245 MeV, respectively). These last examples would be considered high-energy beta-emitters. The use of end-window probes or peanut GM tubes will yield lower counting efficiencies. As with alpha-emitters, proportional counters can be used for beta contamination. Betas and alphas generate different sized voltage pulses as seen by the count rate meter; so they can be distinguished between each other. A NaI detector with a thin window on the end of the detector can be used to measure high-energy beta-emitters. And, plastic scintillators can also be used to measure the presence of beta contamination.

For gamma and x-ray contamination detection, NaI detectors are quite often used. If the contamination is an x-ray emitter, the NaI detector will have to have a thin-window on the end to be able to measure the contamination. GM detectors can be used to measure gamma-emitters but the counting efficiency will be very low, on the order of 1-2%. For more sophisticated measurements, where the actual radionuclides present are to be identified, NaI or Lanthanum Bromide ($LaBr_3$) detectors interfaced with a multichannel analyzer (MCA) are used in portable units that can be taken into the field for measurements. The unit has a library of energy spectra contained in its memory and compares the gamma spectra measured by the instrument against the library of information to identify the gammaemitting radioisotope present. These units often cost $15-20K, depending on the type of detector and the level of analysis of which the software used in the unit is capable.

Now, if the contamination is a mix of different radioisotopes with several different emitters present (i.e., alpha, beta, gamma, x-rays), then it might take two or three different types of instruments to provide the answers that you are looking for. You would go through the questions that are listed above in the discussion for the different types of contamination to help decide on the instrumentation needed for your purpose.

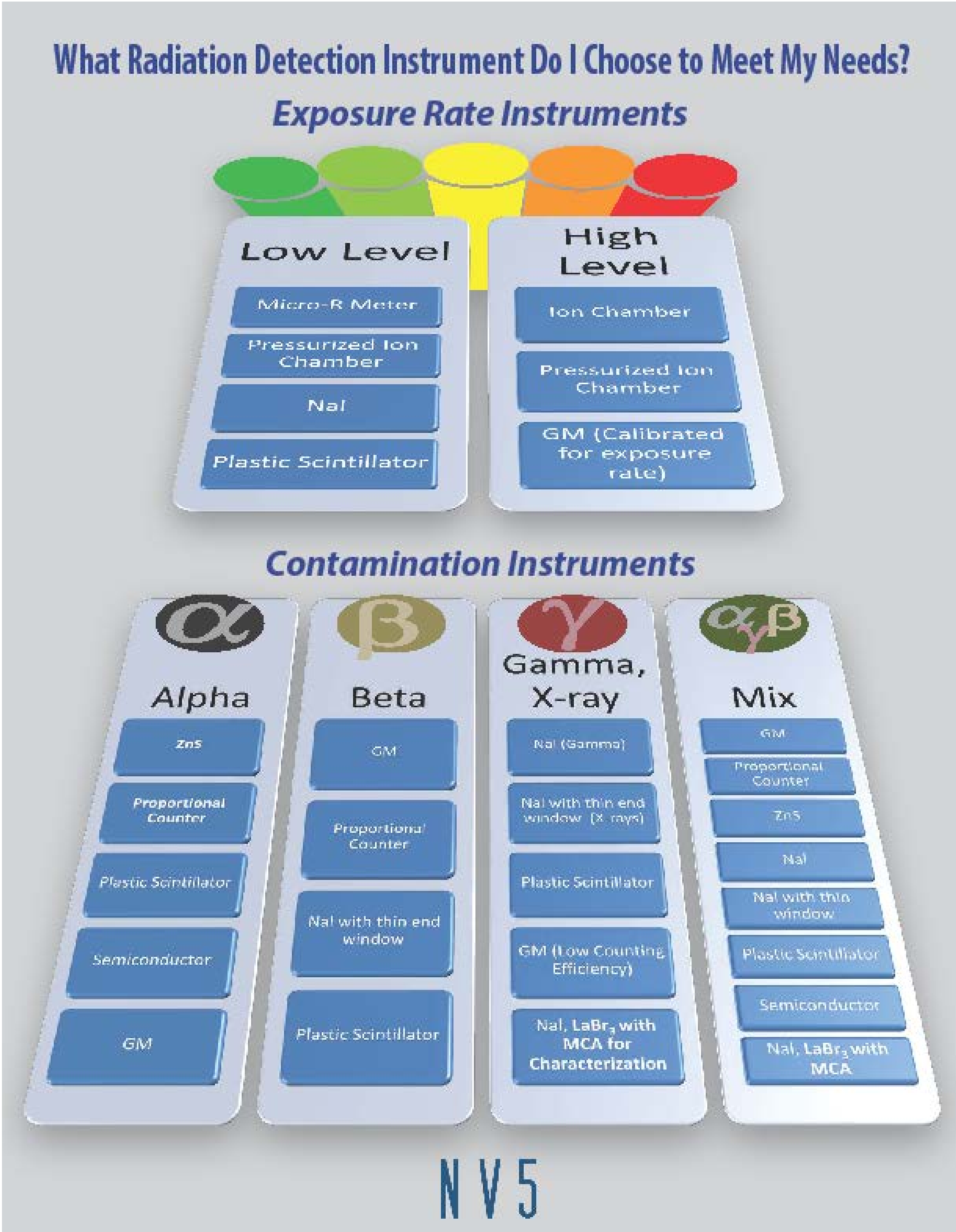
Conclusions

It is not a simple process to determine which instrument to use to meet your needs. You have to know what you are going to use the instrument for (i.e., exposure rate or contamination measurements) and what radioisotopes or types of radiation are present. Some instruments are very specific in terms of what they can measure while others can measure multiple types of radiation but at different counting efficiencies. And, at times, you will have to use more than one type of instrument to meet your needs.

Assumptions

Several assumptions have been made for the above discussion:

- All detectors and count rate meters are calibrated for their use.
- Beta energies are $\geq$ 200 keV.
- GM choices include pancake, end-window, and peanut-type detectors.
- For contamination measurements, use the fast response mode when searching for a source and the slow response mode when making a quantitative measurement (or an integrated count if possible).
- Neutron instruments are not included in this discussion.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Exposure Rate Instruments
Low Level
Micro-R Meter
Pressurized Ion Chamber
NaI
Plastic Scintillator
High Level
Ion Chamber
Pressurized Ion Chamber
GM (Calibrated for exposure rate)
Contamination Instruments
Alpha
ZnS
Proportional Counter
Plastic Scintillator
Semiconductor
GM
Beta
GM
Proportional Counter
NaI with thin end window
Plastic Scintillator
Gamma, X-ray
NaI (Gamma)
NaI with thin end window (X rays)
Plastic Scintillator
GM (Low Counting Efficiency)
NaI, LaBr3 with MCA for Characterization
Mix
GM
Proportional Counter
ZnS
NaI
NaI with thin window
Plastic Scintillator
Semiconductor
NaI, LaBr3 with MCA
NV5