FROM THE TRENCHES

DETECTION SENSITIVITY AND MDA (Part II)

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In the previous newsletter (Part I), we talked about MDA (minimum detectable activity), which we defined as the smallest amount of activity distinguishable from background which can be quantified at a given confidence level (usually 95%). It was also mentioned that another closely related detection limit is the LLD (Lower Limit of Detection). There are many different (and conflicting) definitions for LLD, just as there are for MDA. Possibly the best way of separating the two is to think of LLD as the MDA with sample-specific parameters added. For example, MDA would be the appropriate term in performing measurements of surfaces or wipe samples since the detection limit will remain the same for all of them. LLD would apply to counting air samples since it can be different for each sample (due to differences in flow rate or collection time).

Part I of this article contained a number of equations for calculating MDA, all a form of the following all-encompassing equation:

$$MDA = \frac{2.71 + 3.29\sqrt{R_b t_s\left[1+\frac{t_s}{t_b}\right]}}{(t_s)(E)}$$

where:

MDA = minimum detectable activity in dpm
R_b = background count rate in cpm
t_s = sample counting time in minutes
t_b = background counting time in minutes
E = detector efficiency in counts per disintegration

The equation for calculating LLD for air samples includes additional factors in the denominator:

$$LLD= \frac{2.71+3.29\sqrt{R_b t_s\left[1+\frac{t_s}{t_b}\right]}}{(t_s)(E_d)(E_f)(FF)(SAF)(Vol_{cc})(2.22E6)}$$

where:
LLD = lower limit of detection in μCi/ml
R_b = background count rate in cpm
t_s = sample counting time in minutes
t_b = background counting time in minutes
E_d = detector efficiency in counts per disintegration
E_f = filter efficiency
FF = fraction of filter counted
SAF = self absorption factor
Vol_{cc} = air sample volume in cc (or ml)
2.22E6 = factor to convert dpm to μCi

Consider the following example for use of equation LLD:

Example LLD

You are going to be counting air samples for ^{232}Th using a Model 2224 with a 43-1 alpha scintillation detector. The entire air sample filter fits exactly underneath the detector so the filter fraction will be 1. The air sample will be drawn at 20 lpm (20,000 ml per minute) for 2 hours (120 minutes) making the total sample volume 2.4E6 ml. The background was counted for 24 hours (1,440 minutes) and the air samples will be counted for one hour (60 minutes) each. The alpha self-absorption factor for these glass-fiber filters is 0.9, and the filter efficiency is 99.97% (0.9997). The detector efficiency is 23.4% (0.234). Using Equation LLD,

$$LLD= \frac{2.71+3.29\sqrt{(0.43cpm)(120min)\left[1+\frac{(120min)}{(1,440min)}\right]}}{(120min)(0.234counts/dis)(0.9997)(1)(0.9)(2.4E6ml)(2.22E6)} = 2.03E\text{-}13\ \mu Ci\ per\ ml$$

We offer the following four examples as typical of actual conditions, illustrating calculation of MDA with the equations published in Part I. (The equation numbers referenced refer to the equations as numbered in Part I.)

Example 1

You are using a Model 1000 with a 43-32 alpha scintillation detector to count wipes for removable ^{232}Th contamination. You count background for one hour and count each wipe for one minute. The background count over the hour is 57 counts (or 0.95 cpm) and the efficiency for ^{232}Th is 28% (or 0.28 counts per disintegration). Using Equation 1,

$$MDA=\frac{2.71+3.29\sqrt{(0.95cpm)(1min)\left[1+\frac{(1\ min)}{(60\ min)}\right]}}{(1min)(0.28\ cnts/disintegration)}=21.2\text{ dpm per wipe}$$

Example 2a.

Using the same conditions as in Example 1 except that both the background and the wipes are counted for one minute. Using Equation 2,

$$MDA=\frac{2.71+4.65\sqrt{(0.95cpm)(1min)}}{(1min)(0.28counts/disintegration)}=25.9\text{ dpm per wipe}$$

Example 2b.

You are using a Model 3 with a 44-9 G-M pancake detector to screen wipes for ^{60}Co. The Model 3 does not have the scaler option, so you are "counting" the wipes using slow response. The background in the area is 60 cpm, and the ^{60}Co efficiency you are using is 18% (0.18 counts per disintegration). From the table published in Part I, the value to use for sample and background counting time is 0.323 minutes. Therefore, using Equation 2,

$$MDA=\frac{2.71+4.65\sqrt{(60cpm)(0.323min)}}{(0.323\ min)(0.18counts/disintegration)}=399\text{ dpm per wipe}$$

Example 3.

You are using a Model 3 (which has had the scaler option installed) to quantify ^{14}C contamination on a bench top. You use the scaler to count the background for 10 minutes and get 422 counts (or 42.2 cpm). You use the ratemeter function on fast response to measure activity on the bench top. Efficiency for ^{14}C is 4.3% and the area of the detector is 15 cm^2. From the table published in Part I, the value to use for sample counting time is 0.0587 min. Using Equation 3,

$$MDA=\frac{2.71+3.29\sqrt{(42.2cpm)(0.0587min)\left[1+\frac{(0.0587\ min)}{(10\ min)}\right]}}{(0.0587min)(0.043\ cnts/disintegration)(15cm^2/100)}=20{,}874\text{ dpm per 100 cm}^2$$

Example 4a.

Using the same conditions as in Example 3 except the background and the surface will be counted for two minutes using the scaler option. Using Equation 4,

$$MDA=\frac{2.71+4.65\sqrt{(42.2cpm)(2min)}}{(2\ min)(0.043counts/disintegration)(15cm^2/100)}=3{,}522\text{ dpm per 100 cm}^2$$

Example 4b.

Using the same conditions as in Example 3 except the background and the surface will be determined using only the ratemeter function on slow response. From the table published in Part I, the value to use for time is 0.323 min. Using Equation 4,

$$MDA=\frac{2.71+4.65\sqrt{(42.2cpm)(0.323min)}}{(0.323\ min)(0.043counts/disintegration)(15cm^2/100)}=9{,}541\text{ dpm per 100 cm}^2$$

References

Gollnick, D.A., *Basic Radiation Protection Technology, 3rd Edition.* Altadena, CA; Pacific Radiation Corporation; April 1994.

American National Standard Performance Specifications for Health Physics Instrumentation - *Portable Instrumentation For Use In Normal Environmental Conditions.* New York: Institute of Electrical and Electronic Engineers: ANSI N42.17A-1989.

Berger, J.D., *Manual for Conducting Radiological Surveys in Support of License Termination (NUREG/CR-5849) June 1997.*

Strom, D.J. and Stansbury, P.S., *Minimum Detectable Activity when Background is Counted Longer Than the Sample,* Journal of the Health Phys. 63(3):360-361; 1992.

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NEW PRODUCTS/SERVICES

MODEL 2402 POCKET METER

The Model 2402 Pocket Meter is a lightweight compact survey meter designed to be used with G-M Detectors to offer a small convenient instrument for general purpose surveys. Its size and weight make it ideal for carrying in briefcases, purses, etc.

INDICATED USE: General purpose survey
COMPATIBLE DETECTORS: Model 44-6, Model 44-38, Model 44-7, Model 44-9
CONNECOTR: Series "C" (*others available*)
METER DIAL: 0 - 0.3 mR/hr, BAT OK
MULTIPLIERS: X1, X10, X100
RANGE: 0-30 mR/hr
LINEARITY: Reading within ±10% of true value
AUDIO: Built-in unimorph speaker (*Quiet position turns audio OFF*)
CALIBRATION CONTROLS: Accessible from front of instrument (*protective cover provided*)
RESPONSE: Typically 5 seconds from 10% to 90% of final reading
POWER: 1 each 9-volt battery
BATTERY LIFE: Typically 250 hours with alkaline battery (*battery condition can be checked on meter*)
METER: 2.5" (6.4 cm) arc, 1 mA analog type
CONSTRUCTION: Aluminum housing with beige polyurethane enamel paint and recessed subsurface printed membrane front panel.
TEMPERATURE RANGE: -4°F(-20°C) to 122°F(50°C)
May be certified for operation from -40°F(-40°C) to 150°F(65°C)
SIZE: 1.8" (4.6 cm)H X 3.3" (8.4 cm)W X 5.3" (13.5 cm)L
WEIGHT: 0.9 lbs (0.4 kg) including battery

PRICE: $ 395.00

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