Measurement Quality Objective Considerations for Residual Alpha Surface Radioactivity Measurements at Remediation Sites - 16522

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ABSTRACT

Surveys for residual alpha surface radioactivity on materials, equipment, and other non-porous surfaces are most-commonly performed using the traditional "best-available" equipment. The best available equipment for measuring alpha surface radioactivity includes portable gas-flow proportional or scintillation detectors with active surface areas typically ranging from 50 to 800 square centimeters (cm^2). The measurement equipment is offered by numerous service providers and instrument vendors applying basic detection principles that date back to the early-Atomic Age. The detector face is held as close to the surface as possible and scanned at a typical rate of 2 to 5 centimeters per second (cm/s). Any audible or visual indication of elevated alpha activity would result in a more careful assessment of the possible "hot spot".

Modern surface contamination surveys continue to employ these best available technologies while endeavoring to achieve ever more restrictive measurement quality objectives and screening or release criteria. This paper considers the possibly unforeseen consequences to sensitivity and precision as scanning speeds are reduced to meet constraining measurement quality objectives. Sensitivity calculations are conducted to demonstrate how application of real-world efficiencies and the most common survey approaches are inadequate to meet sensitivity objectives based on American National Standard N13.12-2013, *Surface and Volume Radioactivity Standards for Clearance* screening criteria. Alternate data collection and assessment methodologies are offered to enhance the defensibility of collected data with stakeholders.

Limitations of available or applied alpha survey technologies should be considered when establishing survey programs at project sites where alpha-emitting radionuclides are expected to contribute to residual surface radioactivity. These include but are not limited to nuclear fuel-cycle sites, military/weapons/energy research & production facilities, and 19th-20th Century-era commercial/industrial/research/medical facilities where radioactive materials were handled.

INTRODUCTION

Residual surface radioactivity poses an internal and external radiation hazard to exposed individuals at facilities in operation or undergoing decontamination & decommissioning. Measurements for residual surface radioactivity focus primarily on beta particle or alpha particle emissions from isotopes of concern. Beta based residual surface criteria are readily detectable with commercially available instruments at virtually any expected detection limit. Alpha measurements, on the other hand, are much more challenging as their emission range is very short and easily shortened by everyday field conditions (e.g., dust loading, surface coatings, etc.)

In both cases, the presence of naturally occurring radioactive isotopes in the construction materials (e.g., brick, concrete, steel, asphalt, etc.) and in the environment (e.g., radon and associated progeny) will increase background radioactivity levels and make detection decisions even more challenging.

The measurement sensitivity/detectability parameter is a key MQO when planning surveys. Stakeholder concerns are often manifested in approved working plans as required Minimum Detectable Concentrations (MDCs) that are smaller percentages of the applicable Screening Level (SL). Variables that impact sensitivity-detectability will have similar impacts on other MQOs (i.e., measurement precision) making this a convenient basis for comparison.

Two methods for estimating detectability were evaluated:

- Alpha scanning guidance from the Multi-Agency Radiation Survey and Site-Investigation Manual (MARSSIM) [1].
- Minimum detectable value of the net instrument signal or count guidance from the Multi-Agency Radiation Survey and Assessment of Materials and Equipment (MARSAME) [2].

The following variables were evaluated to determine the impact on detectability on scanning & static measurements:

- Screening level
- Background counts
- Sample count time
- Probe area
- Total efficiency

DESCRIPTION OF METHOD

The detectability of alpha surface radioactivity measurements was evaluated for static and scan measurements using guidance found in MARSSIM [1] and MARSAME [2]. This section describes the calculations performed to evaluate detectability. Descriptions of the variables considered during the evaluation are included along with values selected for individual variables.

MARSSIM Alpha Scanning

MARSSIM Section 6.7.2.2 and Appendix J [1] provide guidance on detectability of alpha surface radioactivity using scanning techniques. MARSSIM uses a two-stage process based on Poisson statistics. The first stage involves scanning at a speed calculated to identify locations where additional investigations will be performed with a specified high probability. The second stage involves performing a static measurement, or pausing during scanning, to determine if the activity at that locations exceed the screening level with a specified high probability.

During the first stage of scanning for alpha surface radioactivity MARSSIM starts with the initial assumption background is zero, and even a single count is sufficient reason to pause and investigate. The probability of detecting at least one count with a background of zero can be calculated using Equation 1.

$$P(n \geq 1) = 1 - e^{-GEAt} \qquad \text{Eq. 1}$$

Where:

P(n≥1) = probability of detecting at least one count
n = number of counts
G = SL or surface activity in Becquerel per square centimeter (Bq/cm^2)
E = total efficiency
A = physical probe area (cm^2)
t = count interval, or dwell time over source in seconds (s)

The alpha radioactivity above background was set equal to the SL to determine the detectability of alpha radiation at concentrations equal to the SL. Note the count interval, t, may be determined based on an assumed scan speed, an assumed area of contamination, and the width of the probe in the direction of scan

In cases where counts may be contributed by background, more than one count may be required before the surveyor decides to stop and investigate further. The probability of detecting one or more counts in the presence of background alpha activity can be calculated using Equation 2, and the probability of detecting two or more counts can be calculated using Equation 3.

$$P(n \geq 1) = 1 - e^{-(GEAt+B)} \qquad \text{Eq. 2}$$

$$P(n \geq 2) = 1 - e^{-(GEAt+B)} \times (1 + GEAt + B) \qquad \text{Eq. 3}$$

Where:

P(n≥2) = probability of detecting two or more counts
B = number of background counts during the count interval t

During the second stage of scanning for alpha surface radioactivity MARSSIM describes a method for estimating the minimum time interval necessary to investigate a location using a static measurement. The minimum time interval required to provide a probability of 0.9 for detecting a single count during an investigation can be calculated using Equation 4.

$$t = \frac{2.3}{GEA} \qquad \text{Eq. 4}$$

Where:

2.3 = constant to provide a detection probability of 0.9

MARSSIM guidance does not account for detecting more than one count during an investigation, detection probabilities other than 0.9, or background when determining the minimal time interval for investigations.

MARSAME Minimum Detectable Net Count

MARSAME Section 7.5 [2] provides guidance for calculating the critical value (S_C) and minimum detectable value of the net count (S_D). S_C is defined as the lowest value of the net count required to give a specified probability that a positive amount of radioactivity is present in the material being measured. S_D is defined as the mean value of the net count that gives a specified probability of yielding an observed net count greater than the critical value (S_C).

One approach to determining S_D is presented as Equation 5.

$$S_D = \frac{\left(z_{1-\alpha} + z_{1-\beta}\right)^2}{4}\left(1+\frac{t_S}{t_B}\right) + \left(z_{1-\alpha} + z_{1-\beta}\right)\sqrt{N_B\frac{t_S}{t_B}\left(1+\frac{t_S}{t_B}\right)} \qquad \text{Eq. 5}$$

Where:

S_D = minimum detectable value of the net count (counts)

$z_{1-\alpha}$ = standard normal cumulative probability for 1-α (default 1.645)

$z_{1-\beta}$ = standard normal cumulative probability for 1-β (default 1.645)

α = Type I decision error rate, incorrectly deciding radioactivity above background is present (default is 0.05)

β = Type II decision error rate, incorrectly deciding radioactivity is consistent with background (default is 0.05)

t_S = sample count time in seconds

t_B = background count time in seconds

N_B = background counts during the background count time

Alternative methods to determining SC and SD are provided in MARSAME Section 7.5 Tables 7.5 & 7.6 [2]. The selection of the appropriate formula is based on the total background counts, the relationship between background and measurement count intervals; the acceptable Type I/II Error Rates and; the application of an assumed Poisson Distribution or Stapleton Approximation.

The minimum detectable concentration (MDA) can then be calculated from the S_D using Equation 6.

$$MDC = \frac{S_D}{EAt_S} \qquad \text{Eq. 6}$$

Screening Levels

A wide variety of SL values are being applied at sites where alpha surface radioactivity measurements are performed. MARSAME Section 3.3 [2] provides guidance on selecting SL values appropriate to the type of survey being performed. The purpose of this paper is not to discuss selection of SL values for a specific application. Instead, a range of SL values has been identified to provide boundaries for the calculations and help define the issue.

NRC policies and practices presented in MARSAME Appendix E [2] use a value of 0.0167 Bq/cm^2 (100 disintegrations per minute per 100 square centimeters [100 dpm/100 cm^2]) for release of materials and equipment. The guidance states the residual radioactivity most be non-detectable with an MDC for alpha surface radioactivity equal to 1/60 Bq/cm^2. This value provides an effective lower bound for SL values applied for most projects.

The American National Standard N13.12 [3] establishes SL values corresponding to 0.01 milliSeivert per year (mSv/y). The majority of alpha-emitting radionuclides have SL values of 0.1 Bq/cm^2 (600 dpm/100 cm^2). These values have also been adopted as part of the U.S. Army Radiation Safety Program [4]. While higher SL values may be available the upper boundary for these calculations was set at 0.1 Bq/cm^2.

Background Counts

Total background counts are used to define the S_C and S_D values, as well as contributing to the probability of detecting a specified number of counts over a specified time interval. Total background counts represent a critical variable for determining detectability for alpha surface radioactivity measurements.

A baseline is typically established at the beginning of a project to allow monitoring of interest performance over the course of a project. Typical projects use 10 one-minute counts to establish a baseline for background. This data can also be used to provide a 600-second total background count. Longer background count times provide more information on the background distribution, resulting in better detectability with a lower MDC. The calculations in this paper are based on a 600-second background count. Longer background count times will result in a higher number of background counts and lower MDC values. Shorter background count times will result in a lower number of background counts and higher MDC values. It is critical to note that background count inputs must be representative of the actual field background conditions for the calculation of “net count” based evaluations (i.e., S_D and S_c)to be meaningful. Since instrument set-up and storage locations are often located based on ALARA considerations, careful consideration should be given to conducting instrument background measurements in actual work areas.

Zero total background counts during a 600-second count is possible, although most survey instruments used to perform alpha surface radioactivity measurements are expected to have between 1 and 5 total background counts. Many surfaces where measurements are performed are constructed from materials that contain some natural radioactivity. Total background counts during a 600-second count on concrete may result in 100 to 150 counts. Therefore, a range of total background counts was established between 0 and 200 counts. This range should encompass most of the materials commonly encountered when performing alpha surface radioactivity measurements.

Sample Count Time

Sample count time is another variable that can have a major impact on detectability. Longer count times result in lower MDC values. Scan measurements tend to have very short count times, usually on the order of 1 or 2 seconds. Static measurements to investigate alpha counts identified during scanning typically range from a few seconds to one minute. Static measurements longer than one minute are generally performed at systematic locations as part of an investigation of average activity over a large area, or to perform more rigorous investigations at specific locations. The calculations performed here include a range of sample count times from 1 second to 300 seconds.

Probe Area

Former guidance documents, such as NRC Regulatory Guide 1.86[5], specified maximum activity over a specified area, such as 100 cm^2. In effect, these restrictions limited the maximum probe area that could be used to perform measurements since the area of residual radioactivity cannot be smaller than the probe area. Current guidance does not specify the area of radioactivity to be measured, so the area is limited by the size of the probe. A larger probe area results in a larger area being measured, and generally results in lower detection limits.

Traditionally alpha surface radioactivity measurements have been performed with small handheld scintillation and gas-proportional detectors, or with large area gas-proportional floor monitors. Handheld alpha radiation detectors have approximately 100 cm^2 probe areas, while floor monitors have probe areas closer to 600 cm^2 or 800 cm^2. Calculations were performed for probe areas of 100 cm^2 and 600 cm^2 to provide a reasonable range of results for comparison.

Total Efficiency

The International Organization for Standardization (ISO) published guidance on evaluating alpha surface radioactivity in ISO-7503-1[6]. The total efficiency for a measurement is the product of the source efficiency and the instrument efficiency. The source efficiency is defined as the ratio between the number of particles of a given type above a given energy emerging from the front face of a source (i.e., the surface emission rate) and the number of particles of the same type created or released within the source. ISO-7503-1 recommends using a generic source efficiency of 0.25. The instrument efficiency is defined as the ratio between the instrument net reading and the surface emission rate of a source under given geometrical conditions. The instrument efficiency is typically determined experimentally by performing measurements.

The total efficiency is used to convert between counts and activity and has a direct impact on detectability. Higher total efficiency increases detectability resulting in a lower MDC.

Static measurements of alpha surface radioactivity are typically performed by placing the probe directly in contact with the surface being measured. Scan measurements, however, are typically performed by suspending the probe a fixed distance from the surface and slowly moving the probe. Two separate instrument efficiencies are required to provide a separate total efficiency for each geometry.

Total efficiencies for commercially available handheld detectors were developed for measurements on contact and at a height of 1 cm above the surface. A 150 cm^2 thorium-230 source traceable to the National Institute of Science and Technology (NIST) and the Deutsch Akkreditierungsstelle (DAkkS) was used to determine the instrument efficiency. Total efficiencies for measurements on contact ranged from 0.07 to 0.11 for both scintillation and gas proportional detectors. Total efficiencies at a height of 1 cm above the surface average approximately 25% of the total efficiency on contact. A total efficiency of 0.1 was used for measurements on contact with the surface, and a total efficiency of 0.025 was used for measurements at a height of 1 cm above the surface being measured for the 100 cm^2 handheld probe.

Total efficiencies for commercially available floor monitors were also determined experimentally using the same thorium-230 source. A total efficiency of 0.08 was used for measurements on contact with the surface, and a total efficiency of 0.06 was used for measurements at a height of 1 cm above the surface being measured for the 600 cm^2 floor monitor probe.

DISCUSSION OF RESULTS

MARSSIM Alpha Scanning

The probability of detecting at least one count during an alpha surface activity measurement was calculated using Equation 1 and Equation 2. The probability of detecting two or more counts during an alpha surface activity measurement was calculated using Equation 3. Values for the SL, background count (shown as a count rate in counts per minute [cpm]), sample count time (or count interval), probe area, and total efficiency were varied to demonstrate the impact on detectability. The results of the calculations for a SL of 0.0167 Bq/cm^2 are shown in Table I. The results of the calculations for a SL of 0.1 Bq/cm^2 are shown in Table II.

Comparing the results in Table I with the results in Table II shows the probability of detecting counts increases as the SL becomes greater. The greater the SL, the greater the activity, and the higher the probability of detecting counts.

The probability of detecting a count increases as the background count rate increases. The probability of detecting a count also increases with increases in sample count time, probe area, and total efficiency.

TABLE I. Probability of Detection for a Screening Level of 0.0167 Bq/cm^2

Total Efficiency	Count Interval (s)	P(n≥1)					P(n≥2)			
		0 cpm	0.1 cpm	1 cpm	10 cpm	20 cpm	0.1 cpm	1 cpm	10 cpm	20 cpm
100 cm^2 Probe on Contact with Surface Being Measured										
0.1	1	0.15	0.15	0.17	0.28	0.39	0.01	0.01	0.04	0.09
0.1	2	0.28	0.29	0.31	0.49	0.63	0.05	0.05	0.14	0.26
0.1	4	0.49	0.49	0.52	0.74	0.86	0.15	0.17	0.38	0.59
0.1	6	0.63	0.64	0.67	0.86	0.95	0.27	0.30	0.59	0.80
0.1	8	0.74	0.74	0.77	0.93	0.98	0.39	0.43	0.75	0.91
0.1	10	0.81	0.81	0.84	0.96	0.99	0.50	0.55	0.85	0.96
0.1	20	0.96	0.97	0.97	1.00	1.00	0.85	0.88	0.99	1.00
0.1	40	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	1.00
0.1	60	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100 cm^2 Probe 1 cm Above Surface Being Measured										
0.025	1	0.04	0.04	0.06	0.19	0.31	0.00	0.00	0.02	0.05
0.025	2	0.08	0.08	0.11	0.34	0.53	0.00	0.01	0.07	0.17
0.025	4	0.15	0.16	0.21	0.57	0.78	0.01	0.02	0.20	0.44
0.025	6	0.22	0.23	0.30	0.71	0.89	0.03	0.05	0.36	0.66
0.025	8	0.28	0.29	0.37	0.81	0.95	0.05	0.08	0.50	0.80
0.025	10	0.34	0.35	0.44	0.88	0.98	0.07	0.12	0.62	0.89
0.025	20	0.57	0.58	0.69	0.98	1.00	0.22	0.33	0.92	1.00
0.025	40	0.81	0.82	0.90	1.00	1.00	0.52	0.68	1.00	1.00
0.025	60	0.92	0.93	0.97	1.00	1.00	0.73	0.86	1.00	1.00
0.025	90	0.98	0.98	0.99	1.00	1.00	0.90	0.97	1.00	1.00
600 cm^2 Probe on Contact with Surface Being Measured										
0.08	1	0.55	0.55	0.56	0.62	0.68	0.19	0.20	0.25	0.31
0.08	2	0.80	0.80	0.80	0.86	0.90	0.48	0.49	0.58	0.66
0.08	4	0.96	0.96	0.96	0.98	0.99	0.83	0.84	0.90	0.94
0.08	6	0.99	0.99	0.99	1.00	1.00	0.95	0.96	0.98	0.99
0.08	8	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	1.00
0.08	10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
600 cm^2 Probe 1 cm Above Surface Being Measured										
0.06	1	0.45	0.45	0.46	0.54	0.61	0.12	0.13	0.18	0.24
0.06	2	0.70	0.70	0.71	0.78	0.85	0.34	0.35	0.45	0.56
0.06	4	0.91	0.91	0.92	0.95	0.98	0.69	0.71	0.81	0.89
0.06	6	0.97	0.97	0.98	0.99	1.00	0.88	0.88	0.94	0.98

0.06	8	0.99	0.99	0.99	1.00	1.00	0.95	0.96	0.98	1.00
0.06	10	1.00	1.00	1.00	1.00	1.00	0.98	0.98	1.00	1.00

TABLE II. Probability of Detection for a Screening Level of 0.1 Bq/cm^2

Total Efficiency	Count Interval (s)	P(n≥1)					P(n≥2)			
		0 cpm	0.1 cpm	1 cpm	10 cpm	20 cpm	0.1 cpm	1 cpm	10 cpm	20 cpm
100 cm^2 Probe on Contact with Surface Being Measured										
0.1	1	0.63	0.63	0.64	0.69	0.74	0.26	0.27	0.33	0.38
0.1	2	0.86	0.87	0.87	0.90	0.93	0.59	0.60	0.68	0.75
0.1	4	0.98	0.98	0.98	0.99	1.00	0.91	0.91	0.95	0.97
0.1	6	1.00	1.00	1.00	1.00	1.00	0.98	0.98	0.99	1.00
0.1	8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.1	10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100 cm^2 Probe 1 cm Above Surface Being Measured										
0.025	1	0.22	0.22	0.23	0.34	0.44	0.03	0.03	0.07	0.12
0.025	2	0.39	0.40	0.41	0.57	0.69	0.09	0.10	0.20	0.33
0.025	4	0.63	0.63	0.66	0.81	0.90	0.27	0.29	0.50	0.68
0.025	6	0.78	0.78	0.80	0.92	0.97	0.45	0.48	0.71	0.86
0.025	8	0.86	0.87	0.88	0.96	0.99	0.60	0.63	0.85	0.95
0.025	10	0.92	0.92	0.93	0.98	1.00	0.72	0.75	0.92	0.98
0.025	20	0.99	0.99	1.00	1.00	1.00	0.96	0.97	1.00	1.00
600 cm^2 Probe on Contact with Surface Being Measured										
0.08	1	0.99	0.99	0.99	0.99	0.99	0.95	0.95	0.96	0.96
0.08	2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.08	4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
600 cm^2 Probe 1 cm Above Surface Being Measured										
0.06	1	0.97	0.97	0.97	0.98	0.98	0.87	0.88	0.89	0.90
0.06	2	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	1.00
0.06	4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Count intervals between 10 and 90 seconds are required to achieve detection probabilities of 0.9 for a 100 cm^2 probe at a height of 1 cm from the surface being measured for a SL of 0.0167 Bq/cm^2. These values correspond to a typical scanning survey performed using a handheld alpha detector. Count intervals between 4 and 8 seconds are required to achieve detection probabilities of 0.9 using a floor monitor to scan at a SL of 0.0167 Bq/cm^2. Traditional approaches to scanning require a significant amount of time and effort when SL values are low.

Static measurements also require between 10 to 20 seconds to achieve detection probabilities of 0.9 for measurements on contact with the surface being measured. Equation 4 was used to calculate minimum count times for different values for the

SL, probe area, and total efficiency. The results of these calculations are shown in Table III.

Table III. Minimum Time Interval

Screening Level (Bq/cm^2)	Total Efficiency	Probe Area (cm^2)	Count Time (s)
0.0167	0.1	100	14
0.1	0.1	100	2.3
0.0167	0.025	100	55
0.1	0.025	100	9.2
0.0167	0.08	600	2.9
0.1	0.08	600	0.48
0.0167	0.06	600	3.8
0.1	0.06	600	0.64

The impact on the probability of detection is expected for most of the changes in values for the variables used in these calculations. Longer count times, larger areas measured, and more efficient detectors make it easier to detect alpha surface activity. However, increasing the number of background counts also increases the probability of detection which is not expected.

MARSSIM guidance does not consider background separately from residual radioactivity. Equation 2 and Equation 3 show counts originating from background are simply added to the counts originating from residual radioactivity. Since the total number of counts increases, the probability of detecting a count also increases. Increasing background has the same impact on detection probability as raising the SL. In addition, MARSSIM guidance uses a two-stage process. The first stage uses scanning to identify locations requiring further investigation. The second stage uses static measurements to investigate locations identified as potentially contaminated by scanning measurements.

Tables I and II show the probability of detection can increase significantly based on the number of background counts, resulting in a larger number of investigations. Table I shows that a 100 cm2 probe suspended 1 cm above the surface being measured moving at a rate of one detector width every 2 seconds with a background count rate of zero has a probability of detecting at least one count of 0.08. If the measurement is performed on concrete with a background of 20 cpm the detection probability increases to 0.53. The probability of detecting two or more counts is 0.17. Table III shows the minimum count time to investigate each location with identified counts is at least 14 seconds. The count time alone to perform the additional 900 investigations for locations with two or more counts in a 100 square meter room would be more than 200 man hours.

Selecting appropriate SL values, using large area detectors, and controlling background can reduce the impact on time and resources required to survey for alpha surface radioactivity.

MARSAME Minimum Detectable Net Count

Equation 5 was used to calculate the minimum detectable net count, and Equation 6 was used to calculate the MDC for alpha surface activity measurements. Values for background counts, sample count time, probe area and total efficiency were varied to demonstrate the impact on the MDC. The calculated MDC values were compared to SL values to determine detectability.

Figure 1 shows the results of the MDC calculations for alpha surface activity measurements using a 100 cm^2 probe suspended at a height of 1 cm above the surface being measured. Each line represents a different number of background counts collected over 600 seconds, and MDC values were calculated for a range of sample count times. The horizontal lines represent the SL values and provide a quick comparison of detectability over a range of conditions that could be encountered in the field.

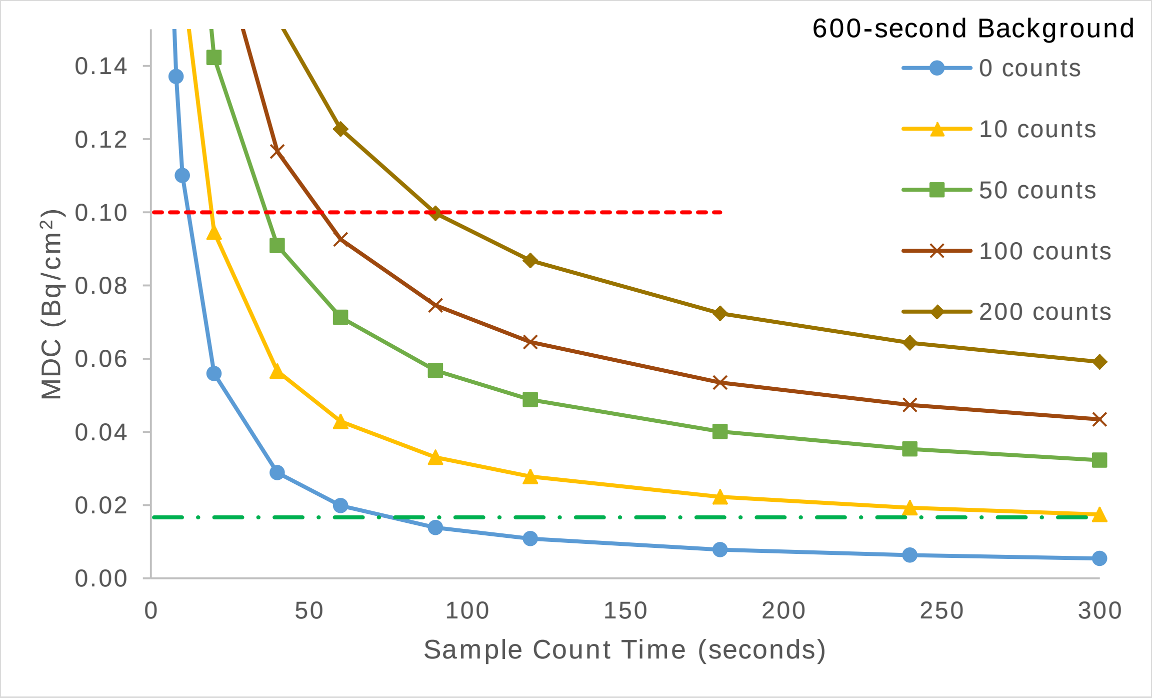

Fig. 1. MDC Values for a 100 cm^2 Probe Suspended 1 cm Above the Surface

Figure 2 shows the results of the MDC calculations for a 100 cm^2 probe on contact with the surface being measured. Figure 3 shows the results of the MDC calculations for a 600 cm^2 probe suspended 1 cm above the surface being measured. Figure 4 shows the results of the MDC calculations for a 600 cm^2 probe on contact with the surface being measured.

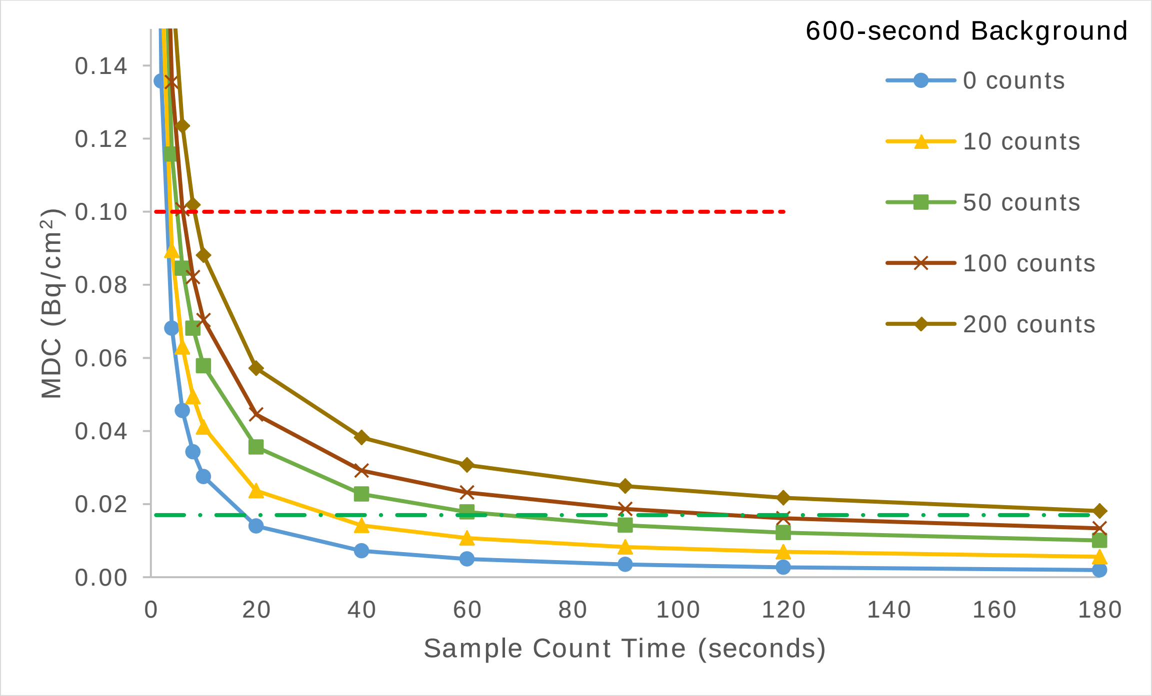

Fig. 2. MDC Values for a 100 cm^2 Probe on Contact with the Surface

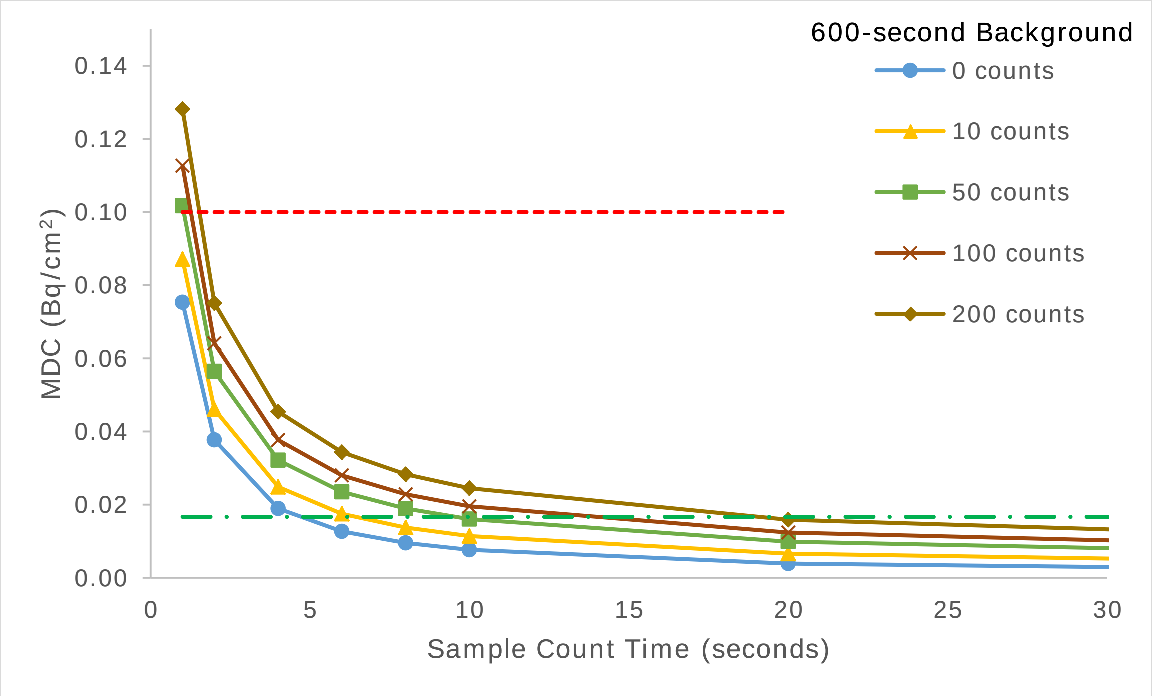

Fig. 3. MDC Values for a 600 cm^2 Probe Suspended 1 cm Above the Surface

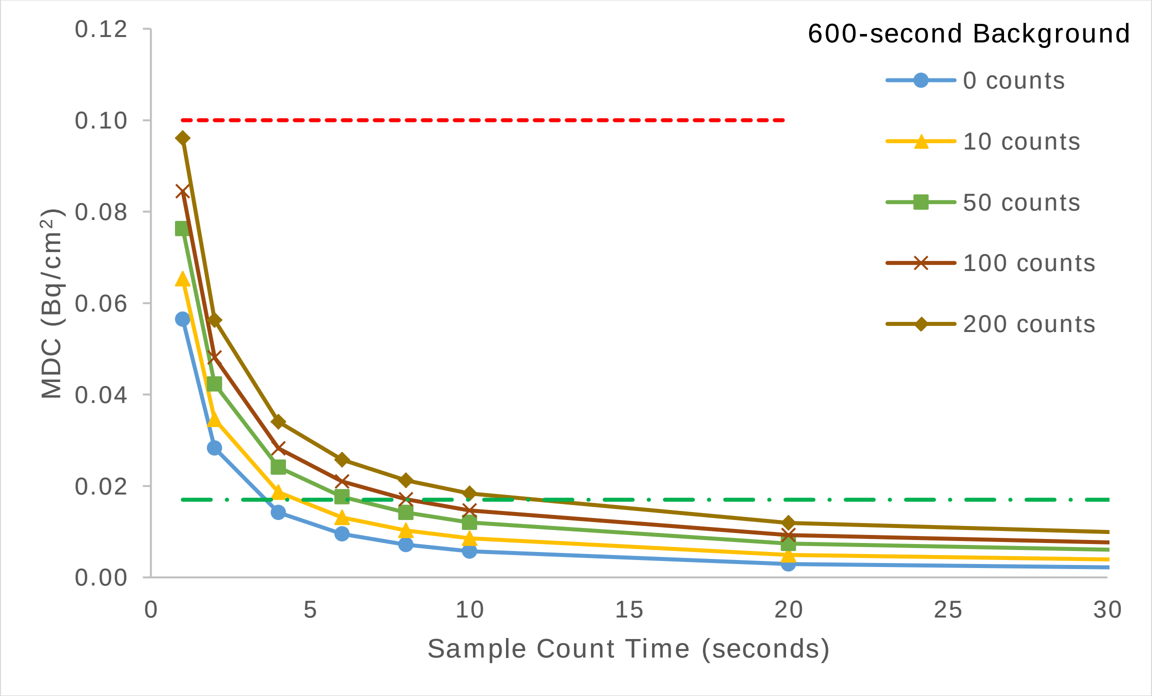

Fig. 4. MDC Values for a 600 cm^2 Probe on Contact with the Surface

The calculated MDC values generally follow expected trends based on changes to individual variable values. Higher background counts result in higher MDC values. Shorter sample count times result in higher MDC values. Smaller probe areas result in higher MDC values. Lower total efficiency values result in higher MDC values.

The calculated MDC results are most useful when compared to the SL values and evaluating the sample count time required to achieve an MDC less than or equal to the SL. For a 100 cm^2 probe suspended 1 cm above the surface being measured, 20 to 90 seconds are required to achieve an MDC less than 0.1 Bq/cm^2 depending on the number of background counts. This simulates scanning for alpha surface radioactivity with a handheld instrument. Sample count times greater than 300 seconds may be required to achieve MDC values less than 0.0167 Bq/cm^2 while scanning with a handheld instrument. Sample count times for a 600 cm^2 probe suspended 1 cm above the surface being measured ranged from 1 to 2 seconds for a SL of 0.1 Bq/cm^2, and 6 to 20 seconds for a SL of 0.0167 Bq/cm^2.

CONCLUSIONS

Establishing appropriate MQOs is an important part of designing radiological surveys. Detectability is an important MQO that is often used to support selection of detection instruments. Detectability may also be used to support selection of parameters for measurement techniques, such as sample count times and scan speeds. MARSSIM [1] and MARSAME [2] provide guidance on detectability when performing alpha surface radioactivity measurements.

The evaluation of detectability based on both MARSSIM and MARSAME demonstrate the importance of selecting realistic and appropriate SLs & MQOs and; understanding how their determination will carry into the selection of instrumentation, trhe feasibility of the survey and, the overall cost to complete the surveys The parameters with the most significant impact on detectability are probe area and number of background counts. The source-to-detector distance is a critical consideration for alpha measurements with significant efficiency loss within the first cm of space between the surface undergoing investigation and the detector window.

The probe area can also be considered the total area covered by a measurement. This measurement area can be significantly greater than the physical probe area. Increasing the probe area, or measurement area, has a direct impact on detectability. Many measurement systems perform averaging over areas considerably greater than the physical probe area to provide MDC values less than the project SL. Understanding the method used to determine the average activity and the total measurement area can be critical MQOs for designing alpha surface radioactivity measurements that meet project objectives.

The number of background counts can have an unexpected impact on detectability, especially when using MARSSIM guidance. Greater numbers of background counts increase the probability of detecting radioactivity during scanning, but also result in significantly more investigations. Both MARSSIM and MARSAME demonstrate that scanning for alpha surface radioactivity is difficult, and in many cases may be impractical. The equations in MARSAME provide similar results to the guidance on detectability in MARSSIM, and are generally easier to implement and understand.

The evaluation considered both scanning and static measurements. The results of the evaluation demonstrate the importance of clearly stating the MQOs for a project and establishing realistic MQOs based on survey requirements. Identification of critical variables assists survey planners in selecting appropriate instruments and measurement techniques while establishing realistic MQOs for a specific survey. This same information assists regulators and other stakeholders in reviewing survey data to ensure the objectives for the survey have been achieved.

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