



DEPARTMENT OF THE ARMY
ST. LOUIS DISTRICT, CORPS OF ENGINEERS
9170 LATTY AVENUE
BERKELEY, MISSOURI 63134

REPLY TO
ATTENTION OF:

March 16, 1999

Formerly Utilized Sites Remedial Action Program Project Office

Mr. Dan Wall
U. S. Environmental Protection Agency
Region VII, Superfund Branch
726 Minnesota Avenue
Kansas City, KS 66101

**SUBJECT: DETECTION LIMITS AT THE HAZELWOOD INTERIM
STORAGE SITE (HISS) LABORATORY**

Dear Mr. Wall:

Enclosed is a comprehensive copy of technical information regarding the detection limits at the HISS laboratory based on current best available technology.

Please contact Mr. Dennis Chambers at (314) 524-3329 if you have any questions on this action.

Sincerely,

A handwritten signature in cursive script, reading "Sharon R. Cotner", is positioned above the typed name.

SHARON R. COTNER
FUSRAP Program Manager

Enclosure
CC: Mr. Robert Geller, MDNR

DETECTION LIMITS AT THE HISS LABORATORY

INTRODUCTION

The Hazelwood Interim Storage Site (HISS) laboratory is located at the site on Latty Avenue in Hazelwood, MO. The laboratory supports remediation activities being conducted at the airport site (SLAPS), the downtown site (SLDS) and other activities authorized by the US Army Corps of Engineers (USACE). The purpose of this paper is to evaluate the detection capabilities of the HISS laboratory with respect to its detection limits for alpha and gamma spectral measurements. Prior to providing laboratory data, a discussion of detection limits as applied to spectral measurements and their limitations is presented. A comparison of the HISS laboratory limits to the detection limits of a commercial laboratory is also provided.

DETECTION LIMITS

A number of very different expressions and definitions of "detection limits" are frequently encountered in the measurement of gamma and alpha emitting radionuclides. Their meanings are often ambiguous, inconsistent and incorrectly interpreted. Some of these terms are "minimum detectable activity", "minimum detectable concentration", "lower limit of detection", "minimum detectable level", etc. Much of the confusion with detection limits for environmental measurements stems not only from the large number of different expressions being used, but also from the incorrect application of some of the original definitions. Therefore, two distinctly different concepts are needed ⁽¹⁾.

DEFINITIONS

The **lower limit of detection (LLD)** is a measure of the lowest level at which a detection system can distinguish activity from background and the intrinsic characteristics of the counting instrument. An analogous definition is that the LLD is the "smallest amount of sample activity that will yield a net count for which there is a confidence at a predetermined level that activity is present" ⁽²⁾. The LLD is the lowest limit of detection in the truest sense of the word.

In theory, calculating the LLD requires the number of counts in the spectral peak to be sufficient such that Gaussian statistics can be applied. In practice, this approximation is good down to a few total counts ⁽³⁾. The LLD depends ONLY on the detection capability of the measurement process (the instrument) itself and is not dependent on other factors involved in the measurement method or sample characteristics. It is important in the application of the LLD to make the distinction between it and other limits that are directly related to the net sample activity (such as MDC; see below). The LLD is generally determined by operating the counting instrument with no sample in the counting chamber⁽⁴⁾ (background measurement).

The second concept, the **minimum detectable concentration (MDC)**, is the most useful for regulatory purposes. It corresponds to a level of activity that is practically

achievable with a given instrument, method and type of sample. It depends not only on the instrument characteristics, but also on many other specific factors involved in the measurement process, as well as the characteristics of the sample being measured. As such, it is not a limit at all, but an estimated level achievable for a given sample under a given set of practical conditions (i.e., length of count time, sample volume or weight, interfering radioactivity, etc.).

EQUATIONS

LLD – Counting data for a series of background measurements should show a Gaussian distribution, and if one calculates the standard deviation for the distribution, it will give an approximation of how well additional measurements of the background will approach the original measurement mean. However, in most environmental measurements we do not have the luxury of multiple analyses or even duplicates. Due to the statistical characteristics of radioactive decay, it is possible to estimate the standard deviation of counting data from a single measurement. Therefore, we can establish a background with its associated standard deviation for a counting system, which gives us a method of estimating our lower limit of detection assuming predefinition of an analytical geometry, efficiency, acquisition time and a background spectrum normal to the sample being analyzed.

The LLD may be approximated as

$$\text{LLD} \cong (k_{\alpha} + k_{\beta}) s_0 \quad (\text{Eq. 1})$$

Where:

k_{α} and k_{β} represent the probability of falsely concluding that activity is present or absent in the sample, respectively. In most applications this probability, or degree of false conclusion, is set at 5% (95% confidence level) for both k_{α} and k_{β} . The statistical factor from the student's t table for both k_{α} and k_{β} is then determined to be 1.645. Therefore, since $k_{\alpha} = k_{\beta} = k$,

$$(k_{\alpha} + k_{\beta}) = 2k \quad (\text{Eq. 2})$$

and, s_0 is the estimated standard deviation for the net activity in the background spectrum.

$$s_0 = \sqrt{s_{\text{gross}}^2 + s_{\text{bkg}}^2} \quad (\text{Eq. 3})$$

If the gross activity, s_{gross} , and the background activity, s_{bkg} , are very close (which is a reasonable approximation near the LLD), then

$$s_0 \cong \sqrt{2s_{\text{bkg}}^2} = s_{\text{bkg}} \sqrt{2} \quad (\text{Eq. 4})$$

At very small background count rates, near zero, the assumption of the gross activity and the background activity being essentially equal is not good. Currie⁽⁵⁾ has shown that a correction for the difference can be made by adding a term of 2.71 to account for the zero background case which corresponds to the 95% confidence level discussed above.

Then, the LLD becomes

$$LLD \cong 2.71 + 2k s_{bkg} \sqrt{2} \cong 2.71 + 3.3s_{bkg} \sqrt{2} \cong 2.71 + 4.66 s_{bkg} \quad (\text{Eq.5}).$$

The lower limit of detection, or minimum activity, can therefore be determined for any nuclide of interest in the gamma or alpha spectrum assuming it is the ONLY nuclide in the spectrum. Factors affecting this assumption are discussed below.

MDC – As mentioned previously, the minimum detectable concentration for a particular radionuclide is determined under a specific set of typical measurement conditions which include the sample size (V), the counting time (T), the chemical yield (Y) and other factors (branching ratio (Br), self-absorption (A), decay corrections, etc.) that affect the reported activity. A typical MDC based on a background count for any specific detector system can be calculated as follows by putting typical values in for the variables defined above:

$$MDC = \frac{LLD}{E * T * V * Y * Br * A * e^{-\lambda \Delta t} * 2.22} \quad (\text{Eq.6}).$$

Substituting equation Eq.5 for LLD yields:

$$MDC = \frac{2.71 + 4.66 s_{bkg}}{E * T * V * Y * Br * A * e^{-\lambda \Delta t} * 2.22} \quad (\text{Eq.7}).$$

Where:

- 2.22 = the conversion factor from disintegrations/minute to picocuries,
- $\lambda = 0.693 / t_{1/2}$; $t_{1/2}$ is the half life of the nuclide in question,
- Δt = length of time between sample collection and actual counting, and
- E = product of the intrinsic efficiency of the detector and sample geometry as a function of energy.

Note that the decay correction term is included since the quantity of usual interest is the activity at the time the sample was collected. For isotopes with long half-lives such as U-235 and U-238 and those radionuclides in secular equilibrium with long half-life isotopes, this term is essentially 1.

Since the MDC is intended to serve as a practical level that is achievable under a given set of conditions, equation Eq. 7 is used to evaluate the MDC for actual samples. As discussed above, s_{bkg} is the standard deviation of the background counts ($\sqrt{\text{counts}}$) in the spectral region of interest.

FACTORS AFFECTING DETECTION LIMITS

- Branching ratio (Br) – the branching ratio is a constant for each individual isotope. It is a ratio of the number of specific radioactive transitions (i.e., gamma-rays or alpha particles) produced per radioactive nuclide decay. For instance, 35 out of every 100 decays of Am-241 result in a 59.5keV gamma-ray resulting in a branching ratio of 0.35.
- The intrinsic detector efficiency, sample geometry and matrix absorption factors for alpha and gamma ray measurements are determined and compensated for by calibrating the detector utilizing a calibration source which has physical characteristics as close as possible to those of the sample. These factors will affect the MDC as the sample characteristics vary from the calibration source.
- Volume and weight are two of the physical characteristics of the sample that can affect the MDC as well as the reported activities. Consider a detector that was calibrated with a container that is full to the top with sample material. If we now count a sample container that is 3/4 full with the same material and all other conditions are the same, we could not expect to report accurate activity levels since the physical size of the sample is now smaller and it only has 3/4 of the activity. (This analogy does not imply actual laboratory practices). By calibrating the detector, we are telling the counting system what unknown samples will look like.

In order to lower detection levels, we could count larger quantities of sample since the larger sample as a whole will contain more radioactivity, therefore better counting statistics leading to lower MDC's. Adding more sample, however, begins to shield (absorb) the gamma-rays prior to reaching the detector, thus resulting in lower counting statistics per volume of sample and effectively raising the MDC.

Because of the destructive nature of the chemistry involved in separating alpha radionuclides from the bulk of the matrix, relatively small sample sizes are required (0.25 – 0.50 grams) for alpha analysis. Alpha particles, because of their size and charge, do not travel very effectively through matter. Therefore, the sample deposit containing the radioactive species of interest must be very thin in order to allow the alpha particle to escape and interact with the detector. With larger starting samples and the resulting larger sample deposit, fewer alpha particles would be detected per unit of sample mass, resulting in a higher MDC.

In the case of water or liquid matrices, samples could be concentrated by evaporation effectively increasing the radioactive component (and counting statistics) per volume of sample. This method takes time and laboratory space. For environmental samples, a significant volume reduction (≈ 10 or $20:1$) is needed to increase counting statistics.

- MDC's are affected by the chemical recovery for any samples that undergo chemical separation. Since this factor is in the bottom of the MDC equation, low recoveries will increase the MDC. Experienced analysts thoroughly trained in the separation chemistry will keep the recovery values as high as possible.

- The MDC is also influenced by the spectral background levels. Radiative contributions to the background level come from two major sources; external environmental sources and internal sources from the sample itself. (1) External environmental radiation comes from sources such as cosmic radiation, radon, and other natural sources of radiation such as the materials of construction used in the building housing the detector system as well as the earth itself. Efforts are made to reduce the effects of these external natural sources by shielding the detector with materials such as lead and steel. (2) If the sample being analyzed has more than one radioactive species, then the background is likely to increase due to compton events from the decay of these other radionuclides. A compton event results from the incomplete deposition of the gamma-ray's energy in the detector. As a result, the background is increased in all energy channels below the interfering gamma-ray energy. A sample that is radioactively "hot" will have higher MDC's due to the compton background. There is nothing that can be done about this contribution to the background short of chemical separation and removal of the interfering species from the sample.

If we look at Eq. 7, we see that s_{bkg} is the square root of the background count. Because the count variable, s_{bkg} , is in the numerator, the magnitude of the MDC is directly related to the number of counts in the background. Therefore, in order to reduce the MDC, every effort is made to reduce the background levels from these sources.

- Counting time is the variable most easily adjusted in attempts to lower sample specific MDC's. As illustrated in Figure 1, a point of diminishing returns is reached as the counting time increases. It may be possible that due to other factors, such as high spectral background from compton events, a certain MDC cannot be reached regardless of how long the sample is counted.

LABORATORY PRACTICE

As stated in the introduction, a lot of confusion exists over the definition and application of the LLD and MDC concepts. Data was obtained from Quanterra's St. Louis laboratory for comparison to the HISS laboratory. Neither the HISS laboratory nor Quanterra's St. Louis laboratory uses or calculates a true LLD. Both labs determine an average environmental background by measuring a background spectra taken over a 1000 minute period with a calibrated detector and no sample matrix in the counting chamber. To determine the "best practical MDC" for the detection system, both laboratories use a clean sample (radiologically clean sample matrix containing no radioactivity of interest) loaded into the sample chamber and counted for 60 minutes. The detection system software calculates an MDC for each isotope listed in its library using a typical set of sample characteristics and counting parameters.

Table 1 below shows data from both the HISS laboratory and the Quanterra laboratory of a typical gamma-analysis of a "clean" sample. Both labs counted a 500 gram sample for 1 hour with similar detectors. The MDC's shown are from that sample alone and typically have propagated errors of about 10%. As can be seen from the table, MDC's from both laboratories are comparable to one another. However, it was also stated by Quanterra, that they do not perform alpha spectral analysis from water matrices. They also do not perform isotopic uranium or radium-226/-228 by alpha spectroscopy.

Table 1. HISS/Quanterra Lab Detection Levels

Nuclide ID	Analytical Method	Sample Size (units)	Counting Geometry	Counting Time (min)	Detector Type ¹⁾	HISS Best Practical MDC ²⁾	Qnt'a Best Practical MDC ²⁾
Soils						pCi/gm	pCi/gm
K-40	γ Spec	500 gm	500 Marinelli	1 hour	HPGe	0.24	0.35
Cs-137	γ Spec	500 gm	500 Marinelli	1 hour	HPGe	0.01	0.02
Ra-226	γ Spec	500 gm	500 Marinelli	1 hour	HPGe	0.02	0.04
Ac-227	γ Spec	500 gm	500 Marinelli	1 hour	HPGe	0.06	NA
Ra-228	γ Spec	500 gm	500 Marinelli	1 hour	HPGe	0.04	NA
Th-228	γ Spec	500 gm	500 Marinelli	1 hour	HPGe	0.04	NA
Th-230	γ Spec	500 gm	500 Marinelli	1 hour	HPGe	3	2
Pa-231	γ Spec	500 gm	500 Marinelli	1 hour	HPGe	0.3	NA
U-235	γ Spec	500 gm	500 Marinelli	1 hour	HPGe	0.06	0.08
U-238	γ Spec	500 gm	500 Marinelli	1 hour	HPGe	2	.2
Am-241	γ Spec	500 gm	500 Marinelli	1 hour	HPGe	0.03	0.02
Soils						(pCi/gm)	(pCi/gm)
Ra-226	α Spec	0.5 gm	Planchet	3 hours	PIP	0.1	NA
Ra-228	α Spec	0.5 gm	Planchet	3 hours	PIP	0.1	NA
Th-227	α Spec	0.5 gm	Planchet	3 hours	PIP	0.1	NA
Th-228	α Spec	0.5 gm	Planchet	3 hours	PIP	0.1	0.01 ³⁾
Th-230	α Spec	0.5 gm	Planchet	3 hours	PIP	0.1	0.09 ³⁾
Th-232	α Spec	0.5 gm	Planchet	3 hours	PIP	0.1	0.7 ³⁾
U-234	α Spec	0.5 gm	Planchet	3 hours	PIP	0.1	NA
U-235	α Spec	0.5 gm	Planchet	3 hours	PIP	0.1	NA
U-238	α Spec	0.5 gm	Planchet	3 hours	PIP	0.1	NA
Water						(pCi/L)	(pCi/L)
Ra-226	α Spec	50 ml	Planchet	3 hours	PIP	1.0	NA
Ra-228	α Spec	50 ml	Planchet	3 hours	PIP	0.3	NA
Th-227	α Spec	50 ml	Planchet	3 hours	PIP	0.3	NA
Th-228	α Spec	50 ml	Planchet	3 hours	PIP	0.3	NA
Th-230	α Spec	50 ml	Planchet	3 hours	PIP	0.3	NA
Th-232	α Spec	50 ml	Planchet	3 hours	PIP	0.3	NA
U-234	α Spec	50 ml	Planchet	3 hours	PIP	0.3	NA
U-235	α Spec	50 ml	Planchet	3 hours	PIP	1.0	NA
U-238	α Spec	50 ml	Planchet	3 hours	PIP	0.3	NA

- 1) The detector types are designated as HPGe and PIP. HPGe refers to an intrinsic germanium detector having an efficiency of 35%-40% for gamma spectroscopy and PIP refers to ion implanted silicon wafer for alpha spectral analysis.
- 2) MDC determined from an analysis of a "clean" sample matrix with count time and sample mass as specified in the table.
- 3) MDC determined from 1gram soil sample.

When analyzing a specific sample, the HISS laboratory calculates an MDC for each gamma or alpha line identified in the sample spectrum that is included in the instrument library. The calculation is completed using equation Eq.7. Parameters specific to the sample being analyzed are input into the computer program as the sample count is begun. These parameters are used to determine the actual MDC for each nuclide for this particular sample. Typically, when a sample has several radioactive components, the reported MDC will be greater than the MDC's shown in Table 1 for the same sample size and counting time.

QUANTIFYING Pa-231 AND Ac-227

Protactinium-231 and Actinium-227 are both part of the natural radioactive decay chain of Uranium-235. Pa-231 decays to Ac-227 by the emission of alpha particles. Ac-227 subsequently decays primarily by beta particle emission to Thorium-227. Both decays are followed by gamma ray emission.

In natural ores from which uranium has never been extracted, all the daughter nuclides of U-235, which include Pa-231 and Ac-227, are in secular equilibrium and all the radionuclides decay at the same rate as the parent U-235 (adjusted for branching decay). In other words, if U-235 is present in a virgin sample at 5 pCi/gm, Pa-231 and Ac-227, being part of the decay chain, are also present at 5 pCi/gm. With the assumption that this natural equilibrium has never been disturbed or broken, one can make a measurement of any one of these radionuclides and quantify the others from the measurement. This is a common technique for the identification and quantification of radioisotopes that decay by beta transition or have very low or no gamma rays associated with them and that are in secular equilibrium with those that have available gamma-rays easier to measure.

Once the equilibrium has been broken by chemical separation of the uranium from the ore, the ability to assume equality of isotopic decay rates for radionuclides in the decay chain disappears. Until equilibrium is reestablished between easy to measure isotopes and those more difficult, quantification can only be accomplished by direct measurement of the isotope of interest.

Ac-227 is one of those isotopes not easily measured by direct methods since it decays primarily by beta emission and has very low abundance gamma rays. It is generally measured from the 236 keV gamma-ray decay of its daughter, Th-227. Equilibrium can be assumed between Ac-227 and Th-227 after about 6 months of decay so quantification based on Th-227 would be valid. Pa-231 has a very long half-life and can be quantified directly from one of several low abundance gamma rays following its alpha decay.

Typically, the average anticipated background for naturally occurring levels of Pa-231 and Ac-227 in soil is approximately 0.05 pCi/gm. Reaching this detection level in a production laboratory using gamma-ray spectroscopy would require an unreasonable amount of analysis time. A value of 1.0 pCi/gm for Pa-231 or Ac-227 in soil samples has been chosen as a reasonable MDC and is achievable with 2 – 4 hours of sample preparation time, a one hour gamma-ray count, and the assumption of secular equilibrium between Pa-231 and Ac-227.

USACE requirements pertaining to liquid effluent concentration limits for radionuclides are delineated in ER 385-1-80 ⁽⁶⁾, Section 17 b. which reference U.S. Nuclear Regulatory Commission regulation 10 CFR Part 20 ⁽⁷⁾. The liquid effluent concentration limits for Pa-231 and Ac-227 contained in 10 CFR 20, Appendix B, Table 2, Column 2 are 6 pCi/L and 5 pCi/L, respectively. Therefore, based on: (1) the effluent concentration limits referenced by USACE regulations, and (2) this technical evaluation of the best available technology (BAT) for determination of the concentration of Pa-231 and Ac-227 in water, the MDC for each radionuclide should not be set below 5 pCi/L. Review of the BAT for determination of the concentration of Pa-231 and Ac-227 in water indicates the difficulty in reaching this MDC (i.e., 5 pCi/L).

Generally, radioactive elements are more concentrated in soil samples than in liquids. The soils act like an ion exchange media absorbing and concentrating the radioactive metal ions. Assume two environmental samples are being analyzed for Ac-227 by gamma-ray spectroscopy; one is a 650 gram soil sample and the other is a one liter water sample. Each sample has a count rate of 1.0 count per minute. If all other factors in equation Eq. 7 are the same for both cases, the calculated concentration of the soil sample is 1.1 pCi/gm for a 10 minute count while the water sample calculation would yield 701 pCi/L for the same 10 minutes. If the gamma-ray counting time is increased to 300 minutes for each sample, the soil will report 0.17 pCi/gm while the water will yield 111 pCi/L. Figure 2 illustrates how the MDC for Ac-227 decreases with increasing gamma-ray counting time. As can be seen, the MDC will quickly reach a point of diminishing returns as count time increases and may never reach a particular desired MDC.

An alternative method to gamma-ray spectroscopy is alpha spectroscopy. This method involves the separation of the isotopes of interest from the bulk of the sample matrix (soil or water) and subsequent counting of the alpha particles emitted from the separated sample. The advantage of this method is that alpha spectroscopy has little or no interference to create spectral background and, therefore, can generally achieve lower detection levels. The disadvantage is that the method is destructive and requires substantial chemical preparation of the sample prior to counting.

The HISS laboratory currently performs isotopic thorium separations and analyses. This method utilizes a potassium fluoride fusion digestion of the sample followed by a barium fluoride co-precipitation of the thorium prior to alpha counting. Th-229 is introduced in this process as a radiochemical tracer to determine percent chemical recovery (yield) of the thorium. The average recovery of thorium in the HISS lab is 87.5%.

The HISS laboratory is currently developing methodologies using Th-227 for determining Pa-231 and Ac-227 concentrations in aquatic media that would meet the desired 5 pCi/L MDC. This methodology relies on previous process knowledge that provides a reasonable and sound basis for assuming secular equilibrium between Pa-231, Ac-227 and Th-227 at the FUSRAP sites.

Based on this knowledge, it is reasonable that thorium could be separated from the sample, the Th-227 counted, and the Pa-231 and Ac-227 activities inferred from the Th-227 count. However, the difficulty with this methodology is that the standard process that uses Th-229 as the tracer would interfere with the Th-227 alpha spectrum preventing quantification. A resolution to this problem would be to determine chemical

recovery from the addition of Th-230 to a control sample; the chemical recovery of Th-230 would then be applied to the whole batch of Th-227 analyses. Acceptance of the yield value would be based on the value being in the laboratory's historical recovery range, and that the duplicate, blank and matrix spike pass the QC requirements.

The detection limit for Th-227, Pa-231, and Ac-227 would be typical of the levels currently being posted by the HISS lab; 0.1 pCi/gm in soils and 0.3 pCi/L in water. These limits can be achieved with approximately 4 – 6 hours of preparation time and 3 hours of counting time. Although chemical recoveries for radiochemical analyses are usually determined on a sample by sample basis, the method of using a single surrogate recovery sample (Th-229) has precedent and is used routinely in the analysis of environmental samples for organic compounds.

Acceptance of this proposed methodology relies on acceptance of the following assumptions: (1) that chemical and secular equilibrium between Pa-231, Ac-227 and Th-227 exists because the residues at this site are those from ores from which uranium was extracted and the daughter products (i.e., Pa-231, Ac-227, and Th-227) remained in the waste, and (2) that the percent chemical recovery of Th-230 from the control sample is the same as the percent thorium recovery from the samples in the batch. Although this proposed methodology for determining Pa-231 and Ac-227 concentrations in aquatic media by alpha spectroscopy is still under development, it offers the best opportunity for achieving the desired MDC of 5 pCi/L.

CONCLUSION

The LLD should be viewed as an estimate of the detection capability for an instrument. Its value is dependent only on the detection characteristics of the instrument (such as the efficiency) and the uncertainty in the background of the detector. The LLD is the truest estimate of the detector's capability with the assumption that only one spectral line is being measured with no other interference.

The MDC should be viewed as an estimated level of activity that is achievable with a specific instrument, measurement method and type of sample. Its value is dependent on the characteristics and conditions of the measurement system as well as the sample characteristics. A typical MDC can be calculated for any radionuclide from typical sample characteristics that are usually those of the standard from which the detector is calibrated.

The MDC for a specific radionuclide may vary from one sample to the next depending on the characteristics of the sample (i.e. weight or volume different from the standard, additional or different radionuclides in the sample contributing to an enhanced Compton background, etc.). It, therefore, must be recognized that an MDC established for one set of conditions may not be applicable to all other conditions.

It has been shown, that the calculated MDC, for any given sample, depends on several variables that can be controlled, to some extent, by the laboratory.

(1) The mass or volume of the sample can be increased to increase the number of radioactive atoms being presented to the detector. But if the amount of material being counted becomes too large, self-shielding of the gamma or alpha particles by the sample

material or residual deposit, negates the increased activity by reducing the counting efficiency of the system. In addition, calibration sources must be prepared to simulate the sample characteristics. For gamma counting, Marinelli beakers are used to surround the detector with sample, effectively increasing the sample surface area available to the detector. For alpha measurements, the HISS lab has optimized the sample size for the separation methods which provides good chemical recoveries.

(2) The time a sample is counted will affect the calculated MDC. However, as shown in Figure 1 of time vs. MDC, increasing the count time will not necessarily achieve the desired decrease in MDC. The HISS lab is using counting times that provides the necessary MDC's for the majority of samples in a reasonable counting period. For certain cases, extended count times can be utilized to obtain lower MDC's, but the limiting nature of this avenue should be recognized.

For gamma spectroscopy, sample mass (or volume) and count time are the only two parameters that can be adjusted to decrease the MDC. The other variables in the MDC equation are either physical constants or constants of calibration. For alpha spectroscopy, the chemical yields for the HISS laboratory run between 85% and 100%. This leaves little room for significant improvement in reducing the MDC through better chemical yields.

The analytical results reported from the HISS laboratory are comparable in magnitude and quality to those of Quanterra's St. Louis commercial laboratory. Measurement of Pa-231 and Ac-227 to an average background level of 0.05 pCi/gm in soil and aquatic media is not feasible for a production laboratory responsible for reporting many other analytical results and is unreasonable due to the amount of detector time needed to analyze the samples. The MDC capabilities at the HISS laboratory for Pa-231 and Ac-227 assuming reasonable sample preparation/count times and BAT are 1.0 pCi/g for soil and much greater than 5 pCi/L for aquatic media using gamma spectroscopy. Development of new site-specific methodologies for determining Pa-231 and Ac-227 by alpha spectroscopy would lower the MDC for aquatic media to below 5 pCi/L.

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FIGURE 1. MDC vs. Count Time

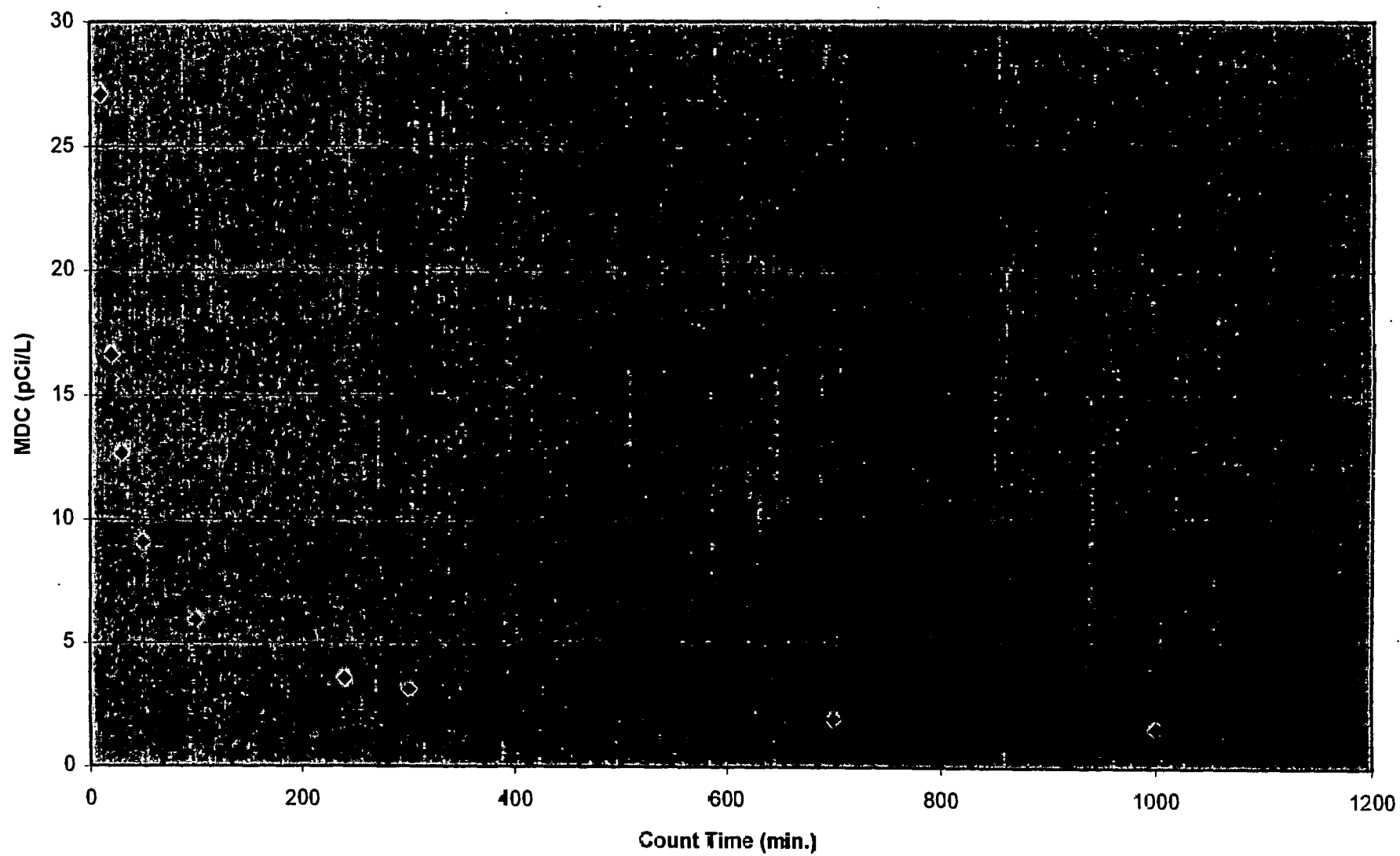
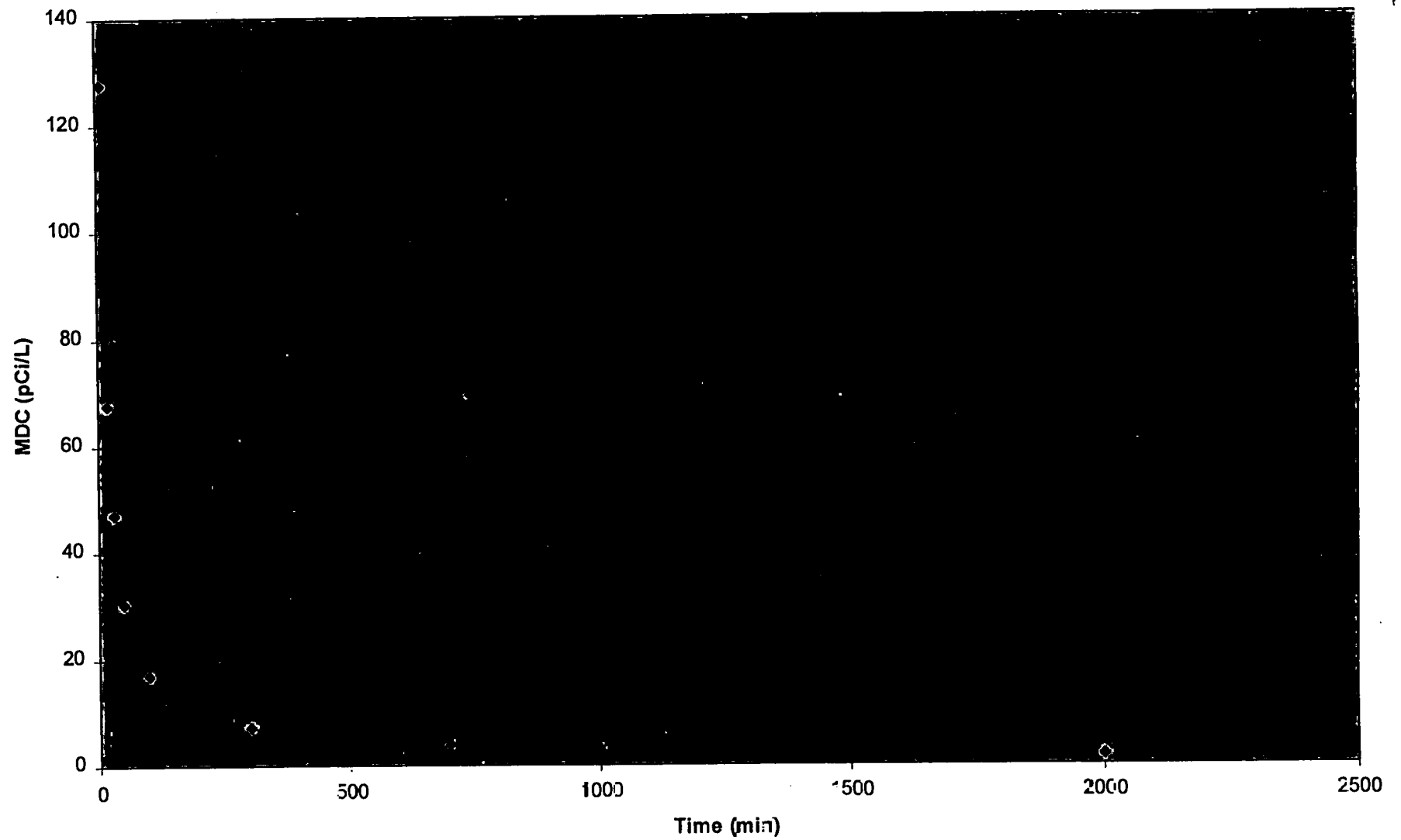


FIGURE 2 MDC vs. Time for Ac-227



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X. Associated with Document(s): _____