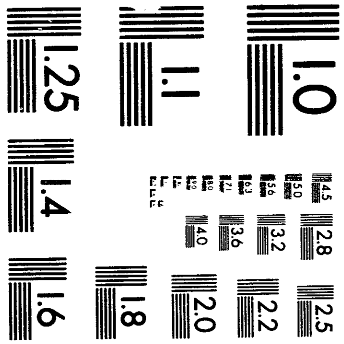

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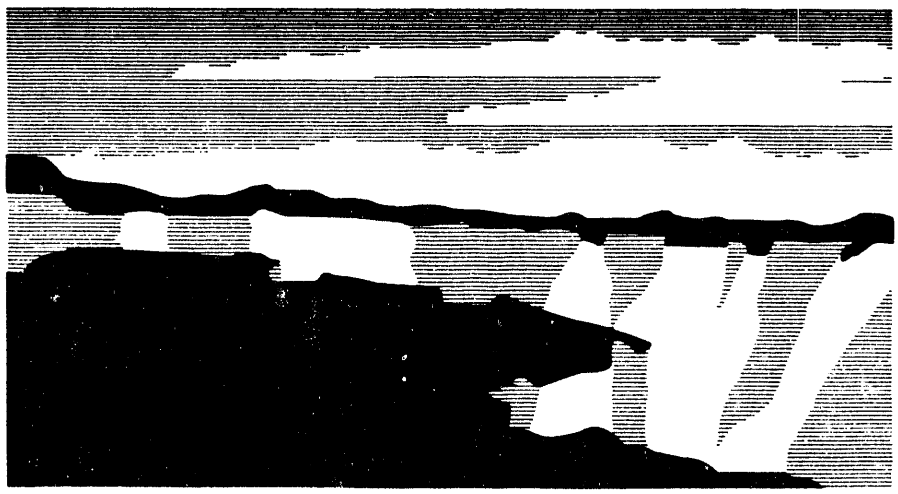

Los Alamos
NATIONAL LABORATORY

APPLICATIONS OF THE LONG-RANGE ALPHA DETECTOR (LRAD) TECHNOLOGY TO LOW-LEVEL RADIOACTIVE WASTE MANAGEMENT

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ABSTRACT

Long-Range Alpha Detector (LRAD) systems are designed to monitor alpha contamination by measuring the number of ions in the air. Alpha particles are a form of ionizing radiation and a typical 5-MeV alpha particle will create about 150,000 ion pairs in air. Field tests at various DOE sites have shown that LRAD Surface Soil Monitors (SSM), Sample Monitors, and Object Monitors are faster and more sensitive than traditional alpha detectors for measuring alpha contamination. This paper will discuss the various applications of LRAD technology to low-level radioactive waste management.

INTRODUCTION

As government regulations regarding the storage and handling of low-level waste become increasingly stringent, it has become apparent that traditional alpha detectors lack the sensitivity, speed, and accuracy to meet these new regulatory goals. LRAD detectors, however, are able to measure very low levels of alpha contamination, as low as 5 pCi/g in some practical applications. Traditional alpha detectors are designed to detect alpha particles directly and must be passed slowly within 3 cm of an alpha source to operate effectively. However, because LRAD detectors collect the ions created from alpha interactions with air, they are better able to monitor equipment and complex surfaces and can be operated at a much greater distance from an alpha source than traditional alpha detectors. Furthermore, because LRAD detectors remain stationary during monitoring, they tend to be more accurate and have a much faster response time than traditional alpha detectors. The LRAD Surface Soil Monitor and the LRAD Sample Monitor have been used to characterize radioactive contamination at LANL (Los Alamos National Laboratory), Fernald and Grand Junction. Besides being highly effective for site and waste characterization, LRAD object monitors are able to measure contamination in confined areas that are not easily measured by traditional alpha detectors, and they can often do so without directly exposing humans to potentially hazardous and radioactive waste. Various LRAD object monitors have been successfully demonstrated at LANL, Savannah River and Rocky Flats.[1-6]

SURFACE SOIL MONITOR DESIGN

The basic design for the LRAD Surface Soil Monitor (SSM), shown in Fig. 1, includes a grounded enclosure and a high-voltage guard plane and signal plane. The geometry of this detector is such that all of the alphas from the ground stop before reaching the signal plane, and ions of one polarity are collected on the signal plane. The alpha contamination can then be calculated by directly scaling the measured current from the signal plane. An electrometer sensitive to the femtoamp (10^{-15} A) level is used to measure the current from the signal plane, and the guard and signal planes are kept at 300 V with a dc battery. The effect of the guard plane is to help control leakage current and, therefore, improve the sensitivity of the detector.

The normal operating procedure for using an LRAD SSM is to place the detector directly on soil to be monitored. The detector and soil form a closed box that is grounded. Three different sized detectors have been used for monitoring soil surface contamination. Tests have shown that the response time, or time required to make a statistically significant measurement, scales as the volume of the detector being used. The source strength per unit area that can be detected seems to be fairly consistent for all three detectors.

Fig. 1. Schematic view of the LRAD Surface Soil Monitor.

The current response of an LRAD detector is a linear function of the activity of the sample being monitored, it is therefore possible to cross-calibrate an LRAD to sources of known activity. As an example, Fig. 2 shows the on-line detector response (fA) for ^{239}Pu sources ranging from 100 to 1100 dpm (disintegrations per minute). The electrostatic LRAD design generally measures 6 dpm/fA.

Fig. 2. Source response calibration using Pu-239 sources for the LRAD Sample Soil Monitor.

RESULTS OF RECENT LRAD TESTS

A series of tests was carried out at LANL to determine the effects of beta contamination on typical LRAD measurements. For these tests the Large SSM (1-m^2 footprint) and Small SSM (0.25-m^2 footprint) were used to measure soil contamination and source strength for alpha and beta emitters. The soil contained only natural background levels of contamination. The alpha emitter used was a 240,000-dpm ^{238}Pu source and the beta emitter used was a 300,000-dpm ^{198}Au source. The measured signals minus backgrounds for the Large SSM were 35,924 fA for the ^{238}Pu, 592 fA for the ^{198}Au, and 697 fA for the soil. The Small SSM tests included both soil on a tray and outdoor soil *in situ*. The measured signals minus backgrounds for the Small SSM were 35,832 fA for the

^{238}Pu, 341 fA for the ^{198}Au , 271 fA for the soil on the tray, and 959 fA for the outdoor soil. Measurements were first made with these three sources (^{238}Pu, ^{198}Au, and soil) alone, then various layers of Mylar were added to cover each source. The sheets of Mylar were 0.25 mils thick, coated with 400 Å of aluminum on each side.

The results for the Large SSM are shown in Fig. 3, and the results for the Small SSM are shown in Fig. 4. These results are given in terms of % signal, normalized to (S1-Bkg) for each source, where S1 is the signal of the source measured with no Mylar. By plotting the results, which varied greatly in terms of absolute current measured, in terms of % signal, it can be shown that the layers of Mylar attenuated the alpha particles significantly while having little effect on the beta particles. The results of these Mylar tests indicate that the signal from the soil is consistent with that of an alpha source, rather than a beta source. This can be seen in Figs. 3 and 4, where the additional layers of Mylar caused the % signal to fall off at roughly the same rate for the alpha source as the soil.

Both the alpha and beta emitters had roughly the same source strength in terms of disnintegrations per minute; however, the alpha source was detected much more strongly than the beta source. This is to be expected from the range and energy of alphas vs those of betas. The LRAD SSM is capable of measuring both alpha and beta contamination; however, the relative contribution of each will depend upon the particular source being measured. The error bars in these tests were typically 5% or less, except for the outdoor soil, where they were 5-10%. These tests have shown that the electrostatic LRAD design is sensitive to both alpha and beta contamination in field measurements of soil. However, the alpha contamination levels are such that they overwhelm the beta readings for typical soil.

Fig. 3. Results of the Mylar tests using the Large SSM. By normalizing each sample to the measurement which has no Mylar, the results are plotted in terms of % Signal from 0 to 100 percent.

Fig. 4. Results of the Mylar tests using the Small SSM. By normalizing each sample to the measurement which has no Mylar, the results are plotted in terms of % Signal from 0 to 100 percent.

SOIL MOISTURE TESTS

To better model field conditions where wet soil is involved and to get a better idea of the sensitivity of the LRAD Surface Soil Monitors, soil moisture levels have been measured at LANL. Ordinary soil taken from outdoors was heat dried and used as the 0% moisture sample. Water was added, and the sample was weighed to determine its percent water content. The LRAD Hand-held SSM was used for this test, and the results can be extended to show that the LRAD electrostatic monitor design can accurately measure soil with >20% water content. This level of moisture was beyond the saturation point for the sample of soil used. These results tend to indicate that an LRAD electrostatic monitor design will be able to monitor soil contamination levels under most reasonable field conditions. The results of these tests are shown in Figs. 5 and 6, where the error bars were typically 5-10%. The fluctuations in the data increased as the water content increased, indicating that the time required to assay soil with a higher water content would increase as well.

Fig. 5. Background levels (with no sample) and soil measurements are shown for soil moisture tests using the Hand-held SSM. The water content is given as a percent of the total weight of the sample.

Fig. 6. Results of the water content measurements shown in terms of % Signal. A straight line curve-fit with $R^2 = 0.920$ has been made to show the tendencyof the signal to drop off as mroe water is added to the soil.

SAMPLE MONITOR DESIGN

The basic design for the LRAD Sample Monitor is shown in Fig. 7. The LRAD Sample Monitor is basically the same design as the LRAD SSM, except that the detector is enclosed on all sides. A door can be opened so that a sample can be inserted on a tray. Fig. 8 shows the LRAD Sample Monitor, electrometer, and data acquisition system. The LRAD Sample Monitor has been demonstrated at LANL and at the Fernald Environmental Management Project (FEMP) site.

Fig. 7. The LRAD Soil Sample Monitor.

Fig. 8. The LRAD Sample Monitor, electrometer, and data acquisition system.

PRELIMINARY RESULTS FROM LABORATORY TESTS AT FERNALD

On August 30 and 31, 1993, the LRAD Conveyor-Belt Soil Surface Monitor prototype was demonstrated at Fernald. A total of nine samples was taken and monitored by the LRAD detector. These samples came from the soil-washing pilot plant at Fernald. Each sample (except for sample 1, which used stainless-steel cups) was spread out on a stainless-steel sample tray, to a diameter of 21.5 cm, and monitored several times (shown in Table 1 as Measurement A-C). Each sample was also monitored in two different geometric configurations, to establish the need for a consistent geometry when operating in conjunction with a conveyor belt. The preliminary results, taken from on-line measurements, are given in Table 1. The activity for each sample is stated in dpm/100 cm^2, and was calibrated to known plutonium sources, which were provided by Fernald.

Table 1. Preliminary Data from Soil Measurements at Fernald.				
Sample No.	Total Activity (dpm/100 cm²)			
	Measurement A	Measurement B	Measurement C	New Geometry
Sample #1(*) EM#93-432-7506	31.40 ± 98.06	56.62 ± 109.51	66.89 ± 103.25	113.72 ± 98 02
Sample #2 EM#93-432-7515	35.24 ± 24.34	35.50 ± 31.00	41.75 ± 28.64	36.72 ± 19 93
Sample #3 EM93-432-7507	43.13 ± 19.16	49.20 ± 21.66	64.49 ± 20.20	32.45 ± 16.38
Sample #4 EM#93-432-7484	30.88 ± 16.66	27.65 ± 18.86	33.86 ± 17.32	30.00 ± 17.95
Sample #5 EM#93-432-7501	183.96 ± 24.23	181.36 ± 28.86	184.79 ± 26.55	129.37 ± 19.04
Sample #6 EM#93-432-7287	61.12 ± 26.19	60.85 ± 24.47	71.24 ± 24.30	55.23 ± 23.25
Sample #6 redo EM#93-432-7287	72.12 ± 22.14	66.95 ± 25.65	57.42 ± 22.16	—
Sample #7 EM#93-432-7288	22.21 ± 18.48	20.55 ± 19.78	28.06 ± 18.76	24.47 ± 18.31
Sample #8 EM#93-432-7586	56.24 ± 22.26	67.98 ± 28.42	68.94 ± 22.45	83.46 ± 24.71
Sample #9 EM#93-432-7585	21.10 ± 21.35	18.61 ± 22.47	19.21 ± 20.14	17.50 ± 17.74

(* surface area of sample #1 was ~1/5 that of the other samples)

These results can be interpreted to suggest several things about the LRAD Conveyor-Belt Soil Surface Monitor prototype. First, the results seem to have been reproducible, within the errors of the measurements. Also, the standard deviation of sample #1 is much higher than the activity read, because the sample surface area was much less than for the other samples. The detector can achieve a much higher confidence on a larger sample surface area, for the same measurement time. It can also be noted that samples with higher activity levels (not as close to background) can achieve a higher confidence level with a shorter measurement time. In general, these measurements had plateaued within 30 s of being placed in the detector. A more thorough analysis is necessary to determine the actual time it took each sample measurement to reach a 95% confidence level of being above the regulatory goals of 5, 15, or 35 pCi/g. When the Fernald laboratory analysis has been received, a comparison can be made, and it will be possible to convert these results into pCi/g and ppm of contaminant. Because longer measurements can significantly reduce the error in sample measurement, this demonstration has additionally shown that the LRAD detector is a very sensitive sample monitor for assaying samples within the laboratory.

SAMPLE MONITOR RESULTS FROM LANL MONITORING

The LRAD Sample Monitor was also used at the PHERMEX site at LANL. This site is a blasting area where depleted uranium is used. Soil samples were taken at six locations, both at the soil surface and at various depths in a trench that had been made for the placement of additional equipment at some future date. These samples were stored in standard plastic airtight containers (~2 L), and labeled. It was possible to monitor 12 samples in a half-day period. These samples were all at a relatively low activity level, except for a surface sample that contained a couple large pieces of D(38) ("yellow-cake") (sample R). The results from these measurements are listed in Table 2.

OTHER LRAD APPLICATIONS TO LOW-LEVEL WASTE MANAGEMENT

Some extensions of the LRAD Sample Monitor design that are currently in the conceptual phase at LANL include a conveyor-belt-based LRAD, a solid waste monitor, and a liquid waste stream monitor. The LRAD Sample Monitor is actually a prototype of a conveyor-belt-based LRAD system that was being developed for the Fernald USID.

Table 2. Resutls of samples atthe PHERMEX Site			
Sample Location	Sample Depth (feet)	dpm/100 cm^2	std deviation
D-1	0	154.21	12.92
E-1	0	102.57	11.19
F-1	0	164.22	10.70
R	0	6477.85	53.50
S	0	145.75	9.01
S	1	135.46	13.16
S	2	140.00	13.99
S	3	176.04	15.82
S	4	158.79	21.02
T	0	99.13	13.36
T	2	90.19	13.47
T	4	178.32	20.80

The LRAD is not only well suited for real-time site characterization or laboratory assays, but it is also ideal for waste monitoring. The results of the tests presented in this paper show that the LRAD Sample Monitor has the ability to detect very low levels of alpha contamination for various soil conditions. The results from these tests can be easily extended to other forms or sources of radioactive contamination. The LRAD SSM can be used to monitor any surface on which it can form an air seal. The LRAD Sample Monitor can be used, as it is currently designed, to monitor waste before disposal; and with slight modifications, it may be useful for real-time monitoring of other forms of solid and liquid waste.

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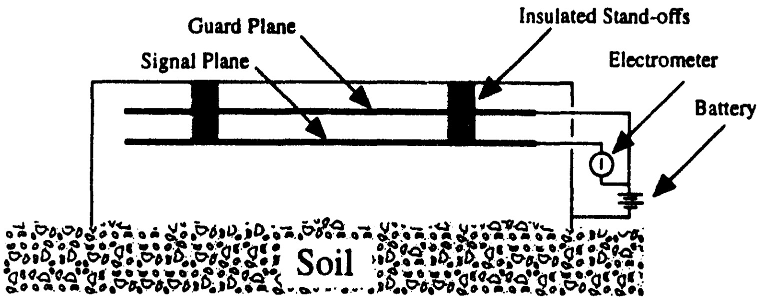
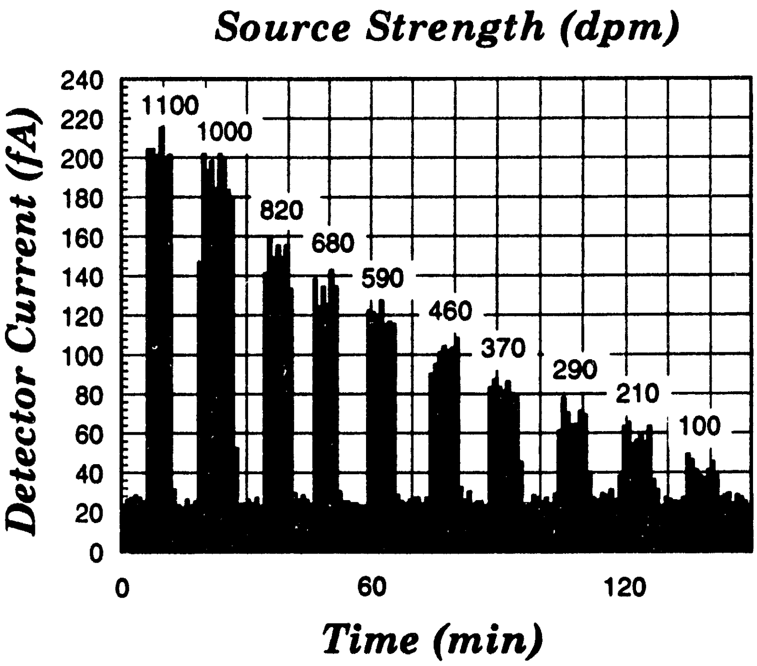
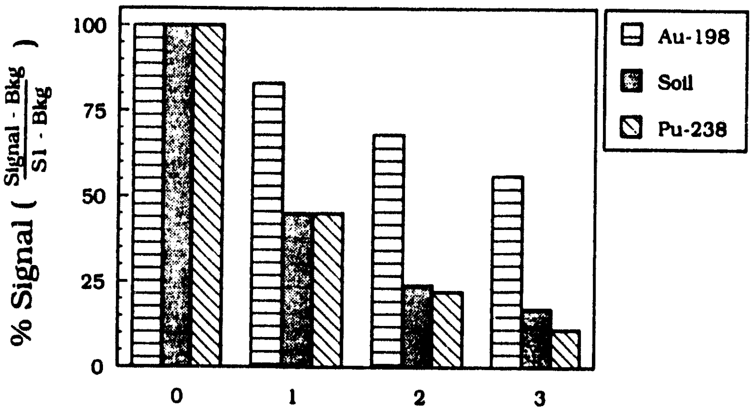
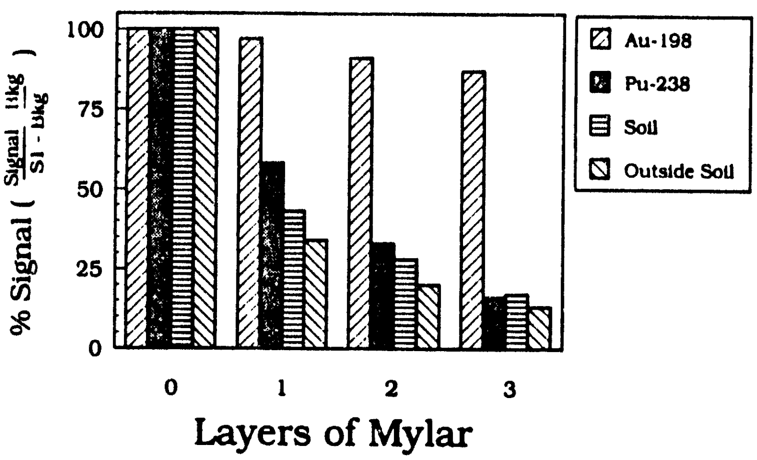

Guard Plane
Signal Plane
Insulated Stand-offs
Electrometer
Battery
Soil

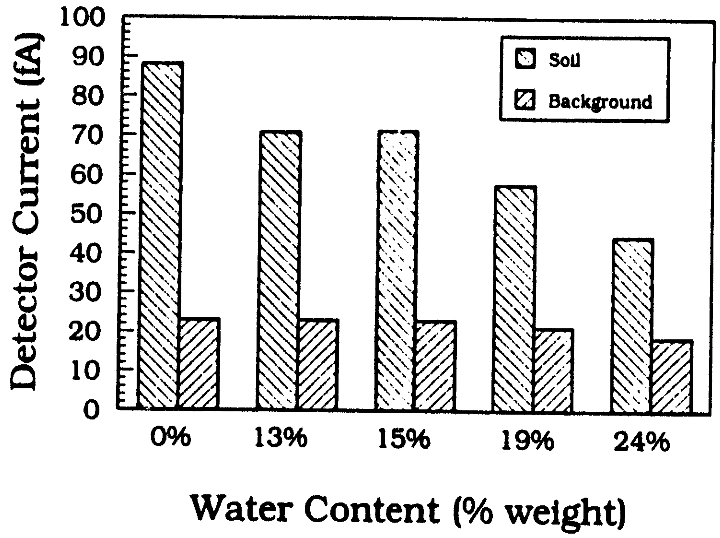


Source Strength (dpm)
Detector Current (fA)
240
220
200
180
160
140
120
100
80
60
40
20
0
1100
1000
820
680
590
460
370
290
210
100
0
60
120
Time (min)

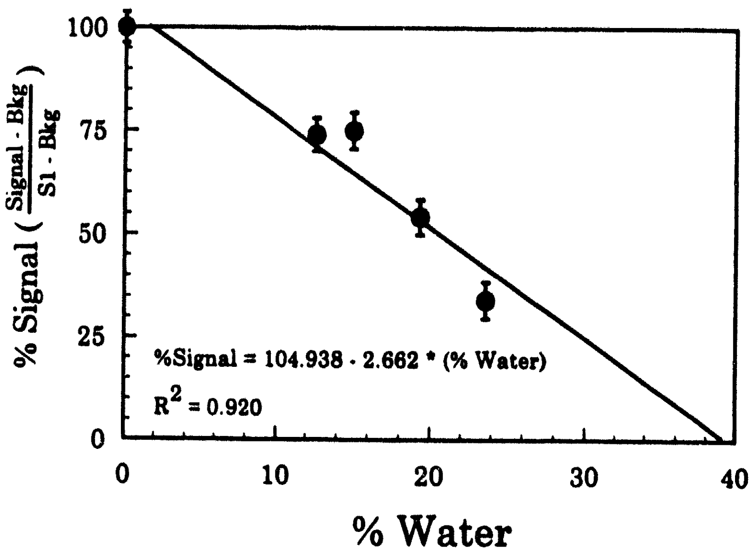


Layers of Mylar

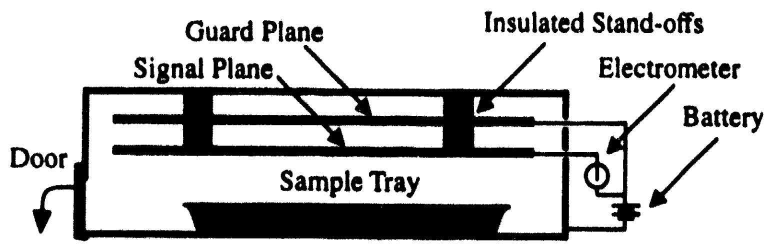

% Signal
100
75
50
25
0
0
1
2
3
Layers of Mylar
Au-198
Pu-238
Soil
Outside Soil



Detector Current (fA)
100
90
80
70
60
50
40
30
20
10
0
Soil
Background
0%
13%
15%
19%
24%
Water Content (% weight)



100
75
50
25
0
0
10
20
30
40
% Signal (Signal - Bkg / S1 - Bkg)
%Signal = 104.938 - 2.662 * (% Water)
R^2 = 0.920
% Water


Guard Plane
Insulated Stand-offs
Signal Plane
Electrometer
Battery
Door
Sample Tray