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Activities: Monitoring Concrete Surfaces*

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*Alpha Contamination Assessment for D&D Activities:
Monitoring Concrete Surfaces*

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ALPHA CONTAMINATION ASSESSMENT FOR D&D ACTIVITIES: MONITORING CONCRETE SURFACES

by

M. W. Rawool-Sullivan, J. G. Conaway, and D. W. MacArthur

ABSTRACT

The process of decontaminating and decommissioning former nuclear facilities sometimes requires that large areas of concrete and other materials be scanned to verify they are not contaminated. A specially developed concrete surface monitor (CSM) can greatly expedite that process. The CSM is basically an aluminum box, open on the bottom, that uses an electrostatic field to transport ions created by alpha particles interacting with ambient air to a collection grid or plate. A sensitive electrometer measures the resulting current, which is essentially proportional to surface alpha activity. The initial prototype CSM surveys a surface area of some 300 cm² at one time, while a second-generation prototype surveys 2500 cm² and is designed to compensate automatically for radon, which can cause substantial errors in estimating surface contamination in some cases. These monitors have been successfully demonstrated on a number of concrete surfaces in situ as well as on concrete pieces cut from former facilities.

MONITORING CONCRETE SURFACES

Ongoing work at sites undergoing decontamination and decommissioning (D&D) requires extensive characterization of radioactive contaminants before and after decontamination. Many D&D sites have large concrete surfaces that must be scanned for alpha-emitting contaminants, but conventional detectors are insensitive, slow, and easily damaged. To help address those problems, we designed a concrete surface monitor (CSM) based on electrostatic Long-Range Alpha Detector (LRAD) technology. An overview of LRAD technology is given elsewhere,¹ and a description of LRAD surface monitors for investigating soil surfaces has been given in several earlier reports.^{2,3} This CSM has been tested under laboratory conditions and field tested at a D&D site at Los Alamos National Laboratory. The CSM is sensitive, rugged, and is much faster than conventional alpha-scanning instruments when contamination of large surfaces is being assessed.

Concrete Surface Monitor design

The CSM uses an electrostatic field to transport the ions, created by alpha particles interacting with ambient air, to a collection grid or plate. The signal and guarded stand-offs are held at 300 V; this voltage provides the necessary potential to ensure efficient ion collection. A sensitive electrometer measures the resulting current and relays the data to a data acquisition system (Fig. 1).

Figure 1. Conceptual drawing of LRAD electrostatic surface monitor.

The prototype CSM surveys a surface area of some 300 cm² at once; instruments capable of assessing much larger areas in a single reading can also be built. Once the detector is positioned on the surface, an accurate reading can be acquired in a minute or two. Because the CSM was built for surveying relatively small areas on concrete block edges, it was designed with an active volume of 27 cm x 11 cm x 10 cm, yielding a 300 cm² detection surface (Fig. 2). An adjustable clamp may be used to station the detector on surfaces at various angles.

Figure 2. A CSM with a 300 cm² detection surface used to assess edges of cut concrete blocks.

Radon compensation

The simple prototype CSM described above was subject to large background errors due to the presence of radon and other effects. A second-generation CSM has now been built and tested

that incorporates background compensation. In this detector (Fig. 3) the alpha particles emitted from contaminated surfaces produce ions only in the lower chamber, giving a signal only on the first signal plane. Radon enters both chambers freely; to ensure uniform mixing of radon gas in both chambers, a small fan is located between the chambers.⁴ The radon decays essentially equally in both chambers, resulting in an equal contribution to signals from both signal planes, thereby allowing an effective background compensation.

The background-compensated CSM has a 2500 cm² detection surface, allowing measurements over larger surfaces with a single reading. Again, the response time for this CSM is a minute or two per reading depending on the level of alpha contamination.

Figure 3. Schematic diagram of the prototype background-compensated CSM.

System calibration

Prior to field experimentation, the first-generation (uncompensated) prototype CSM detectors were calibrated using ²³⁹Pu sources ranging in strength from 100 to 5620 dpm. A representative calibration curve for one CSM is shown in Fig. 4. The calibration for this detector was 7.1 dpm/fA; for various CSMs the calibration factor ranged from 5.5 to 7.1 dpm/fA. A later, more detailed set of laboratory experiments and calibrations extended our understanding of the system response over five decades of source activity (Fig. 5).

Figure 4. A CSM calibration curve using calibrated ^{239}Pu sources, yielding a calibration factor of 7.1 dpm/mV.

Characterization of concrete pieces

We used the first-generation (uncompensated) prototype CSM to measure the residual alpha contamination on concrete pieces cut from concrete-lined trenches at Technical Area 21 (TA-21) at Los Alamos National Laboratory (a Technical Area is a site typically consisting of one or more buildings and other facilities).

The block surfaces had varying degrees of roughness and irregularity and the blocks were situated at various angles, so a clamp attachment was sometimes used to secure the detector and create an adequate seal between the concrete surface and the detector volume. For background measurements, an uncontaminated aluminum plate was measured using the same procedure; use of the aluminum plate against the detector prevents penetration of alpha radiation from the concrete or ground into the detector. This procedure gives an instrumental background measurement including any leakage current, electronic noise, and leakage of outside air and radon into the monitor due to an imperfect seal, along with some beta and gamma radiation penetrating the walls of the detector, but does not measure any naturally occurring alpha emissions from the ground.

Figure 5. Response of the prototype CSM for source strengths of 10^1 to 10^6 dpm.

Concrete blocks results

Ten readings were made at various locations on three different concrete blocks (Table 1). Readings were also made at various locations around the city of Los Alamos, including apartment complexes, sidewalks, public buildings, and so forth. These values ranged from 62 to 93 dpm/100 cm². In all cases, the measured reading had the instrumental background subtracted from it. The measurement error was ± 20 dpm/100 cm². Even uncontaminated concrete contains radioactive materials, such as naturally-occurring uranium and thorium, and these readings may be showing variations in the inherent activity of the concrete.

Table 1. Results from field experiments on contaminated concrete blocks at TA-21 D&D site, and the Los Alamos town sites.

Block number	Sample number	Reading (dpm/100 cm ²)
1	1	854
1	2	467
1	3	467
2	1	777
2	2	933
2	3	621
3	1	621
3	2	700
3	3	700
3	4	210

Utility pad and concrete floors

Both the background-compensated and uncompensated hand-held prototype CSMs were used to measure the residual alpha contamination on the floors of Building 146 and the surrounding concrete pads at the TA-21 site. A comparison of detection surface area and detection volume for the two surface monitors used in these tests is given in Table 2.

Table 2. Detection surface area and volume comparison for the two surface monitors used in these tests. Each detector is basically an aluminum box with an open bottom that is placed against the surface to be surveyed.

Detector Type	Active Detection Volume	Detection Surface Area
Hand-held CSM	27 cm x 53 cm x 10 cm	1431 cm ²
Background-subtracting surface monitor:	50 cm x 50 cm x 10 cm	2500 cm ²

The background-compensated CSM was used on the floor in Building 146 because that instrument has the larger detection area. Two instrumental background readings were made on

the aluminum plate as shown in Table 3; this table shows nearly identical results for the upper and lower chamber for each of the two background measurements.

Table 3. Instrumental background readings (with uncertainties in parentheses) made using the dual-chamber background-compensated CSM.

Background measurement number	Current from lower chamber (fA)	Current from upper chamber (fA)
1	-184(8)	-179(9)
2	-122(11)	-121(12)

In the data analysis the current was measured from the top chamber (background reading) and subtracted from the current measured from bottom chamber (signal plus background) to give the background-compensated reading. The background-compensated CSM calibration factor was determined to be 6 dpm/fA. Fig. 6 shows a contour map of the 24 readings taken on the concrete floor.

Figure 6. Contour plot of alpha activity on the concrete floor at TA-21, Building 146. Some regions were inaccessible as shown by the cross-hatched areas.

The utility pad outside Building 146 was spot checked with the hand-held CSM, as were small and hard to reach locations. Instrumental background was checked using the aluminum plate at a regular interval. The collected charge was measured using an Arnone electrometer, developed in-house (Gaetano Arnone, private communication) and a portable oscilloscope. A total of 42

readings were taken at 61 cm between each point of the utility pad. The measured background-compensated activity varied from 0 to 40 dpm/100 cm² for most readings.

Inside the building, most of the activity was in the range from 0 to 50 dpm/100 cm²; three of the readings show higher levels of alpha activity. One reading shows 193 dpm/100 cm²; this reading was made on a large grease spot. Two other locations close to this spot gave readings of 51 dpm/100 cm² and 83 dpm/100 cm². Clearly, the grease spot shows elevated contamination levels, as verified by the site health physicist.

In addition to the measurements made in building 146 at TA-21, the dual-chamber background-compensated CSM was also used to monitor the concrete floor in building 324 at TA-21. Instrumental background was recorded at 62 fA using the procedure described earlier, and a total of 26 readings were taken over an 90 m² area. The result shows activity ranging from 0 to 30 dpm/100 cm².

Conclusions

Using the concrete surface monitors described above, the task of waste minimization and characterization can be accomplished effectively and efficiently. Depending on the size of the area to be characterized, appropriate LRAD-based detectors can accommodate the necessary measurements.

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