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Scott Marquess	EPA	11/14/2001

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VII
901 NORTH 5TH STREET
KANSAS CITY, KANSAS 66101

NOV 14 2001

Mr. Rodger Allison
ATTN: SMAIA-INE (Mr. Rodger Allison)
17571 State Highway 79
Middletown, IA 52638-5000

Dear Mr. Allison:

Enclosed, please find a copy of a report entitled "Detection of Depleted Uranium and Cesium 137 Using the AMS Bell 412 Aerial Survey System and the Kiwi Ground Survey System". This evaluation was prepared by EPA's Technical Support Center in Las Vegas, Nevada at my request. We are providing the report for your information and consideration as the Army and other agencies are considering radiological scoping surveys for the IAAP.

If you would like to discuss the report, please contact me and I will make arrangements with the authors.

Sincerely,

Scott Marquess
Project Manager
Federal Facilities/Special Emphasis Branch
Superfund Division

Enclosure

cc: Sharon Cotner, USACE
Kevin Howe, USACE
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SEP 18 2001

OFFICE OF
RESEARCH AND DEVELOPMENT

MEMORANDUM

SUBJECT: Aerial Radiological Survey - Iowa Army Ammunition Plant S. F. Site

FROM: Ken W. Brown, Director, TSC
Environmental Sciences Division

TO: Scott Marquess, RPM
Region VII

Scott, please find attached the report titled "Detection of Depleted Uranium and Cesium-137 Using the AMS Bell 412 Aerial Survey System and the Kiwi Ground Survey System." This report, dated September 18, 2001, was provided by Tim Ehli a senior LMSG engineer and Doug Akers and Ken Moor senior scientists of INEEL. As you will note, the attached analysis addresses only the technical capability of the systems based on available information, which was somewhat limited. Also, as we discussed, a report generated by the Army was requested but was not received. The TSC would like to obtain, and review, this report if possible.

It appears from the attached assessment that an aerial screening of the 19,000 acre site would provide a cost-effective determination of unattenuated depleted uranium (DU) at the surface. However, the effects of mass attenuation and burial depth may make detection difficult. Following the deployment of an aerial survey the TSC recommends that a ground survey be conducted in areas suspected of containing radioactive materials and/or where radioactive materials were detected during the aerial survey.

I hope the attached will be helpful to you and your co-workers at the subject site. As previously mentioned, the TSC would like to review additional information pertaining to this technology if and when it becomes available. If you require additional explanation of the attached comments and suggestions please give me a call at (702) 798-2270.

Attachment

cc: Bob Mournighan, Region VII

SEP 18 2001

Detection of Depleted Uranium and Cesium 137 Using the AMS Bell 412 Aerial Survey System and the Kiwi Ground Survey System

Summary

An analysis was conducted to assess the theoretical capability of the AMS Bell 412 Aerial Survey System and the Kiwi Ground Survey System to detect depleted uranium (DU) and cesium 137 (^{137}Cs). The capability of these two systems is briefly described in a memo by H. Clark entitled "AMS Performance for an Aerial Radiological Survey of IAAP". This analysis addresses only the technical capability of the systems based on the available information, which is quite limited or nonexistent concerning some aspects of the systems (e.g., detector efficiencies and the analysis methodology). A cost estimate was not developed due to the uncertainties involved.

The performance document for the AMS suggested that the aerial survey system is capable of detecting 15 kilograms (kg) of DU as a Minimum Detectable Activity (MDA). This is for operating conditions that assumed a direct overflight at 50 feet (ft) and that the helicopter is moving parallel to the ground at 60 miles per hour (mph). An initial sensitivity analysis indicated that the three primary parameters affecting the MDA for DU are the helicopter speed, physical geometry of the depleted uranium, and the depth below the surface where the DU was located.

Analysis results for an unattenuated distributed source (10 ft. diameter) of 15 kg of DU indicates that about 9 photons/second would be deposited in the entire detector volume. Detection efficiency will reduce this by some value depending on photomultiplier tube efficiency and other factors. Consequently, the detector would actually see on the order of about 4 counts/second, which would be detectable depending on background, data collection periods, and analysis methodology.

If the source is moved to various distances away from the centerline beneath the detector, reductions in the flux at the detector can be significant and appear to be greater than the reduced quantity indicated in the Clark report. This effect can be compensated for by flying tighter patterns to minimize measurement distances.

A more significant problem is the particle size of the DU (i.e., mass attenuation), which has a significant impact on detection limits. If mass attenuation is included in the analysis (i.e., a 1 kg piece of DU with dimensions of 2.5 x 3 centimeters (cm)) the flux is reduced to 38% of the unattenuated source value. This is not a major impact on the count rate (i.e., 1.5 counts/second); however, if the 15 kg of DU is present as a single piece (5.7 x 9 cm), the flux is significantly reduced to about 0.5 counts/second deposited in the detector. This is a significant reduction in flux and depending on operational parameters (e.g., overflight speed) may not be detectable. As indicated by the above cases, the affect of mass attenuation alone may make the MDA unobtainable. Further information on system performance characteristics is needed to quantitatively assess the MDA.

The other parameter that may significantly affect the MDA is the burial depth of the DU source. For a distributed source, under 1 ft of soil the flux is reduced to 14% of the unattenuated flux (0.6 counts/second) and for 2 ft of soil to 0.7% of the unattenuated value (2.8E-2 counts/second). Both cases would likely make the MDA unobtainable depending on the AMS performance characteristics. Consequently, both the physical geometry and the burial depth can have major impacts on the MDA making the DU undetectable.

The ^{137}Cs analysis of the aerial survey system indicates that about 0.03 millicuries of ^{137}Cs would be detectable, as indicated in the Clark memo. A point or distributed source would produce about 8.5 million electron volts per second (MeV/s) or 13 photons/second over the face of the detector. The detection efficiency is higher for the ^{137}Cs is higher and would result in a nominal detection of about 8.6 photons/s, which is slightly higher than the unattenuated DU source. However, the effect of soil is greater on the ^{137}Cs; 0.5 ft of soil would reduce the response to 40%, 1 ft to 7.5%, and 2 ft to 0.1%. Consequently detection through more than 6 inches of soil is likely not possible depending on the system operating parameters.

The DU analysis of the Kiwi ground survey system indicates that about 50 counts/second would be present for a 1-second residence time over the source. The primary parameters affecting detection would again be the source configuration and depth. However, although the source configuration would have a significant affect on quantification (i.e., it would be difficult to discriminate between a small distributed source and a large particle), it would probably be detectable on the surface. However, depth affects also have a significant affect. In this case it is likely that 1 kg of DU would not be detectable at 2 feet below the ground surface.

Recommendations

To determine if radioactive materials are present outside the buildings within the IAAP boundary, an aerial screening of all areas would provide a cost-effective determination of unattenuated DU at the surface. However the affects of mass attenuation for large particle sources and burial depth make detection and definition of a well-defined MDA difficult. A ground survey should be conducted for the firing range area and for any areas where radioactive materials are detected during the aerial survey. The aerial survey will provide a "quick screen" for the large area (~19,000 acres) and the ground survey will provide a focused evaluation of areas with suspected contamination. However, the aerial survey cannot be considered definitive for buried or large particulate pieces of DU.

A report generated by the Army was requested for this analysis, but was not received. It is recommended that EPA Region 7 request the report to determine the cost of a comprehensive survey and data assessment of the IAAP.

Introduction

The objective of this analysis is to provide an assessment of the minimum detectable quantities of depleted uranium (DU) and cesium 137 (^{137}Cs) for two measurement scenarios: 1) an aerial survey using the AMS Bell 412 system operated at a 50 foot altitude, and 2) a ground survey using the "Kiwi" vehicle-mounted detection system. These scenarios are based on assumptions set forth in the referenced memo[1]. The primary assumptions with the greatest degree of uncertainty are DU and ^{137}Cs particle size and depth of soil over the target materials.

Scenario #1, aerial survey - Detection limit with a helicopter-mounted detector at 50 feet (ft) with a speed of 60 miles per hour (mph). The nominal detection amount is 1 kilogram (kg), which can easily be scaled to greater quantities. The source will be considered as a point source, distributed unattenuated source, and as an attenuated source where mass attenuation is considered. The aerial survey analysis was conducted for DU and ^{137}Cs.

Scenario #2, ground survey - A truck is used to transport the detector array over the area at a rate of 5 mph. The cases considered are surface distributed material and distributed/large particles located at a depth of 2 ft. The ground survey analysis was conducted for DU.

Analysis Results

The results of the analysis are divided into 3 analyses; 1) Aerial Survey for DU, 2) Aerial Survey for ^{137}Cs, and 3) Ground Survey for DU.

Analysis Parameters

The specific parameters used for the three analyses are:

1 kg DU = 3.352 E-4 curies (Ci) = 1.20 E+7 disintegrations/second (dps)
The primary daughter radionuclide of DU is protactinium 234 (^{234m}Pa). The DU gamma rays are difficult to detect, therefore the gamma rays from ^{234m}Pa are measured.

The ^{234m}Pa gamma ray yields from 1 kg of DU are:

Gamma ray energy (keV)	yield	gammas/sec
766.4	0.002067	2.48 E+4
1.0	0.005891	7.07 E+4
0.926	0.03739	4.49 E+4

NaI(Tl) density = 3.67 grams/cubic centimeter (g/cm^{3})
Soil density = 1.6-2.2 g/cm3 (average = 2.0 g/cm^3)
DU metal density = 18.7 g/cm^3
keV = thousand electron volts

1. Aerial Survey for DU

Analysis results utilized in this assessment are listed in Table 1. One kilogram of DU is assumed for Cases 1 through 9, and 15 kilograms are assumed for Case 10.

Cases 1 through 3 address a distributed source with a 10 ft diameter. Case 1 addresses the anticipated flux at 50 ft, with the primary gamma ray line from ^{234m}Pa (1.001 million electron volts (MeV)) having a maximum flux of 2.39 E-3 MeV/square centimeter/second ($MeV/cm^2/sec$). This is equivalent to about 2.18 E-3 $photons/cm^2/sec$ for the uncollided flux reaching the detector. The total flux reaching the detector is about 4.60 E-3 $photons/cm^2/sec$. For a detector dimension of 4 inch x 4 inch x 16 inch, the bottom surface area of the detector is about 64 square inches (in^2), or about 413 cm^2. For a 1-second exposure period, assuming the helicopter is hovering over the source, the total flux reaching the detector would be about 1.9 photons. For the 1.001 MeV line likely used for isotopic analysis, the uncollided flux reaching the entire detector surface would be about 0.9 photons/sec. This does not consider detector sheathing, the fraction of total flux expected to be deposited in the detector and the rate of travel of the detector system over the source.

Cases 2 and 3 address the effect of deposition in the detector for 2 inch and 4 inch thick detectors. Deposition in the detector is determined by assessing the difference from the uncollided flux to that calculated to collide within the detector. For the 1.001 MeV line, the deposition is calculated by subtracting the collided flux from the uncollided flux (2.39 E-3 minus 9.00 E-4). Consequently, about 30% of the flux would be expected to deposit in the 2 inch detector and 62% in the 4 inch detector. The deposited flux in the 4-inch thick detector is $\leq$ 0.6 photons/sec with some reduction in flux from the sheath on the detector.

Cases 4 and 5 address the "field of view" of the detector and the resultant change in distance between the detector and the DU source as the helicopter moves forward at a speed of 60 mph (88 ft/sec). For a one-second exposure period, the helicopter would be a maximum of 44 ft linear distance on each side of the source point with a corresponding straight-line distance of 66 ft between the source and the detector. This results in a reduction of the flux reaching the detector to about 57% of the maximum flux at the 50 ft height. For a two-second exposure period (i.e., 88 linear ft), the maximum flux at a straight-line distance of 101 ft would be 24%. Consequently, the maximum potential detection distance is on the order of a two-second exposure period on either a lateral line or on-line distance of not more that 100 ft. This would provide a field of view of about 4000 square feet (ft^2). Deposition in the detector from greater distances is not highly credible.

In reference 1, it is indicated that the minimum detectable activity for direct overflight of a point source at 50 ft is 15 kg, and midway between the flightlines the minimum is 23 kg. For an unattenuated distributed source as described above, the flux reaching the detector would be on the order of 9 photons per second deposited in the detector from the 1.001 MeV line, depending on the location of the source off the center line. Statistically, this is detectable, however, the effects of background and the relatively poor resolution of NaI(Tl) would hinder detection. The effect of source configuration and intervening material (i.e., soil) would also limit the number of photons deposited in the detector.

Cases 6, 7, and 8 address the effects of soil over the material. Cases 6 and 7 address the cases where there is a distributed source (10 ft. diameter) under 1 and 2 ft. of soil and Case 8 addresses the case where 1 kg plug is located under 1 ft of soil. For the 1.001 MeV line, the effect of 1 ft.

of soil is a reduction to 14% of the unattenuated flux and for 2 ft., the flux is reduced to 0.7% of the unattenuated flux, or a reduction of more than two orders of magnitude. It is feasible to detect DU when covered with 1 foot of soil, but it is not credible to expect detection of DU when covered with 2 ft of soil.

The source configuration issue was evaluated in Case 9. In this case, the source was collapsed into a chunk of solid DU with a density of 18.7 g/cm^3. The dimensions of this chunk of material are 2.5 x 3 cm for a 1 kg piece. Table 1 indicates that the flux is attenuated at 50 ft. to 38% of the unattenuated source value. This level of attenuation is probably tolerable for pieces of this size; however, for large pieces of material, the effect becomes more significant.

Case 10 lists the results for a 15 kg piece of DU in a geometry of 5.7 cm radius by 8 cm long. The flux for the 1.001 MeV line is 4.54 E-3 MeV/cm^2/sec, or only an increase of 89% above the flux for 1 kg of unattenuated material (Case 1). Consequently, the detectable amount of DU is highly dependent on the geometry of the DU.

Table 1. Analysis Data Summary for 1 Kilogram Depleted Uranium at Helicopter Height

Case	Source Configuration	Dose Point	0.766 MeV*	0.926 MeV*	1.001 MeV*
1	10 foot diameter no attenuation	50 foot distance in air	6.44 E-4	1.40 E-3	2.39 E-3
2	10 foot diameter no attenuation	50 foot distance in air deposition after 2 inches NaI(Tl)	4.48 E-4	9.76 E-4	1.66 E-3
3	10 foot diameter no attenuation	50 foot distance in air deposition after 4 inches NaI(Tl)	2.27 E-4	5.19 E-4	9.00 E-4
4	10 foot diameter no attenuation	66 foot distance in air 1 second flyover	3.70 E-4	8.06 E-4	1.37 E-3
5	10 foot diameter no attenuation	101 foot distance in air 2 second flyover	1.56 E-4	3.39 E-4	5.76 E-4
6	10 foot diameter 1 foot soil cover	50 foot distance in air	7.44 E-5	1.86 E-4	3.33 E-4
7	10 foot diameter 2 feet soil cover	50 foot distance in air	2.37 E-6	7.98 E-6	1.61 E-5
8	2.5 x 3 cm at 18.7 g/cm^3 1 foot soil cover	50 foot distance in air	1.45 E-4	3.77 E-4	6.82 E-4
9	2.5 x 3 cm at 18.7 g/cm^3	50 foot distance in air	2.03 E-4	5.11 E-4	9.14 E-4
10	5.7 cm radius x 8 cm @ 18.7g/cm^3 *(15 kg DU)*	50 foot distance in air	9.49 E-4	2.49 E-3	4.54 E-3

* Photon flux in MeV/cm^2/sec at the dose point with buildup

2. Aerial Survey for ^{137}Cs

Cases 11-20, described in Table 2, address the detection of 0.03 millicuries (mCi) of ^{137}Cs from a 50 ft elevation with various attenuations. These data indicate a higher degree of detectability than DU; however, the detection through soil is still poor and would indicate that buried ^{137}Cs may not be detectable. The effects of burial depth are a significant factor in the detection capability from helicopter born detection systems.

Table 2. Analysis Data Summary for 0.03 mCi ^{137}Cs at Helicopter Height

Case	Source Configuration	Dose Point	0.661 MeV*
11	10 foot diameter no attenuation	50 foot distance in air	2.06 E-2
12	10 foot diameter no attenuation	50 foot distance in air deposition after 2 inches of NaI(Tl)	1.44 E-2
13	10 foot diameter no attenuation	50 foot distance in air deposition after 4 inches of NaI(Tl)	7.05 E-3
14	10 foot diameter no attenuation	66 foot distance in air 1 second flyover	1.19 E-2
15	10 foot diameter no attenuation	101 foot distance in air 2 second flyover	4.66 E-3
16	10 ft. diameter 0.5 ft soil cover	50 foot distance in air	8.28 E-3
17	10 foot diameter 1 foot soil cover	50 foot distance in air	1.53 E-3
18	10 ft. diameter 1.5 ft soil cover	50 foot distance in air	2.07 E-4
19	10 foot diameter 2 feet soil cover	50 foot distance in air	2.44 E-5
20	Point source	50 ft. distance in air	2.10 E-2

* Photon flux in MeV/cm^2/sec at the dose point with buildup

3. Ground Survey for DU

Cases 21-27, described in Table 3, address the detection of DU using the ground-based Kiwi system. The rate of speed of the Kiwi system was not addressed, but this type of system is generally operated at less than 5 mph. In summary, it would be difficult to detection of 1 kg of DU at a 2 foot distance using the Kiwi system.

Table 3. Analysis Data Summary for 1 Kilogram Depleted Uranium at 2-foot Kiwi Height

Case	Source Configuration	Dose Point	0.766 MeV*	0.926 MeV*	1.001 MeV*
21	10 foot diameter no attenuation	2 foot distance in air	5.47 E-2	1.19 E-1	2.03 E-1
22	10 foot diameter no attenuation	2 foot distance in air deposition after 2 inches of NaI(Tl)	1.80 E-2	4.06 E-2	7.02 E-2
23	10 foot diameter no attenuation	2 foot distance in air deposition after 4 inches of NaI(Tl)	5.10 E-3	1.22 E-2	2.17 E-2
24	10 foot diameter 1 foot soil cover	2 foot distance in air	7.00 E-4	1.90 E-3	3.56 E-3
25	10 foot diameter 2 feet soil cover	2 foot distance in air	7.60 E-6	2.90 E-5	6.18 E-5
26	Point source no attenuation	2 foot distance in air	4.20 E-1	9.19 E-1	1.56
27	Point source 2 feet soil cover	2 foot distance in air	7.64 E-6	2.91 E-5	6.21 E-5

* Photon flux in MeV/cm^2/sec at the dose point with buildup

Reference

1. H. Clark, "AMS Performance for an Aerial Radiological Survey of IAAP", 02/01/01. Mr. Clark is with the Remote Sensing Laboratory (RSL) at the DOE Nevada Test Site.