TECHNICAL REPORT

INVESTIGATION OF THE POSSIBLE DEPLETED URANIUM CONTAMINATION IN LEBANON AFTER THE 2006 SUMMER ISRAELI ATTACK

O. El Samad, B. Nsouli, H. Nasr, M. Assi, R. Abou-Rjeili, M. El-Akoum, A. Reslan, M. Saate, H. Jeaid and H. Reslan
National Council for Scientific Research, Lebanese Atomic Energy Commission, P.O.Box: 11-8281, Beirut, Lebanon
osamad@cnrs.edu.lb

(Received 15 November 2006 - Accepted 20 February 2007)

ABSTRACT

Following the Israeli bombardment of Lebanon in 2006, a radiological and physical assessment in relation to the possible use of Depleted Uranium (DU) in Israeli ammunitions was assigned. In cooperation with the United Nations Environment Programme (UNEP), The International Atomic Energy Agency (IAEA), and the Lebanese Army, 90 samples from 80 locations: Beirut Suburb, Baalbeck, Bekaa, and South of Lebanon, were analyzed for uranium isotopes content (^{235}U and ^{238}U). The analyses were conducted using gamma spectrometry, ICP-MS and TI-MS. The results indicated that the uranium concentrations do not exceeded the normal environmental values. All the analyzed samples contain no enriched or depleted uranium.

Keywords: Depleted Uranium, uranium ratio, activity, Lebanon

INTRODUCTION

Following the Israeli bombardment of Lebanon from July 12, 2006 till August 14, 2006, the Lebanese Atomic Energy Commission (LAEC)-CNRS was assigned to carry out a radiological and physical assessment in relation to the possible use of Depleted Uranium (DU) in Israeli ammunitions. This assessment was deemed necessary as there were concerns over the possible impact of DU on local population, and on military personnel (Bleise *et al*., 2003; Griannardi & Dominici, 2003).

On August 15, 2006, the LAEC conducted different field missions in close coordination with the IAEA. Additional investigations were carried out in cooperation with UNEP post-conflict assessment in September-October and November 2006.

During the field missions and, with the cooperation of the Lebanese Army, the LAEC experts surveyed over 80 sites and collected a total of 90 samples from different locations, mainly from Beirut Suburb, Baalbeck, Bekaa, and South of Lebanon. The missions extended from August 15, 2006 to November 21, 2006. The samples were brought to the LAEC gamma spectroscopy laboratory for analysis. Some of these samples were analyzed by

the IAEA laboratories and by the UNEP *via* the Swiss SPIEZ Laboratories. In this work, the findings of the field work and the laboratory results are listed and commented.

FIELD WORK

A primary assessment of the penetrators used in the ammunitions resulting from the bombardments was conducted. Based on open sources and army coordination, not any DU penetrator was located. Unexploded ordinances were also measured with survey detectors but did not give any indication for the presence of DU.

The field work was divided into multi-sequential missions during which the following sites were visited:

TABLE 1

Sites Visited and Surveyed

Beirut	Achrafieh; Al Manara; Engineering regiment
Southern Beirut – Dahie	Sayyed Abbas Al Mousawi Street; Haret Hreik; Security perimeter
South	Yahmour; Nabatiye(Manar TV); Jdeidat Marjeyoun; Khiam (Jelahia, Musium,Dardara,Prison); Rihane- kfarhounat road; Huchaymiyeh bridge; Gnam rabak-Dalloul station; Ali el-nahri- square; Hussainiyat Ali el-nahri; Gnam rabak-Dalloul station; South - Borj El Moulook; Entrance; Kantara; Hujair valley; Ghandooriye; Froon; Kakaiet el jisr; El frara bridge; Majdal Silm; Bint Jubail; Aytaroon; Ayta el shab; Kafar-Chouba; Debin-Marjeoun.
Baalbeck	Baalbeck city; Cheik-habib; Bouday

The primary mission (4 weeks durations) started on the first day of the cease-fire (August 15, 2006).

The technical equipment that were used in the field during this primary mission were three Exploranium GR-110 1.5”x1.5”x 2” NaI detectors, a Graetz X5-DE, and a MiniRad surface contamination detectors. These detectors were used to identify any abnormal radiation measurements. The background counts were around 64 cps, and did not vary significantly at all the different places that were visited. In addition to the field survey, samples such as soil (0-5 cm off the ground surface), building material rubbles, and metallic fragments left from the bomb impacts were taken according to IAEA (2003) procedures.

The IAEA Radiation Protection Section has sent additional and complementary equipments that were received on September 5, 2006. A second mission was thus conducted in which the IAEA survey kits were used. This mission allowed us to cover other areas that were not covered before, and to revisit suspected sites, with the use of alpha, beta, and gamma detectors.

The additional portable equipments used in the second survey mission were: DG5A plastic scintillator detector (Novelec), DELTA surface contamination monitor for beta radiation - scintillator probe (Thermo electron), Minicon surface contamination monitor for beta radiation, and Graetz gamma dose rate.

A third mission was conducted in cooperation with the UNEP expert's and 38 (smear, dust and soil) samples were taken from 32 sites that were visited. These samples were analyzed in Swiss SPIEZ Laboratories.

A fourth mission in Khiam in south Lebanon was conducted in cooperation with the UNEP expert's to build an extensive database of the uranium content of soil in this area. 16 (smear, water and soil) samples were taken from 3 sites that were visited in Khiam. These samples were analyzed by LAEC Laboratory and by Swiss SPIEZ Laboratories.

LABORATORY ANALYSIS AND RESULTS

The Gamma Spectroscopy Laboratory at the LAEC is extensively used for analyzing the samples collected in the field for DU residues (Papachristodoulou & Assimakopoulos, 2003). It is noted that the Laboratory is a member of the ALMERA (Analytical Laboratories for the Measurement of Environmental Radioactivity) network (IAEA) and is currently in the process of reaching the ISO/IEC 17025 standard.

More than 90 collected samples (soil, Bombs and missiles fragments, and building material) from 80 areas were brought to the Gamma Spectroscopy Laboratory. 55 samples were homogenized and then dried at 105 ^{0}C. The rest of samples, which consist of bombs and missiles fragments, and some building materials were difficult to homogenize. All samples were put into 500 ml containers, and subsequently measured with the following equipments:

- A portable Graetz with a Beta sonde XXS-226 for Beta radiation survey and, a portable 3*3 NaI detector with a NOVELEC SM-1024 Multi Channel Analyzer for Gamma radiation survey.

- Two sets of gamma spectrometry detecting systems consisting of two coaxial HPGe detectors. The first detector has a relative efficiency of 30%, and a resolution of 1.85 (FWHM) at 1332 keV. The second detector has a relative efficiency of 40% and a resolution of 2.0 keV (FWHM) at 1332 keV. Both detectors were surrounded by a 10 cm-thick lead shield in order to reduce the background, and covered from inside by a 0.5 cm copper layer to attenuate x-rays emitted by the lead shield. The linearity of the detectors was checked with a ^{152} Eu source. The electronics used were: a Canberra desktop inspector and an integrated signal data processor (model 1510) with 8K multichannel analyzer (MCA). The detectors were energy-calibrated with a standard multigamma reference sources, and the efficiency calibration was performed. The efficiency curves were corrected for attenuation and self-absorption. Because of the low activity concentration in the samples, a counting time of around 36 hours was necessary to obtain acceptable statistics for the 143 and 185 keV of ^{235}U and for the 1001 keV of ^{238}U. The spectra were analyzed off-line with the Canberra GENIE–2000 analysis program. The background spectra were measured under the same conditions than the sample measurements and were used to correct the calculated sample activities. The quality control procedures were applied using a standard reference material.

The Beta and Gamma Surveys used for the collected samples is given in Table 2. As it can be seen, the value with the Beta Sonde varies between 48 lmp/s and 72 lmp/s. The measured background count was approximately 55 lmp/s. The Beta and Gamma Surveys used in laboratory for the collected samples did not give any indication of DU contamination. Soil samples collected in one site in Khiam (Jelahia-Taamir), samples code 35, 36, 58, 59, 61, 62, 63, 64, 65, and 66 indicated a relatively high count, up to 72 lmp/s. With the use of the HPGe detectors, it was found, taking into account the analytical uncertainties, that the activity ratios of (U-235/U-238) samples were very close to the natural uranium ratio.

TABLE 2

Measurement of Collected Samples in the Gamma Spectroscopy Laboratory with the Use of Portable Gamma and Beta Detectors

Sample Number	Sample Type	Lab.Sample Code	Graetz With Beta Sonde (XXS-226) Background 45-55 lmp/s	NOVELEC SM-1024 3*3 NaI Background 40-45 cps
1	Soil+BM	1604_1-1	50	38
2	Soil+BM	1604_1-2	48	41
3	Soil	1605_2-1	49	40
4	Soil	1605_2-2	49	43
5	Soil	1606_3-1	52	43
6	Soil	1606_3-2	50	41
7	Soil	1607_1-1	54	43
8	Soil	1607_1-2	54	43
9	Soil+BM	1608_1	54	42
10	Soil	1608_2	56	44
11	Missile Parts	1609	52	38
12	Missile Parts	1610_1	45	41
13	Soil+BM	1610_2	52	42
14	Soil	1611	58	46
15	Soil	1612_1-1	58	45
16	BM	1612_1-2	57	45
17	BM	1613_2-1	60	46
18	BM	1613_2-2	53	42
19	Soil-Gravel	1614	60	46
20	Soil	1615_1-1	53	46
21	BM	1615_1-2	52	44
22	Soil+BM	1615_1-3	53	44
23	BM	1616_2-1	53	42

Sample Number	Sample Type	Lab.Sample Code	Graetz With Beta Sonde (XXS-226) Background 45-55 lmp/s	NOVELEC SM-1024 Background 40-45 cps
24	BM	1616_2-2	56	43
25	BM	1616_2-3	51	41
26	BM	1625_1	54	45
27	BM	1625_2	55	46
28	Soil	1626_1	53	44
29	Soil	1626_2	55	45
30	Soil	1627	53	45
31	Missile Parts	1629	50	43
32	Gravel	1630_1-1	50	42
33	Gravel	1630_1-2	51	41
34	Missile Parts	1630_1-3	48	41
35	Soil	1636_1	72	56
36	Soil	1636_2	62	49
37	Soil	1637	53	42
38	Soil	1638	55	45
39	Soil	1639	56	45
40	Soil	1640	55	44
41	Soil	1640_1	54	45
42	Soil	1640_2	53	44
43	Soil	G7	60	NA
44	Soil	B15	53	NA
45	Soil	B4	53	NA
46	Soil	B5	49	NA
47	Soil	G3	54	NA
48	Soil	G4	54	NA
49	Soil	B18	55	NA
50	Soil	G2	58	NA
51	Soil	B16	49	NA
52	Soil	B17	51	NA
53	Soil	B8	55	NA
54	Soil	G5	53	NA
55	Soil	G1	55	NA
56	Soil	B22	60	NA
57	Soil	B21	62	NA

Sample Number	Sample Type	Lab.Sample Code	Graetz With Beta Sonde (XXS-226) Background 45-55 lmp/s	NOVELEC SM-1024 Background 40-45 cps
58	Soil	1674	61	NA
59	Soil	1675	56	NA
60	Soil	1676	59	NA
61	Soil	1677	61	NA
62	Soil	1678	59	NA
63	Soil	1679	65	NA
64	Soil	1680	72	NA
65	Soil	1681	72	NA
66	Soil	1682	62	NA
67	Soil	1683	54	NA
68	Soil	1684	55	NA
69	Soil	1685	57	NA
70	Soil	1686	47	NA
71	Soil	1687	52	NA
72	Soil	1688	52	NA
73	Soil	K1	49	NA
74	BM	K2	45	NA
75	Missile Parts	K3	49	NA
76	Soil	K4	57	NA
77	Soil	K5	50	NA
78	Soil	K6	54	NA
79	Soil	K7	54	NA
80	Soil	K8	49	NA
81	Soil	K9	55	NA
82	Soil	K10	50	NA
83	Missile Parts	Taamir-1	43	NA
84	Missile Parts	Taamir-2	40	NA
85	Missile Parts	Taamir-3	44	NA
86	Missile Parts	Taamir-4	45	NA
87	Missile Parts	Cheik-habib1	47	NA
88	Missile Parts	Cheik-habib2	40	NA
89	Soil	1669	50	NA
90	Soil	1670	48	NA

(BM: Building Materials; NA: not available)

90 samples were measured with HPGe detectors. Among them, 55 were homogenized, and then quantified as activity concentration (Bq/kg) for U-235 and U-238 *via* their gamma lines 143 keV, and the 1001 keV, respectively (McLaughlin *et al*., 2003). Table 3 gives the activity concentrations of U-235 and U-238 and the activity ratio. The activity values varies between 0.9 Bq/kg and 7.0 Bq/kg for U-235, and from 15 Bq/kg to 163 Bq/kg for U-238, except samples collected in one site in Khiam (Jelahia-Taamir / samples code: 35, 36, 58, 59, 61, 62, 63, 64, 65, and 66) which exhibited relatively high activity concentration (up to 35.5 Bq/kg for U-235 and 808 Bq/kg for U-238). The analytical activity concentration uncertainties was calculated, taking into account a 95% confidence level. The calculated activity ratio of U-235/U-238 varied between 0.033 and 0.067. Taking into account the activity concentration uncertainties, these values were within the natural activity ratio of U-235/ U-238, which is 0.046 (Letter to the editor, 2003).

For the non-homogeneous samples, and from their corresponding measured spectra, the net peak area ratio of the gamma 143 keV of U-235 over the gamma 1001 keV of U-238 was calculated. This ratio did not give any abnormal values.

TABLE 3

Activity Concentrations of U-235, U-238 and Activity Ratio of U-235/U-238 Obtained with the Use of the Two HPGe Detectors (30% and 40% Efficiency)

Sample Number	Activity Concentration U-235 [Bq/Kg]	Activity Concentration U-238 [Bq/Kg]	Activity Ratio U-235/U-238
1	1.0 ± 0.1	22 ± 5	0.045 ± 0.011
3	1.6 ± 0.1	29 ± 7	0.055 ± 0.014
5	0.9 ± 0.1	15 ± 5	0.060 ± 0.021
6	1.1 ± 0.1	17 ± 4	0.066 ± 0.017
7	1.8 ± 0.3	33 ± 8	0.055 ± 0.016
15	1.7 ± 0.4	39 ± 9	0.044 ± 0.015
17	7.0 ± 0.8	163 ± 13	0.043 ± 0.006
20	3.9 ± 0.2	NA	NA
24	6.8 ± 0.3	122 ± 9	0.056 ± 0.005
26	1.7 ± 0.3	32 ± 7	0.053 ± 0.015
27	2.5 ± 0.4	44 ± 6	0.057 ± 0.012
35	33.0 ± 3.0	774 ± 24	0.043 ± 0.004
36	18.0 ± 2.0	432 ± 19	0.042 ± 0.005
37	1.6 ± 0.3	NA	NA
38	2.5 ± 0.3	68 ± 7	0.037 ± 0.006
39	3.0 ± 0.8	62 ± 10	0.048 ± 0.015
40	3.1 ± 0.1	50 ± 6	0.062 ± 0.008
41	1.4 ± 0.3	21 ± 4	0.067 ± 0.019

Sample Number	Activity Concentration U-235 [Bq/Kg]	Activity Concentration U-238 [Bq/Kg]	Activity Ratio U-235/U-238
42	0.9 ± 0.3	27 ± 6	0.033 ± 0.013
58	18.9±1.6	432 ± 22	0.044 ± 0.004
59	13.6 ± 1.3	290 ± 18	0.047 ± 0.005
60	3.4 ± 0.4	86 ± 9.0	0.040 ± 0.006
61	17.7 ± 1.7	371 ± 18	0.047 ± 0.005
62	8.6 ± 0.8	196 ± 13	0.044 ± 0.005
63	25.2 ± 2.3	606 ± 25	0.042 ± 0.004
64	35.5 ± 3.0	808 ± 27	0.044 ± 0.004
65	28.0 ± 2.6	707 ± 24	0.040 ± 0.004
66	19.3 ± 1.9	477 ± 23	0.041 ± 0.005
67	3.4 ± 0.5	NA	NA
68	4.4 ± 0.7	74 ± 14	0.059 ± 0.015
69	3.1 ± 0.5	64 ± 11	0.048 ± 0.009
70	5.8 ± 0.7	119 ± 15	0.049 ± 0.009
71	6.6 ± 0.7	134 ± 14	0.049 ± 0.007
72	NA	39 ± 11	NA
89	2.3 ± 0.3	52 ± 7	0.044 ± 0.008
90	0.9 ± 0.3	NA	NA

(NA: not available)

An additional investigation was carried out in order to explain the relative high uranium content in the Khiam (Jelahia-Taamir) site. At this site, samples of soil, water, smear, and metal remnant of bombs were collected. The LAEC experts also took samples from other locations in Khiam (Jelahia, Museum, Prison, Dardara, and agricultural zone). Duplicates of all samples were given to the UNEP experts, and some of them were sent to the IAEA laboratories for analysis by using thermo-ionization mass spectrometry (TIMS) technique. All these samples were analyzed by the gamma spectroscopy laboratory at the LAEC, and by the UNEP *via* the Swiss SPIEZ Laboratories using high resolution ICP mass spectrometry for the determination of uranium isotopes, and a quadruple ICP mass spectrometry for the screening of heavy and other relevant metals (UNEP, 2007). Table 4 gives comparative results at the Khiam region. As it can be seen, the samples taken at Khiam did not give any indication of DU contamination, and confirm the natural uranium isotopic composition of the uranium.

A radiological equilibrium between the Th-230 nuclide and its parent U-238 nuclide was found. The Swiss SPIEZ Laboratories confirmed this result. The man-made industrial uranium would not contain the Th-230 nuclide (Bleise *et al*., 2003; Griannardi & Dominici, 2003; UNEP, 2001; 2007).

Metal pieces found in the Khiam (Jelahia-Taamir) hole were analyzed. No uranium was found. The steel was identified, by UNEP experts and by the Swiss SPIEZ Laboratories, as 25 Mn4- steel (W.No. 1.1177), which is typically used in MK-type bombs (UNEP, 2007).

The Khiam (Jelahia-Taamir) hole clearly showed that the ground was composed of non-homogeneous soils and materials that were placed there before the bomb attack occurred. The samples taken at different depths in the hole confirm the natural composition of the uranium. The UNEP expert and the Swiss SPIEZ Laboratories confirmed this result (UNEP, 2007).

TABLE 4

Comparison of $^{235}U/^{238}U$ Mass Ratio at the Khiam Region

Sample Code	**LAEC** $^{235}U/^{238}U$	**UNEP** $^{235}U/^{238}U$	**IAEA** $^{235}U/^{238}U$
17 (behind Prison, bombarded area)	0.00675 ± 0.00074	0.00721 ± 0.00003	NAp
35 (impact hole)	0.00691 ± 0.00076	0.00722 ± 0.00001	0.00749 ± 0.00006
36 (blank hole, 2 m from impact hole)	0.00707 ± 0.00078	NA	0.00736 ± 0.00007
A (Dardara, bombarded area)	0.00644 ± 0.00071	0.00723 ± 0.00002	0.00718 ± 0.00008
B (impact hole, 2.5 m depth)	0.00659 ± 0.00073	NA	0.00738 ± 0.00007
58 (70 m from impact hole)	0.00688 ± 0.00076	0.00725 ± 0.00005	NAp
59 (30 m from impact hole)	0.00736 ± 0.00081	0.00727 ± 0.00005	NAp
60 (20 m behind impact hole)	0.00628 ± 0.00069	0.00726 ± 0.00003	NAp
61 (close impact hole)	0.00749 ± 0.00082	0.00726 ± 0.00003	NAp
62 (impact hole)	0.00691 ± 0.00076	0.00725 ± 0.00003	NAp
63 (impact hole, 1 m depth)	0.00653 ± 0.00072	0.00722 ± 0.00006	NAp
64 (impact hole, 2 m depth)	0.00691 ± 0.00076	0.00728 ± 0.00003	NAp
65 (impact hole, 2 m depth, close to metal piece)	0.00628 ± 0.00069	0.00724 ± 0.00005	NAp
66 (impact hole, 3 m depth)	0.00644 ± 0.00071	0.00728 ± 0.00003	NAp
67 (Prison, bombarded area)	NA	0.00729 ± 0.00003	NAp

68 (Prison, bombarded area)	0.00926 ± 0.00102	0.00729 ± 0.00004	NAp
69 (Prison, bombarded area)	0.00754 ± 0.00083	0.00728 ± 0.00003	NAp
70 (Dardara, agriculture field)	0.00765 ± 0.00084	0.00726 ± 0.00004	NAp
71 (Dardara, agriculture field)	0.00769 ± 0.00085	0.00728 ± 0.00005	NAp

(NAp: not applicable)

CONCLUSION

Extensive investigations were carried out to find if depleted or enriched uranium was used in the last Israeli attack against Lebanon in July 2006. Around 80 bombarded sites located in Beirut Suburb, Baalbeck, Bekaa, and South of Lebanon were surveyed. From these sites 90 samples of soil, building materials, ammunition fragments were analyzed using Gamma Spectrometry, HR- ICP/MS and TIMS techniques. The $^{235}U/^{238}U$ ratio shows that all samples contain natural uranium isotopes. The activity concentration varies between 0.9 Bq/kg and 35.5 Bq/kg for U-235, and from 15 Bq/kg to 808 Bq/kg for U-238. These concentrations are in the normal range of natural uranium, and do not pose any health risk for resident and public. The relative high natural uranium isotopes in some location at the Kiam (Jelahia-Taamir) were deeply investigated. The Kiam (Jelahia-Taamir) hole clearly showed that the ground was composed of non-homogeneous soils and materials that were placed there before the bomb attack occurred.

ACKNOWLEDGMENT

The authors would like to thank the IAEA Department of Nuclear Safety and Security and the IAEA Laboratories for their efficient cooperation. Thanks are also due to the Lebanese Army Engineering Regiment for his assistance.

REFERENCES

Bleise, A., Danesi, P.R., Burkart, W. 2003. Properties, use and health effects of DU: a general overview. *J. Environmental Radioactivity*, 64: 93-112.

Griannardi, C. and Dominici, D. 2003. Military use of DU: assessment of prolonged population exposure. *J. Environmental Radioactivity*, 64: 227-236.

IAEA 2003. *Radiological assessment in Kuwait.* Report.

Letter to the editor 2003. What ICRP advice applies to DU? *J. Environmental Radioactivity*, 64: 89-92.

McLaughlin, J.P., Vintro, L., Smith, K.J. 2003. Actinide analysis of a DU penetrator from a 1999 target site in southern Serbia. *J. Environmental Radioactivity*, 64: 155-165.

Papachristodoulou, C.A. and Assimakopoulos, P.A. 2003. Use of HPGe gamma spectrometry to assess the isotopic composition of uranium in soils. *J. Environmental Radioactivity*, 64: 195-203.

UNEP 2001. *DU in Kosovo, post-conflict environmental assessment*. Report.

UNEP 2007. *Final post-conflict report environmental assessment in Lebanon.* Report.