

Battlefield fallout: evidence of Uranium and  
Niobium in weapons employed by the Israeli  
Military in Gaza  
Analysis of ambulance air filter and bomb crater

Preliminary report

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## 1. Introduction

In 2006 Green Audit organised the collection and analyses of material from the areas of the Lebanon where the Israeli army and air force were deployed. Bomb crater soil and water samples were analysed for uranium isotopes and the engine air filter from an ambulance which had been active during the bombardments was examined for uranium isotopes and also for 43 other elements (Busby and Williams 2006). Results showed the presence of significant levels of uranium in all the samples. The material in the filter was enriched uranium. The uranium from the craters was variable in its isotopic ratio, showing enriched in some samples and natural in others.

It was therefore of interest to obtain similar results for materials obtained from Gaza where the Israeli forces were presumably engaged in deploying similar weapons. Through contacts in Egypt we obtained the engine air filter from a Toyota ambulance operating near Gabal el Rayes which had been active during the Israeli invasion and also soil material from the surface of a rocket crater in the same place. The samples were obtained for us the week after the bombing stopped by Dr Taher Halawa Fawzy, a forensic pathologist working for the Arab Medical Union in Cairo. Sections of the Toyota air filter were examined using Mass Spectrometry by Harwell Scientifics, Didcot, UK. Multiple sample tests were also carried out on the blackened crater surface sample. In addition a 43 element analysis was carried out on both the air filter and the soil sample. Both were analysed for total uranium and the uranium isotopes U235 and U238. The isotopic ratios U238/U235 were obtained from the raw counts corrected for background and normalized to a Bismuth control. A second piece of the air filter was examined at the radiochemical laboratory of the Chalmers University of Technology, Goteborg, Sweden and analysed for uranium and uranium isotopes.

## 2. Methods

### *Harwell: filter*

The ambulance air filter was dismantled and cut into 3 pieces with a saw (Fig 1). One piece was packed in polythene bag and sent to the Harwell laboratory.

(1) The initial analysis used 100mg dissolved in HF/ HNO<sub>3</sub> in a PTFE vessel by microwave heating (3.5ml 48% hydrofluoric acid/ 7ml concentrated nitric acid). There was insufficient material to obtain an isotope ratio but the total uranium content was found to be 0.41mg/kg in this sample.

(2) To improve sensitivity 3 separate portions of the filter weighing approximately 1g each were separately dissolved in the HF/HNO<sub>3</sub> solution. All the digested samples were diluted in demineralised water and measured by ICPMS (Agilent 7500c). Each sample was then measured three times in separate runs. Calibration was by standard addition from a mixed element standard. Quality control uranium standards were employed and instrumental drift was normalized to a bismuth standard. (3)

(3) These solutions were re examined on a second day to investigate the precision of the isotope ratio result.

(4) The solutions were each re-run on a third day to follow up on the precision investigation.

(5) 43 element analysis was carried out on these solutions by ICPAES (Perkin Elmer Optima 4300DV)

*Harwell: crater soil*

The sample consisted of pieces of compacted reddish soil which had a blackened surface. The surface was cut away with a blade and it was this blackened surface material which was analysed. It should be noted that the flakes of material were not homogenous in colour, some pieces having more and some less of the blackened surface material.

(1) In the first analysis, 100mg of material was dissolved in triplicate (i.e. three separate pieces) in the HF/HNO<sub>3</sub> solution in fluoropolymer vessels by microwave. Following this the samples were made up to known volume with demineralised water and analysed for 45 elements using the ICPAES equipment (see above). The samples were diluted as necessary and analysed by ICPMS as above.

(2) In the second analysis, 100mg of material was dissolved in triplicate as above and three separate runs were carried out at daily intervals in order to examine the instrumental precision of the analysis.



**Fig 1.** Ambulance air filter from Gaza before and after cutting up.

*Chalmers University Sweden: filter*

Two 12 g pieces of the filter were cut out and placed in plastic bottles with screw caps then about 90ml 7M HNO<sub>3</sub> was added. Three different dilutions of the samples were made with 1M HNO<sub>3</sub> 1000, 100 and 10. Measurements were made by ICPMS

(Perkin Elmer ELAN6000) with Indium internal standard. Calculations for the isotope ratios were made by dividing the net counts per channel after subtraction of the blank.

### 3. Results for air filter

*3.1 Harwell Initial 1g triplicate.* Concentrations are mg/kg.

#### Ratios from concentrations.

Reference	U235	U238	Utotal	Ratio 238/235
Detection limit	0.00006	0.0002		
Sample 1	0.00176	0.224	0.226	127
Sample 2	0.00161	0.232	0.233	144
Sample 3	0.00179	0.239	0.241	133

#### Ratios from counts

Reference	Ratio based on blank corrected counts
Sample 1	130.8
Sample 2	132.5
Sample 3	140.1
mean	134.5
SD	4.96

*2. Harwell; second analysis; same solutions as above 1g triplicate; second day with three runs each sample.* Concentrations are mg/kg.

#### Ratios from concentrations.

Reference	U235	U238	Utotal	Ratio 238/235
Sample 1 (1)	0.00151	0.227	0.229	150
Sample 1 (2)	0.00170	0.232	0.234	136
Sample 1 (3)	0.00196	0.227	0.229	115
<b>Sample 1 (mean)</b>				<b>134</b>
Sample 1 (SD)				17.4
Sample 2 (1)	0.00190	0.240	0.242	126
Sample 2 (2)	0.00190	0.237	0.239	124
Sample 2 (3)	0.00150	0.235	0.236	157
<b>Sample 2 (mean)</b>				<b>136</b>
Sample 2 (SD)				18.2
Sample 3 (1)	0.00218	0.253	0.256	116
Sample 3 (2)	0.00199	0.249	0.251	124
Sample 3 (3)	0.00166	0.249	0.251	149
<b>Sample 3 (mean)</b>				<b>130</b>
Sample 3 (SD)				13.3
<b>All (mean)</b>				<b>133</b>
<b>All (SD)</b>				<b>15.6</b>

**3. Harwell; third analysis; same solutions as above, third day; isotope ratios from concentrations**

<b>Sample</b>	<b>U ratio (from counts)</b>
Sample 1 (1)	131
Sample 1 (2)	133
Sample 1 (3)	141
<b>Sample 1 (mean)</b>	<b>135</b>
Sample 1 (SD)	5.07
Sample 2 (1)	132
Sample 2 (2)	130
Sample 2 (3)	140
<b>Sample 2 (mean)</b>	<b>134</b>
Sample 2 (SD)	5.26
Sample 3 (1)	139
Sample 3 (2)	141
Sample 3 (3)	140
<b>Sample 3 (mean)</b>	<b>140</b>
Sample 3 (SD)	1.23
<b>All (mean)</b>	<b>136</b>
<b>All (SD)</b>	<b>4.6</b>

**Concentrations; Mean of all determinations = 0.239mgkg<sup>-1</sup>; SD = 0.009**  
**Ratios; Mean of all determinations = 136; SD = 10.8**

**3.4 Chalmers University**

Chalmers result was quoted at 0.085mg/kg and 0.080mg/kg filter for the two separate analyses. The isotope ratio obtained by dividing counts was 135.9 but examination of the data suggested that this value was quite uncertain. Chalmers have been asked to repeat their analysis.

**3.5 43 Element scan**

The results for the elemental scan of the filter are given for the three samples. Results are expressed as mg/kg filter.

Harwell filter: 43 element scan mg/kg filter; < means Limit of detection LOD; to obtain levels in the dust multiply by factor of 21)

Element	LOD	Sample 1	Sample 2	Sample 3
Ag	0.8	<	<	<
Al	0.3	2500	2500	2700
As	10	<	<	<
Ba	0.008	120	130	140
Be	0.004	0.14	0.14	0.15
Bi	1	<	<	<
Ca	0.1	24000	25000	29000
Cd	0.5	<	<	<
Co	0.3	13	13	14
Cr	0.07	8.4	8.3	8.3
Cu	0.1	32	32	34
Fe	0.06	2500	2600	2700
Ga	0.6	5	4	5
Ge	0.5	<	<	<
Hf	0.2	<	<	<
Hg	0.8	<	<	<
In	5	<	<	<
K	0.9	890	920	970
Li	0.03	1.8	1.9	2
Mg	0.009	3900	4100	4300
Mn	0.02	49	51	53
Mo	2	<	<	<
Na	1	1200	1300	1300
Nb	0.05	8.1	8.1	8.3
Ni	0.4	7.1	4.8	3
P	7	330	350	370
Pb	2	20	20	20
Rb	4	<	4	<
S	80	1100	1000	900
Sb	3	100	98	97
Sc	0.006	0.45	0.48	0.49
Se	20	<	<	<
Sn	2	<	<	<
Sr	0.6	51	52	57
Ta	0.6	<	<	<
Te	6	<	<	<
Ti	0.02	1900	1900	2000
Tl	2	<	<	<
U	<b>0.0002</b>	<b>0.23</b>	<b>0.23</b>	<b>0.25</b>
V	0.08	8.3	8.6	8.9
W	1	<	<	<
Y	0.01	1.1	1.1	0.93
Zn	0.1	140	140	150
Zr	0.03	5.9	6.3	6.4

#### 4. Crater sample surface

All measurements made by Harwell Scientifics.

##### 4.1 Initial analysis 100mg; three samples

mg/kg sample

Sample	U235	U238	Total U	Ratio
LOD	0.0006	0.002		
Sample 1 (1)	0.00831	0.964	0.973	116
Sample 2 (1)	0.00797	0.936	0.944	117
Sample 3 (1)	0.00817	0.927	0.935	113
Mean				<b>116</b>
SD				<b>2.00</b>

*4.2 Second analysis: 100mg; three samples were measured in triplicate. Ratios are from concentrations. These runs were carried out on the second day*

Sample	U235	U238	Total U	Ratio
LOD	0.004	0.03		
Sample 1 (1)	0.0106	1.06	1.07	100
Sample 1 (2)	0.0964	1.06	1.07	109
Sample 1 (3)	0.0121	1.08	1.09	88.6
Mean				<b>99.4</b>
SD				<b>10.5</b>
Sample 2 (1)	0.00857	0.989	0.998	115
Sample 2 (2)	0.00842	0.982	0.991	116
Sample 2 (3)	0.00779	0.990	0.998	127
Mean				<b>120</b>
SD				<b>6.39</b>
Sample 3 (1)	0.00732	0.990	0.998	135
Sample 3 (2)	0.00862	0.921	0.929	107
Sample 3 (3)	0.00628	0.953	0.960	151
Mean				131
SD				22.7
All 12 measurements mean				<b>116.2</b>
All 12 measurements SD				<b>16</b>

Note lower LOD on instrument for second day.

##### 4.3 Third analysis

In order to further examine the variations in the ratios, a third series of runs on the same samples was carried out on the third day. Results indicated a reduction in the U-235 values which moved the calculated isotope ratio up into the depleted region. (mean of 9 measurements 154 SD 4.8). Standard deviations were low and values were

in agreement with each other across the samples. We are unable to explain this result although the LOD of the instrument (the background scatter) was deteriorating over the three day period of the analyses. The first four sets of data were relied upon. Further investigations of the isotope ratio are in progress using more precise equipment.

#### **4.4 45 element results for soil crater sample**

Results are given in mg/kg sample

#### **Crater soil: 45 element scan mg/kg sample; < means Limit of detection LOD**

<b>Element</b>	<b>LOD</b>	<b>Sample 1</b>	<b>Sample 2</b>	<b>Sample 3</b>
<b>Ag</b>	0.8	<	<	<
<b>Al</b>	0.3	45000	44000	41000
<b>As</b>	100	<	<	<
<b>Ba</b>	0.08	230	260	210
<b>Be</b>	0.04	1.8	1.7	1.7
<b>Bi</b>	10	<	<	<
<b>Ca</b>	1	24000	22000	20000
<b>Cd</b>	5	<	<	<
<b>Co</b>	3	140	140	140
<b>Cr</b>	0.7	74	71	71
<b>Cu</b>	1	13	14	15
<b>Fe</b>	0.6	33000	33000	31000
<b>Ga</b>	6	30	30	30
<b>Ge</b>	5	<	<	<
<b>Hf</b>	2	<	<	<
<b>Hg</b>	8	<	<	<
<b>In</b>	50	<	<	<
<b>K</b>	9	7400	7500	6800
<b>Li</b>	0.3	19	18	17
<b>Mg</b>	0.09	9900	9600	8900
<b>Mn</b>	0.2	320	390	330
<b>Mo</b>	20	<	<	<
<b>Na</b>	10	3000	3000	2800
<b>Nb</b>	0.5	<	<	<
<b>Ni</b>	4	30	20	20
<b>P</b>	70	300	300	300
<b>Pb</b>	20	<	<	<
<b>Rb</b>	40	80	80	80
<b>S</b>	800	<	<	<
<b>Sb</b>	30	<	<	<
<b>Sc</b>	0.06	11	11	9.6
<b>Se</b>	200	<	<	<
<b>Sn</b>	20	<	<	<
<b>Sr</b>	6	130	120	110
<b>Ta</b>	6	<	<	<
<b>Te</b>	60	<	<	<
<b>Ti</b>	0.2	4900	4800	4700



<b>Tl</b>	20	<	<	<
<b>U</b>	<b>0.0002</b>	<b>1.0</b>	<b>0.98</b>	<b>0.99</b>
<b>V</b>	0.8	95	96	94
<b>W</b>	10	<	<	<
<b>Y</b>	0.1	16	16	13
<b>Zn</b>	1	49	48	46
<b>Zr</b>	0.3	94	90	93

## 5. Discussion

Results for the ambulance filter gave the uranium concentration of 0.238mg/kg filter. The total element concentration in the filter was 45g/kg. On this basis, the uranium concentration in the dust was 5.3mg/kg. Expressed as U-238 this is 66Bq/kg in the filter dust. The level in the soil crater sample was 1.0mg/kg (12.4 Bq/kg) and if we take this as a background level we can say that the uranium in the filter was about 5 times higher than the background. The quantity of uranium in the filter was not high enough to determine the isotope ratio given the level of instrumental precision either in the Harwell instrument or the Chalmers instrument. However further work is being carried out using sector field instruments to pursue this point and results will be reported later. The crater soil surface sample uranium level was relatively normal for a soil uranium concentration: however, the indication was that the uranium was enriched. Three sets of determination amounting to nine measurements on three samples all gave results with statistically significant levels of enrichment. The first determination, where the LOD of the instrument for the critical measurement of U-236 was very low (0.0006) gave a mean isotope ratio of 116, SD 2.0. Thereafter the LOD for U-235 deteriorated to 0.004 but still the ratios for two of the measurements were significantly low, namely 99.4 SD 10.5, 120 SD 6.4. The final measurement gave 131 SD 22.7 owing to one outlier at 151 in the third reading. Accordingly, we conclude that the uranium in the crater sample was enriched to about the same level that we found in the sample from the ambulance air filter from Beirut, obtained just after the Israeli incursion to Lebanon in 2006 (Busby and Williams 2006). The concentration of uranium in the Lebanon filter was 0.12mg/kg. The total elemental concentration in the Lebanon filter was 35g, and so the concentration of uranium in the Gaza filter dust was significantly greater, about two-fold. Table 1 compares the two filters and soil from the Gaza crater with soil from the crater at Khiam in the Lebanon.

**Table 1.** Comparison of Uranium 238 concentration and in the dust in ambulance filters from two Israeli war zones, Gaza 2009 and Lebanon 2006 with Gaza crater soil and Lebanon (Khiam) crater soil sample.

<b>War zone</b>	<b>Uranium 238 concentration in dust mg/kg (Bq/kg)</b>	<b>Isotope ratio 238/235 R (95% CI)</b>
Gaza filter 2009	5.3 (65.7)	136 (116<R<156)
Gaza soil 2009	1.0 (12.4)	116 (84<R<148)
Lebanon filter 2006	2.85 (35.3)	123 (103<SD<143)
Lebanon (Khiam) soil 2006	13.12 (170)	108 (107<R<109)

The natural uranium isotope ratio is 137.88. The Gaza filter mean is not statistically significantly different from this but the instrument accuracy is poor. The level of uranium in the filter dust is greater than in the soil and therefore the atmosphere is clearly loaded with uranium whose source is not the soil of the area. There are a number of possibilities. Certain building materials contain uranium and dust in the air would be loaded with vapourised building materials. The levels of calcium in the air filter are greater than the levels in the soil (about 5 times higher) see elemental analysis and discussion below).

The crater soil sample appeared to show an enriched signature, 116, but total uranium concentration was low. Given that this was the case, the amount of enriched uranium on the surface contributing to the reduction in the uranium isotope ratio must have been very small. We conclude that the contamination of the crater was from dust that had come from elsewhere and not from the weapon that made the crater. The weapon that produced the (far larger) crater in Khiam Lebanon left behind a significant amount of enriched uranium on that crater surface (Table 1).

We now briefly examine the results from the elemental scans, which are interesting. It is clear that the Gaza action vapourised a considerable amount of both natural and exotic material into the atmosphere to be sucked into the ambulance air filter. Table 2 shows levels of some expected and unexpected elements in the Gaza ambulance filter.

The most interesting element in the Gaza filter is Niobium. This was completely absent from the soil sample and was not found in the Beirut sample either. Niobium is used as an alloying element with Uranium (Niobium Uranium alloys 2009). The element is fairly unusual and it is strange to find it in the air above Gaza in such large amounts. There is clearly also a significant amount of aluminium and magnesium, titanium and iron, also various other elemental components of specialized stainless steel alloys.

It is of interest that no tungsten was found in any sample: tungsten is the alternative element to uranium which can be employed for armour piercing weapons or hard target penetrating.

**Table 2** Concentrations of selected elements in vehicle engine filter from Gaza from Beirut and from the Gaza soil crater sample. (Filter results mg per kg filter; to obtain mg per total dust multiply by 20.8 for Gaza filter and by 28.6 for Beirut filter.)

Element	Gaza filter (/20.8)	Gaza crater	Beirut filter	Note (Gaza filter)
Al	2500	45000	970	Significant excess Al
Ca	25000	22000	18000	Significant excess Ca
Co	13	140	1.1	
Cr	8.3	72	7.1	
Cu	33	14	62	Significant excess Cu
Fe	2600	33000	2200	Slight excess Fe
K	920	7500	310	
Mg	4100	9500	1600	Significant excess Mg
Mn	51	340	49	
Na	1300	3000	2800	
Nb	8.2	<0.5	<0.7	??Niobium alloys with Uranium
Ni	5	23	5.2	
P	350	300	140	Significant excess phosphorus
Pb	20	<20	340	
S	1000	<800	2300	Significant excess S
Sb	98	<30	<4	Significant excess Sb (detonators?)
Sr	51	130	25	
Ti	1900	4900	52	
V	8.6	95	5.4	
W	<1	<10	<0.3	No tungsten
Y	1.1	16	0.83	
Zn	140	48	150	Very large excess Zn
Zr	6.2	94	<3	Zr alloys with Uranium

## Conclusions

An air filter from an ambulance operating in Gaza during the Israeli action in Spring 2009 was analysed using ICPMS at two laboratories and showed levels of uranium which were significantly greater (about five times higher) than control levels found in a soil sample from the same area. The isotopic signature could not be accurately assessed owing to the limitations of the instruments employed. The soil crater sample was also examined for uranium and showed relatively low levels: however the isotopic signature of the uranium in the soil crater sample appeared to be enriched with a mean isotope ratio of 116; SD 16 based on 12 measurements. It was concluded that this material was not from the weapon that produced the crater but from precipitation from the air.

Multiple element analysis showed the presence of significantly high amounts of Niobium in the air filter. The origin of this is unknown. The filter also had a significant excess of Aluminium, Copper, Magnesium, Zinc, Phosphorus, Sulphur and Antimony relative to a soil control.

No tungsten was found in any analysis.

It is believed, on the basis of these results that uranium weapons of some kind were probably employed in Gaza. The enriched uranium signature is similar to that found in the Lebanon following the Israeli action there. The nature of the weapon which employs or produces enriched uranium is unknown.

Further work is under way to obtain more accurate isotope ratios and results will be reported in due course. These preliminary conclusions are based entirely on our interpretation of the laboratory results together with the results of earlier work and other laboratory work carried out using CR39 alpha track plastic which will be reported elsewhere.

In 2006 we examined an air filter and a number of crater and water samples from Lebanon following the Israeli bombing there. We earlier found enriched uranium and reported this to the media at the time (Busby and Williams 2006). There was considerable argument about this finding. UNEP reported that they could find no enriched or depleted Uranium yet an independent Lebanese scientist, Dr Mohammed Ali Khobeissi had samples analysed and also found both enriched and depleted uranium at different bomb sites.

There has been discussion in the media over the weapons employed by Israel (e.g Lancet: The Wounds of Gaza) and we believe it is a matter of some urgency to publicise the existence of uranium in the air in Gaza so that present and future illnesses may be considered in the light of the problems of potential Uranium inhalation exposure (Busby and Schnug 2008, Busby 2009).

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