Measurements of radiation dose rates, radionuclides and other contaminants on EdF Energy's site for the proposed Hinkley Point C Nuclear Power Station

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Summary

Follow-up work examining contamination at EdF Energy's Hinkley Point C site, adjacent to the west of the two existing nuclear power stations, has been carried out. Gamma dose rate measurements on the site show much higher levels of radiation than are expected. A mean dose rate of 160nSv/h (SD 35) was obtained from readings taken at 1m above ground level during a walk-over survey of the site in Jan 2011 with a highest level of 210nSv/h measured. These compare with a mean expected level based on earlier reported measurements of between 70 and 90nSv/h and suggest the presence of radioactive contamination.

Soil samples from the site were examined by low and (for one sample) high resolution gamma spectrometry. The result showed the presence of significantly high concentrations of Uranium (128Bq/kg) with an isotope activity ratio between 6.01 and 17.95 (Expected 21.3[1] for Natural Uranium). This relates to an atom ratio of between 38 and 113 (Expected 137.88 for Natural Uranium). Thus the Uranium is slightly enriched, confirming earlier analyses by the authors of data from EdF Energy's contractors, AMEC.

Two samples were also sent to a laboratory for examination by Inductively-Coupled Plasma Mass Spectrometry (ICPMS). Results showed the presence of enriched Uranium with atom ratio between 116 and 130 for both samples. Elemental scans of the two soil samples by ICPMS also showed elevated concentrations of Iron, Copper, Chromium, Manganese, Nickel and Arsenic suggesting the origin of the material was unusual. These may originate in stainless steel corrosion residues from the nuclear plants brought ashore by sea-to-land-transfer. An elevated level of Iodine in soils indicates seawater as does the high level of Selenium found. Calculations based on the activities of Uranium and other natural nuclides of Thorium and Potassium found in the soil samples showed that the expected gamma ray dose rate over the surface was approximately what was measured but much higher than that expected for the area or indeed much higher than that measured and reported in the literature for the same place in 1991. The authors cite the increased levels of breast cancer found associated with Uranium contamination in the Iraqi city of Fallujah as supporting evidence for a link between Uranium exposure and breast cancer as an explanation of the excess breast cancer rates found in Burnham-on-Sea, downwind of the Hinkley site.

The authors recommend a re-evaluation of the levels of contamination on the site and the funding of a co-investigation into the origin of the unusual concentrations of elements in the soil and also in soil downwind of the plant at Burnham-on-Sea where there is a breast cancer cluster. The authors recommend following the SAFEGROUNDS protocols for examination of contaminated land.

1. Background

This brief report addresses the historic contamination of the EdF Energy site west of the Hinkley Point Nuclear Power Stations in Somerset. It presents new data obtained by making gamma dose rate measurements over the site in addition to some analytical measurements of surface soil samples collected from the site.

[1] Expected 21.6 for Natural Uranium when taking into account the atomic weight difference.

The site in question is currently the subject of a major development application to the Infrastructure Planning Commission for permission to build two new, EPR nuclear plants there by the company EdF Energy. An associated initial planning application prior to this for Site Preparation Works was accompanied by various Environmental Impact Assessment documents that depended upon data presented relating to levels of radioactivity on the site and measurements of gamma emitting radionuclides. These reports were accepted by the Environment Agency (EA) as representing a pristine site with no excess radiological contamination from the historic releases from the plant. However, analysis of data relating to the largest area section identified as Built Development Area West (BDAW) (see AMEC reference) showed that the site was contaminated with slightly enriched Uranium with a mean activity isotope ratio of 17. 4, (natural ratio is 21.3). This is an atomic isotope ratio of 112 (natural Uranium has an atomic isotope ratio U-238/U-235 of 137.88). The overall contamination suggested that over the whole site there would have been several tons of slightly enriched Uranium present and that the gamma dose rate to those working on the site would be significantly above EURATOM levels defining limits for exposure from a single source. A report on this was published (Busby and Collingridge 2011).

The response of the applicants and the EA was to attack the Busby and Collingridge report, to deny the significance of the AMEC gamma spectrometric data used for the analysis and finally to collect samples of soil from 11 locations on the large site to be measured by Mass Spectrometry at the University of Southampton. Results of the ICPMS measurements showed natural Uranium isotope ratios in all but one sample that showed anthropogenic depleted Uranium with an activity ratio of 22.6 and mass ratio of 145.11 – a finding the EA denied. However, no results were given for the confidence intervals or detection limit statistics for the instruments used. Further, the EA were disingenuous regarding the U-238 mass concentrations that exceeded their own estimated range of mg/kg values for the area that needs an adequate explanation. They were criticised for taking samples without following their own previous agreements to conform to the SAFEGROUNDS protocols for investigating radioactively contaminated land: consequently there was no independent verification of where the samples used for the ICPMS measurements were taken from. This is an important point for what follows in the present report.

2. The Busby/ Collingridge 2011 findings

Briefly, analysis of the AMEC gamma spectrometry data showed that the overall concentration of Uranium was significantly higher than was predicted on the basis of levels published for the area by a previous EA study (Beresford et al, 2007). In addition, the Uranium isotope activity ratio showed that the uranium was slightly enriched and that this enrichment was higher at the surface than in deep samples where the ratios approached the expected value. Furthermore, levels of Uranium were higher near the sea. These three findings were interpreted by the authors as suggesting that contamination was by sea-to-land transfer of discharges from the historic Hinkley Point operations.

This was an interesting possibility since high levels of breast cancer have been reported in wards of Burnham-on-Sea, downwind and exposed to sea-to-land transfer from water by mechanisms such as re-suspension to air via evaporation, deposition of marine spray aerosols and direct inundation in storm conditions as well as from the re-

suspended wind-blown transport inland of radionuclides deposited in the extensive, contaminated mudflats in Bridgwater Bay exposed at low tide.

The possibility that the causative exposures for the breast cancer and infant mortality excess found in wards of Burnham-on-Sea could have been due to enriched Uranium was interesting in that other inhalation exposures to Uranium have been reported as causes of cancer in Iraqi populations of the town of Fallujah, where cancer, congenital anomaly and other genetic effects have been reported (Busby et al 2010, Alaani et al 2011).

3. Analytical work for the present study

The present study aimed to investigate the credibility of the Environment Agency's response to the questions raised by Busby and Collingridge and the following work was carried out:

1. A walk-over survey of the site with two gamma detecting Geiger counters and a GPS position detector to make gamma dose rate measurements to be compared with those reported by AMEC.
2. Collection of surface soil samples at a depth of 0.25m below ground level from recorded positions on the site to be examined by low resolution gamma spectrometry and high resolution gamma spectrometry at long count times.
3. Collection of surface soil samples at a depth of 0.25m bgl from recorded positions on the site for examination by Inductively-Coupled Plasma Mass Spectrometry (ICPMS) to obtain concentrations of 52 elements and Uranium concentrations and atom ratios.

4. Results

4.1 Gamma measurements over the site

The following results were obtained in January 2011. The operation was videoed and photographs were taken of the readings on two separate instruments. These were an NPL calibrated Mini Instruments MiniRad 1000RL extended low range pancake Geiger counter and a sensitive Russian SOSNA twin chamber Geiger Counter which has a detection limit of 5nSv/h.

1. Near Sea N51.20898; W003.14731; SOSNA 170nSv/h; Mini Instruments 200nSv/h
2. N51.20875; W003.14650; SOSNA 210nSv/h; Mini Instruments 180nSv/h
3. N51.20876; W003.14318; SOSNA 200nSv/h; Mini Instruments 150nSv/h
4. N51.20590; W003.14196; SOSNA 130nSv/h; Mini Instruments 180nSv/h
5. N51.20449; W003.13801; SOSNA 150, 120, 170, 150, 120nSv/h; Mini Instruments 100-140nSv/h
6. N51.20433; W003.13902; SOSNA 130nSv/h; Mini Instruments 100nSv/h
7. N51.20865; W003.14440; SOSNA 200nSv/h; Mini Instruments 150-200nSv/h

Mean of all SOSNA = 160; SD 33; Mean of all Mini Instruments = 163; SD 37
Range of SOSNA = 130-210; Range of Mini Instruments = 100-200

The dose rates are higher than those reported in 1991 at the perimeter fence when the reactor was switched off. In a paper by IMG Thomson in Radiation Protection

Dosimetry (2000) Vol 92 Nos 1-3 pp 71-76 entitled: Technical recommendations on measurements of external environmental gamma radiation doses. A report of EURADOS working group 12 “Environmental Radiation Monitoring” There are comparisons made between different types of radiation detectors for gamma radiation. Usefully, in the present context, the example given is of a site near Hinkley Point nuclear power station. Monitoring is carried out continuously between 6 Nov 1990 and 7 Mar 1991 and displayed in a graph. The mean dose rate at the perimeter fence in 1991 was 90nGy/h. The levels measured over the EdF site are also higher than the expected level based on the 1992 NRPB survey of gamma radiation in the British Isles, which would predict 35nSv/h from terrestrial and 35nSv/h from cosmic rays or a total of 70nSv/h, slightly less than the perimeter fence measurements made by Thomson.

So if we take the mean level over the site from our results as 160nSv/h this exceeds the expected level by about 70-90nSv/h. This must be due to excess radionuclide activity from some contaminants, in agreement with the gamma spectrometry reports of enriched Uranium.

4.2 Low resolution gamma spectrometry

These measurements were made for a quick identification of the overall radioactivity of the samples and the existence and concentration of any contaminants that could be resolved. 30,000 sec long count time measurements were made on 5 different surface 200g samples obtained along the northern end of the site using a 2” NaI(Tl) lead shielded detector (Scionix-Netherlands) and a MCA. Results showed presence of natural nuclides only but with comparatively high overall radioactivity for soil samples. Natural U-238, Th-232 and Ra series nuclides were detected e.g. Bi-214, Tl-208. Presence of Thorium seemed high but the digital spectra have not yet been examined analytically.

4.3 High resolution gamma spectrometry; Uranium level and ratios

One surface soil sample taken from the same area near the coast where gamma measurements had been made (‘Sample 4 West’ approximately 55m from BDAW’s eastern boundary, 10m inland from the coastline) was sent to ESG Harwell for long count time gamma spectrometry. The digital spectrum (Appendix) was analysed by ESG and also by Green Audit using commercial Fitzpeaks software. Results are given below in Table 1. The spectrum showing the Th-231 and Th-234 peaks is presented at the end of this paper.

Table 1. High resolution gamma spectrum of Sample GA7114 (Sample 4 West).

Nuclide	Conf	Bq/kg	+/- %	Note
Ac-228	1.00	28.7	19	Th-232 series
Bi-212	1.00	31	52	Th-232 series
Bi-214	1.00	32.6	12	U-238 series
Cs-137	1.00	5.1	27	Fission product
K-40	1.00	576	11	Natural
Pb-210	1.00	88	23	Ra-226 daughter
Pb-212	1.00	31.4	9.5	Th-232 series
Pb-214	1.00	32.8	9.4	U-238 series
Th-231	1.00	21.3	33	U-235 series; should be in equilibrium
Th-234	1.00	128	16	U-238 series; should be in equilibrium
Tl-208	1.00	10.3	15	Th-232 series
U-235	1.00	10.6	22	U-235 parent

The uncertainties largely relate to background noise levels at the low gamma activity areas in the small sample. However, activity ratios for the U-238 and U-235 can be obtained by dividing out the signals from the immediate daughter nuclides, Th-234 and Th-231. The half-life of Th-234 is 24.1 days and so this nuclide should be in equilibrium with the parent U-238. Similarly for Th-231, the half-life of 25.5 hours means that this nuclide should be in equilibrium with the parent U-235. This is taken to give the correct activity for the U-235 since the Fitzpeaks estimation from the U-235 peak at 186keV is confounded by the presence of the Ra-226 peak at the same position. The uncertainties in these peak areas will be the same. Doing this gives an activity ratio of 128/21.3 = 6.01. If we employ the U-235 peak the activity ratio is 128/10.6 = 12.08.

If we take the extremes of the ranges of error then we have Th-234 = 148.48 and Th-231 = 14.27and the highest ratio becomes 10.41. If we do the same for the U-235, that gives 8.27 for the lowest possible U-235 activity and a ratio of 17.95.

So it appears from these results that the sample contains slightly enriched Uranium at an activity of about 128Bq/kg +/- 16%. This supports the earlier Busby Collingridge report and would also support the high gamma background found in the walk over survey reported above. The EA's estimated uranium concentration range for the area, by contrast, is 24-31Bq/kg.

In addition it seems that there is a significant quantity of Thorium on the site and detectable Caesium-137.

4.4 ICPMS

Two samples (one from same location as above – Sample 4; Sample 3, 10m to the east of it) were sent to the laboratory, Microtrace Minerals, in Germany for analyses by ICPMS. The samples were treated with Nitric acid/hydrogen peroxide; resultant solution was filtered, diluted and injected into the ICPMS system. Uranium isotope ratios were obtained from the ratio of counts in the respective 235 and 238 channels with subtracted background. Results are given in Table 2. Results for the Uranium isotope ratios are given in Table 3.

Table 2 below gives concentration results for samples GA7113 and GA 7114 (Sample 3 and Sample 4 West. Mg/kg soil. Only elements above detection limit are shown. *Significantly high* as labelled by laboratory.

Element	**GA7113**	**GA7114**	**LOD**	**Note**
Al	31400	26490	1.00	
As	14.53	12.29	0.5	Significantly high
B	57.21	51.38	1.00	
Ba	123.9	106.1	0.5	
Be	1.82	1.49	0.5	
Ca	15620	25250	100	High
Cd	1.4	1.32	0.5	
Ce	55.73	43.54	0.5	
Co	18.15	14.27	0.5	
Cr	53.00	45.27	0.5	High
Cs	4.69	4.01	0.5	
Cu	49.44	42.91	1.00	Significantly high
Dy	4.48	3.63	0.5	
Er	2.31	1.87	0.5	
Eu	1.32	1.09	0.5	
Fe	31510	25880	25	Significantly high 31g/kg
Ga	10.32	8.64	0.5	
Gd	6.03	4.88	0.5	
Ge	3.77	2.93	0.5	
I	57.07	40.12	0.5	
La	24.18	19.81	0.5	
Li	35.4	29.71	0.5	
Mg	5427	4734	25	Significantly high
Mn	844	721	0.5	High
Mo	12.66	11.66		
Na	Not done	Not done		
Nd	28.63	23.07	0.5	
Ni	57.27	47.38	0.5	High
Pb	29.66	23.83	0.5	
Pr	6.82	5.60	0.5	
Rb	59.93	50.51	0.5	
Se	0.88	0.86	0.5	High. Suggests sea water
Sm	5.88	4.77	0.5	
Sr	50.93	57.12	0.5	
Th	6.45	5.40	0.5	
Ti	25.61	27.00	0.50	
Tl	1.18	1.06	0.50	
U	1.02	0.91	0.25	
V	89.4	78.8	0.5	Significantly high
Yb	1.8	1.45	0.5	
Zn	132.3	120.8	5.00	
Zr	10.79	9.43	0.5	

Table 3. Uranium isotope atomic ratios for samples GA7113 and GA 7114

	Sample GA7113	Sample GA7114
Raw counts	117	116
Channel 239 corrected	130.6	130.4

5. Discussion

The elemental ICPMS scan shows unusually high levels of Iron, Copper, Manganese, Chromium, Nickel and also Arsenic. This suggests that the soil is unusual and possibly indicative of contamination rather than interpreted as a geochemical characteristic of the underlying Blue Lias enhanced by natural processes in the soil. Contaminants may contain stainless steel corrosion components from reactor materials, brought ashore by sea-to-land transfer along with the enriched uranium.

The high Selenium levels suggest seawater. Also, the US Geological Survey quantify the mean Iodine value in soils as 1.2 parts per million (1-2 mg/kg) - the samples have 40-57 mg/kg.

The overall levels of Uranium in the soil are far lower than are expected from the gamma spectrum of the same sample, which suggests that the Uranium extraction using the nitric acid/hydrogen peroxide method is very inefficient. Other work carried out by Green Audit on Uranium in soils in Wales and elsewhere suggests that much more aggressive dissolution is necessary to fully extract Uranium into solution (e.g. HF and HNO3 or *aqua regia*). Nevertheless the Uranium isotopes should be equivalently extracted and the isotope ratio should be correct. This shows slightly enriched Uranium and supports the gamma analysis.

The gamma spectrum indicates a high overall concentration of Uranium, more than 120Bq/kg on the basis of the Th-234 signal. According to calculations given by the NCRP94 Table 5.1 (NCRP94) this would give a gamma radiation dose rate over soil uniformly contaminated to this level of 60nGy/h. The Thorium-232 level of 30Bq/kg (from the Ac-228) would contribute 20.5nGy/h and the Potassium-40 would give 26nGy/h. Adding 35uGy/h for cosmic rays would give a total dose rate at 1m over this surface from all these nuclides and their daughters alone of 141.5nGy/h in fair agreement with the gamma measurements reported here, but significantly greater than those expected on the basis of EA reports (see above).

6. Conclusions

Although further work is being carried out within the constraints of funding, these results support our earlier conclusions that the site is contaminated with enriched Uranium and call into question the analyses and conclusions of the Environment Agency. The origin of this contamination may be sea to land transfer of historic releases to the sea and contamination of marine sediment. We recommend that the SAFEGROUNDS protocols are now applied and funding made available to make a joint study of the area. If enriched Uranium is present on the site, its origin must be investigated. To say, as the EA and the operators have, that it cannot have come from the plant because there is no mechanism, is to beg many questions.

In view of the high levels of breast cancer in populations of Fallujah, in Iraq, now known to be contaminated with enriched Uranium (Busby et al 2010, Alaani et al

2011), measurements of Uranium should be made in environmental samples from Burnham-on-Sea, downwind of the Hinkley Point nuclear plants, where an on-going breast cancer excess exists.

7. Acknowledgements

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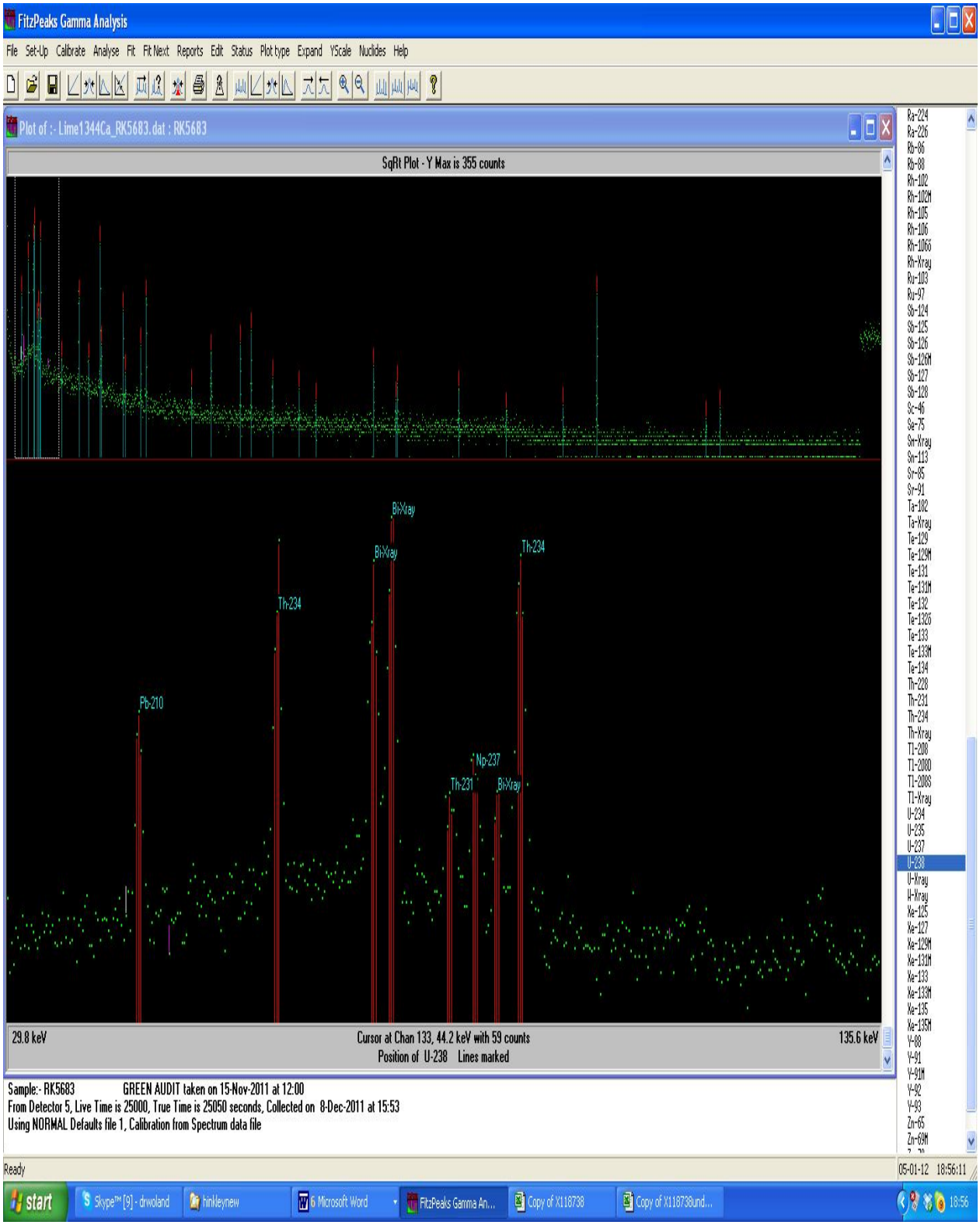
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Plot of :- Lime1344Ca_RK5683.dat : RK5683
SqRt Plot - Y Max is 355 counts
Bi-Xray
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Th-234
Pb-210
Np-237
Th-231
Bi-Xray
29.8 keV
Cursor at Chan 133, 44.2 keV with 59 counts
Position of U-238 Lines marked
135.6 keV
Sample:- RK5683 GREEN AUDIT taken on 15-Nov-2011 at 12:00
From Detector 5, Live Time is 25000, True Time is 25050 seconds, Collected on 8-Dec-2011 at 15:53
Using NORMAL Defaults file 1, Calibration from Spectrum data file
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