MALRAD SCENARIO DETAILS

The following provides some basic details as to the scenarios of the NKS MALRAD activity. Fuller details are contained in the final report to NKS. The scenarios were hoped to represent situations whereby one is required to analyse materials that one is not used to analysing – it was supposed that the participants did not have access to specialist software such as those used in U or Pu analysis - and that the analyst was being asked to work with material that was perhaps not optimal – such as measurement of U on a coaxial detector or the use of low resolution detectors. It was also hoped that the scenario materials would provide a challenge for the analyst as opposed to just challenging the software. In all cases, a careful analysis by ”hand” could have yielded more information than perhaps would have been the case where reliance was made solely on software.

Scenario 1.

The background of scenario 1 was response to a hypothetical radiological dispersion device (RDD). Although there are essentially no documented examples of such an event, the consequences of such a device and the attention they receive warranted its inclusion. The source for scenario 1 was assumed to have been an RDD employing a 10 Ci (370 GBq) ^{241}Am/Be well logger that was 10 years old. Based on an initial activity of 10 Ci and an age of 10 years, the activities of the source and its daughters were calculated to be:

Isotope	Initial activity (GBq)	Activity after 10 years (GBq)
Am-241	370	3.64117E+02
Np-237	0	1.18881E-03
Pa-233	0	1.17623E-03
U-233	0	2.55966E-08
Th-229	0	7.98090E-12
Ra-225	0	7.84030E-12
Ac-225	0	7.74780E-12
Fr-221	0	7.74780E-12
At-217	0	7.74780E-12
Bi-213	0	7.74780E-12
Po-213	0	7.58130E-12
Tl-209	0	1.67351E-13
Pb-209	0	7.74780E-12

Table 1. Decay of source and ingrowth of daughters over 10 years for Scenario 1. Shaded isotopes are those included in the simulation.

Given that inappreciable amounts of daughters would be present below ^{233}U, the simulation was only conducted for this isotope and the preceding parents. For the purpose of MALRAD, it was assumed that the logger had been fully dismantled and the source had been exposed and was present in a dispersible form of small volume. The bomb type chosen for the scenario was that of the London Docklands bombing of 1996 and the source was assumed to have been placed centrally within a mass of 500 kg of an ammonium fertilizer/fuel oil blasting mixture (ANFO) as is typically found in homemade bombs. The mixture was assumed to primarily have the chemical composition NH_4NO_3 (5% H, 35% N , 60% O w/w nominal) which has a density of 1.725 g/cm^3 but a density of 0.84 g/cm^3 when mixed with the appropriate amount of fuel oil. The matrix had a volume 0.595 m^3 in the geometric form of a cube of side length 84 cm which was assumed to have a neglilgble contribution to shielding (paper or cardboard packing). This was then assumed to have been covered by a lead sheet (standard "lead blanket") of uniform thickness 2 mm and then placed centrally in the back of a truck whose construction on the side for measurement was to be 1 mm of iron. The width of the truck was 2 m and the detector was then positioned normal and central to one side of the cube and at a distance of 1.0 m from the source itself, in effect up against the side of the truck. The problem reduced to that of a point source with shielding between it and the detector. The effective shielding was that of 2 mm lead plus 1 mm of iron in addition to the shielding provided by 43 cm of the hydrogen rich explosive. Self attenuation within the "point" source itself was neglected. The neutrons that may have been expected to emanate from the well logger were not simulated although it is plausible that such neutrons would not have been detectable outside of the truck given the hydrogen rich nature of the bomb materials. On the other hand it is also plausible that there would be some induced activity due to the neutrons which would have resulted in a gamma signal but this was neglected based on the assumption that that activity would have been negligible relative to the source activity.

Two dose measurements were provided, one calculated for the same position at which the spectrum was taken and the second one meter further back along the same axis. The background dose in the area wasstated as 0.11 μSv/hr. The dose rate at position one (side of the truck) was stated as being 0.5 μSv/hr and at position 2 (1 m away from the side of the truck) 0.21 μSv/hr. The simulated detector was a standard 3 x 3 inch NaI detector with an aluminium case of 0.5 mm thickness being 4 mm from the crystal face. The nominal resolution was 6.9% at 662 keV. The spectrum was counted over 1024 channels covering the energy range 10 to 2600 keV. The count was for a live time of 600 seconds. The participants

were informed that the detector was collimated such that scattering effects could be expected to be lessened with respect to the spectrum. Random statistical noise was added to the spectrum after simulation. A simulated background signal was also added to the spectrum, the primary effect of this being the appearance of a slight ^{40}K peak at 1460 keV.

The primary potential problems with the spectrum as provided were the activity of the source and the thick shielding between source and detector. Although ^{241}Am has a range of gamma rays, the vast majority of commercially provided libraries include just the one primary line at 59.5 keV. Normally this line will dominate the spectrum of ^{241}Am but in this situation, the shielding present served to reduce the significance of this line in the spectrum and allow other normally less significant lines to dominate. In particular, ^{241}Am possesses a range of weak lines in the 200 to 400 keV and the 600 to 800 keV region, one of which has the potential for being easily mistaken for the 661 keV line of ^{137}Cs.

In theory, it was hoped that participants could correctly identify the source and hazard a guess as to potential activity present. Identification was potentially difficult given the much greater attenuation of the characteristic 59 keV peak and the potential for misidentification of the peak in the 600 keV as ^{137}Cs.

Scenario 2

Scenario 2 was intended to simulate an incident involving the siezure of an amount of weapons grade plutonium (WGPu). A number of incidents have been reported over the years involving varying quantities of such materials in a range of situations with perhaps the best known being the interdiction of several hundred grams of ^{6}Li and over half a kilo of mixed oxides of plutonium and uranium at Munich airport in 1994. Of this some 408 g was plutonium oxide of which 87% was fissile ^{239}Pu of 99.75% purity. Although the seizure of such materials would ultimately require or involve international assistance/authorities, it can be argued that any individual country should be in a position to conduct at least a preliminary analysis of the material for identification purposes and in that respect it was included in the MALRAD suite of scenarios.

The source for this scenario was considered to be 100 g of of 25 year old WGPuO sealed in a steel cylinder for the purposes of convenient smuggling. The PuO volume was 8.69 cc (assumed density 11.5) and was, for the purpose of the simulation, in the geometric form of a cylinder of dimensions 2 cm in diameter and 2.77 cm in height. This was then sealed in a steel cylinder of wall thickness 1 cm, external diameter 4 cm, and external

height 5 cm. The PuO was presumed to consist of the following weight composition at the time of purification, being typical for WGPu (Fetter S, 1990, et al., "Detecting nuclear weapons," Science & Global Security, 1 (3-4) 225-302,):

^{238}Pu 0.005% (0.005 g)

^{239}Pu 93.3% (93.3 g)

^{240}Pu 6.0% (6 g)

^{241}Pu 0.4% (0.4 g)

^{242}Pu 0.015% (0.015 g)

The Pu source was allowed to "decay" for 25 years to simulate Pu that was stolen from a repository for such materials or similar and daughters built up over that time were included if they had an activity of more than 10 Bq. Non-Pu impurities in the initial source were assumed to be less than 0.3%. For the purposes of the scenario, the following specific activities were used: ^{238}Pu – 6.3E+14 Bq/kg, ^{239}Pu – 2.3E+12 Bq/kg, ^{240}Pu – 8.4E+12 Bq/kg, ^{241}Pu – 3.8E+15 Bq/kg, ^{242}Pu – 1.5E+11 Bq/kg. Based on the above, the following was assumed to be present after 25 years decay.

	Bq		Bq		Bq		Bq		Bq
^{238}Pu	2.585E+09	^{239}Pu	2.144E+11	^{240}Pu	5.027E+10	^{241}Pu	4.563E+11	^{242}Pu	2.25E+06
^{234}U	2.030E+05	^{235}U	5.281E+03	^{236}U	3.727E+04	^{241}Am	3.463E+10	^{238}U	8.72E-03
^{230}Th	2.360E+01	^{231}Th	5.279E+03	^{232}Th	2.308E-05	^{237}U	1.119E+07	^{234}Th	8.69E-03
^{226}Ra	8.631E-02	^{231}Pa	1.394E+00	^{228}Ra	1.259E-05	^{237}Np	1.693E+05	^{234m}Pa	8.67E-03
^{222}Rn	8.615E-02	^{227}Ac	3.062E-01	^{228}Ac	1.259E-05	^{233}Pa	1.681E+05	^{234}Pa	2.86E-05
^{218}Po	8.615E-02	^{227}Th	2.996E-01	^{228}Th	9.631E-06	^{233}U	6.712E+00	^{234}U	3.07E-07
^{214}Pb	8.615E-02	^{223}Fr	4.225E-03	^{224}Ra	9.616E-06	^{229}Th	4.168E-03	^{230}Th	2.30E-11
^{218}At	1.723E-05	^{223}Ra	3.021E-01	^{220}Rn	9.616E-06	^{225}Ra	4.131E-03	^{226}Ra	5.70E-14
^{214}Bi	8.615E-02	^{219}Rn	3.021E-01	^{216}Po	9.616E-06	^{225}Ac	4.105E-03	^{222}Rn	1.25E-13
^{214}Po	8.615E-02	^{215}Po	3.021E-01	^{212}Pb	9.616E-06	^{221}Fr	4.105E-03	^{218}Po	1.33E-15
^{210}Pb	1.456E-02	^{211}Pb	3.021E-01	^{212}Bi	9.616E-06	^{217}At	4.105E-03	^{214}Pb	0.00E+00
^{210}Bi	1.452E-02	^{211}Bi	3.021E-01	^{212}Po	6.159E-06	^{213}Bi	4.105E-03	^{218}At	1.30E-17
^{210}Po	1.338E-02	^{207}Tl	3.013E-01	^{208}Tl	3.455E-06	^{213}Po	4.017E-03	^{214}Bi	1.09E-13
		^{211}Po	8.461E-04			^{209}Tl	8.869E-05	^{214}Po	2.31E-13
						^{209}Pb	4.105E-03	^{210}Pb	1.06E-13
								^{210}Bi	5.91E-14
								^{210}Po	9.65E-14

Table 2. Isotopes and activities based on 25 years decay and ingrowth of the 100 g of WGPuO for Scenario 2. Shaded isotopes with activities above 10 Bq were used in the simulation.

For the purposes of Scenario 2, the steel cylinder was counted over a HPGe detector as a preliminary step in its analysis and it was the result of this analysis which formed the basis for the scenario. The distance between the endcap of the detector and the bottom of the cylinder was 15 cm which would be a typical distance for measurements of this type. Self absorption by the PuO matrix was included in the simulation as was the 1 cm of steel shielding due to the cylinder itself. The detector was a standard coaxial HPGe detector with an aluminium endcap,

dead layer of 0.5 mm, relative efficiency of 50% and a resolution of 1.9 keV at 1332 keV. The spectrum was between 10 keV and 2000 keV with a discrimination of 30 keV and 8192 channels. The live time was 3600 seconds. No efficiency data was provided to the participants. Such a situation, due to lack of information of the geometry, would of course not facilitate generation of efficiency values.

It was hoped that the source would have been identified as plutonium and at least some Pu isotopes should have been relatively easy to identify (including the ^{241}Am daughter of ^{241}Pu). *Although the spectrum is complex and the detector used was not optimal for the purpose, it is potentially possible to establish some information about the source. Efficiency information was not provided but if the isotopes had been correctly identified it should have been feasible to establish the ^{239}Pu/^{240}Pu relationship and decide that the material was weapons grade even in the absence of efficiency data as these two have a couple of peaks near each other that would allow for a ratio to be established. To determine the age of the material since separation would be difficult but a reasonable estimate should have been possible. One weakness was that the ^{17}O peak at 870 keV was not included and this is traditionally used to indicate the presence of the oxide as opposed to the metallic form.*

Scenario 3

Scenario 3 was intended to simulate the use of radiation for murder such as has occurred in a number of cases but of most relevance in this instance is the incident where a Chinese nuclear scientist, Gu Jiming, employed ^{192}Ir pellets in an attack on a business rival. Having used forged papers to acquire an industrial device containing ^{192}Ir, the source was then placed in the ceiling panels in the hospital office of the victim. The victim reported symptoms including memory loss, fatigue, appetite loss, headaches, vomiting, and bleeding gums. Another 74 staff members of the hospital, including one pregnant woman, also exhibited symptoms. Gu was convicted for the crime on the 29th of September 2003 (Nature, "Researcher faces life in prison for revenge radiation poisoning," Nature, 2003. 425:552) . The context of the placing of the source for Scenario 3 was taken from the situation involving the exposure of a man in Russia as a result of a 1.3 Ci ^{137}Cs source having being placed in the door of his truck as reported by Sevan'kaev et al (Sevan'kaev, A. V., D. C. Lloyd, A. A. Edwards, G. F. Mikhailova, V. Yu. Nugis, E. V. Domracheva, A. E. Baranov, A. A. Davtian, A. A. Gordeeva, I. A. Gusev, A. K. Guskova, V.V. Moiseenko, and Yu. V. Olshanskaya, 1999, "Protracted overexposure to a ^{137}Cs source: I, Dose reconstruction," Radiation Protection Dosimetry,

81:85-90.). The source in Scenario 3 consisted of the isotope ^{192}Ir in the form of brachytherapy seeds. The source was assumed to be an effective point source of 300 mCi (11.1 Gbq) of ^{192}Ir placed in the car seat of the victim. The shielding provided by the car was assumed to be equivalent to 4 mm of iron. A point source spectrum of ^{241}Am, ^{137}Cs and ^{60}Co was also provided. Dose measurements were also taken at a point 2 m from the source where the dose rate was 229 μSv/hr and at 4 m from the source where the dose was 57 μSv/hr. The detector was a CdZnTe of 3 cm^3 volume with a supposed resolution at 1332 keV of 16 keV. The spectrum was taken over 4096 channels covering the energy range 10 keV to 1500 keV (0.36376 keV/channel) for a period of 60 seconds. Random statistical noise was added but no background.

It was intended that the participants should have had enough information to identify the source for what it was and derive a reasonable estimate of activity.

Scenario 4

The purpose of this scenario was to simulate the use of irradiated graphite in a malevolent act. Such materials have been employed maliciously before, in particular the use of irradiated graphite under the driver's seat of a car whereby the victim sustained a 25-30 rad dose to his spinal bone marrow and 400-500 rads to his testes (Mullen, Robert K., "Nuclear Violence", in Preventing Nuclear Terrorism: The Report and Papers of the International Task Force on Prevention of Nuclear Terrorism, ed. by Paul Leventhal and Yonah Alexander, 1987, Lexington, MA: Lexington Books, pp. 231-247). The material was included in MALRAD due to its being less securely guarded than high level materials and its being an interesting source in relation to identifying the material. The scenario intended to simulate a situation where the material had been spread over an area and in-situ measurements were made in an attempt to identify the material. 1 kg of graphite of density 2 g/cm was assumed to have been spread over 5000 cm^2 to an average thickness of 1 mm. Due to there being little available information as to the actual activity of activated graphite, the work of Ancius et al (Ancius, D., Ridikas, D., Remeikis, V., Plukis, A., Plukiene, R., Cometto, M., Evaluation of the activity of irradiated graphite in the Ignalina Nuclear Power Plant RBMK-1500 reactor, Nukleonika 2005;50(3):113−120.) was used and the graphite for scenario 4 was assumed to have been 10 years old. Calculations for this time period indicate no appreciable build up of daughter products. The activity details of gamma emitting isotopes in the dispersed graphite are contained in Table 3.

Isotope	Total activity Bq
^{60}Co	1.9E+07
^{244}Cm	1.6E+07
^{137}Cs	1.6E+05
^{154}Eu	1.1E+05
^{155}Eu	1.8E+04

Table 3. Isotopes and activities for the source of Scenario 4.

A 3 x 3 NaI detector (10 – 2500 keV, 7% @ 661 keV, 1.2158 keV/channel, 2048 channels) was suspended 50 cm above the source and a spectrum taken for a period of 20 minutes. A point source spectrum of ^{241}Am, ^{109}Cd, ^{137}Cs, ^{88}Y and ^{60}Co was also provided. No background was added. The primary features of the spectrum as provided were the two characteristic peaks of ^{60}Co which dominate the spectrum. The higher activity of this isotope plus the strength of its emissions tended to obscure most other features of the spectrum although the 661 keV peak of ^{137}Cs and the 123 keV peak of ^{154}Eu were visible on inspection. The sub 100 keV region was dominated primarily by x-rays of the Eu isotopes. It is doubtful whether successful identification of the isotopes involved other than ^{60}Co and ^{137}Cs could be conducted based on the spectrum to hand or whether or not the material itself could be identified for what it was.

This scenario was perhaps a little difficult as ^{60}Co dominates but a careful examination of the spectrum should have facilitated the analyst identifying at least one of the other isotopes.

Scenario 5

This scenario involved the placing of a radioactive source on a bus intended to be representative of the type of situations where radioactive sources have been left in public places for whatever purpose. A ^{99}Tc generator was chosen largely due to the relatively easy availability of such scources. The source in this case was a standard medical ^{99}Mo/^{99m}Tc generator. For the purpose of the exercise the source was assumed to be a 10 day old generator whose activity was 40 GBq at time 0. After 10 days the activity was 40 x 0.0804 ^{99}Mo, 40 x 0.0775 ^{99m}Tc (3.216 GBq ^{99}Mo and 3.1 GBq ^{99m}Tc). The detector was a typical handheld 2 x 2 inch NaI detector, of resolution 7% at 661 keV. The spectrum was taken one meter from the source for a period of 10 mins over 2048 channels covering 10 keV to 2500

keV (1.2158 keV/channel). A background signal was also added to the spectrum manifesting itself primarily as a ^{40}K peak at 1460 keV.

This scenario was intended to be simple enough and the spectrum and dose data should have allowed for both identification and an activity estimate.

Scenario 6

The sixth scenario was directed towards a situation involving theft of a source which in this instance was the radiographic isotope ^{75}Se. The source consisted of 40 Ci (1480 GBq) of ^{75}Se which is a midrange activity for ^{75}Se based radiography sources. The source was positioned within a pile of scrap such that an effective shielding of 10 cm of aluminium was covering the source. The detector was a 3 cm^3 CdZnTe detector positioned 5 m from the source (including the 10 cm of Al). The detector had a relative efficiency of 1% and a resolution of 16 keV at 1332 keV. A spectrum was taken for 20 seconds over 2048 channels covering 10 keV to 1500 keV (0.72755 keV/channel). No background was added. A low energy scattering continuum was added to the spectrum.

Se-75 is perhaps not so well known as a source although it is actually reasonably common in certain applications. The resolution of the detector should have been sufficient to facilitate identification and a reasonable activity estimate should also have been possibl even in the presence of shielding. The main challenge was perhaps the scattering although this should not have been insurmountable.

Scenario 7

The source in this scenario was considered to be highly enriched uranium and was intended to represent a situation whereby a laboratory may be asked to analyse a sample of nuclear material which it may be assumed is outside the suite of usual activities of many labs and yet represents a situation that may arise. The basis of the source was the composition of the smuggled uranium seized in Bulgaria in 1999. The isotopic composition of this uranium was as follows at the time of its seizure:

^{242}Pu 4.6x10^{-9}	^{238}U 13.9	^{231}Pa 4.6x10^{-7}
^{241}Pu 7.9x10^{-9}	^{236}U 11.9	^{230}Th 2.0x10^{-5}
^{240}Pu 2.6x10^{-8}	^{235}U 72.7	^{229}Th 9.9x10^{-10}
^{239}Pu 2.2x10^{-7}	^{234}U 1.1	^{228}Th 2.6x10^{-8}
^{238}Pu 1.1x10^{-8}	^{233}U 2.9x10^{-5}	^{227}Ac 3.3x10^{-11}
^{137}Cs 4.6x10^{-10}	^{134}Cs 3.3x10^{-13}	^{125}Sn 5.3x10^{-11}
^{237}Np 6.6x10^{-7}	^{232}U 1.1x10^{-6}	^{226}Ra 6.3x10^{-10}

Table Isotopic composition %w/w (taken from Forensic Analysis of a Smuggled HEU Sample Interdicted in Bulgaria, Lawrence Livermore National Laboratory, US Dept. of Energy, UCRL-ID-143216, 2001.)

For MALRAD, all isotopes except those of uranium were removed from the consideration and the uranium composition of the material in the Bulgarian sample was assumed to be that at the time of last purification. This was then allowed to decay for a period of ten years and the daughters calculated. The sample was considered to be 10 g which was then counted 10 cm above the surface of a HPGe detector. The activities of the uranium isotopes were derived from the mass composition as follows:

Isotope	^{238}U	^{236}U	^{235}U	^{234}U	^{233}U	^{232}U
w/w % of U	1.39E+01	1.19E+01	7.27E+01	1.10E+00	2.90E-05	1.10E-06
Mass of sample g	10	10	10	10	10	10
Isotope mass	1.39E+00	1.19E+00	7.27E+00	1.10E-01	2.90E-06	1.10E-07
Specific activity Bq/g	1.20E+04	2.40E+06	8.00E+04	2.30E+08	3.60E+08	7.90E+11
Sample activity Bq	1.67E+04	2.86E+06	5.82E+05	2.53E+7	1.04E+3	7.89E+4

The activities of the isotopes and ingrown daughters were as in Table 4. and any daughter with an activity over 20 Bq was included in the simulation. The density of uranium oxide was taken to be 10.96 g/cm^3, the volume of the sample presented to the detector being 0.912 cm^3, this being presented in the form of a compact disc 2 cm in diameter and 2.9 mm in height. The detector was calibrated with an aqueous solution of equivalent geometry of the following nuclides: ^{241}Am – 30000 Bq, ^{57}Co – 10000 Bq, ^{60}Co – 10000 Bq, ^{54}Mn – 10000 Bq, ^{65}Zn – 10000, ^{88}Y – 10000 Bq, ^{137}Cs – 10000 Bq and ^{109}Cd – 10000 Bq and counted in the same

configuration (ie. 10 cm above the detector). The composition of the uranium matrix was 11.85% w/w O and 88.15% w/w U. The sample was counted on a standard coaxial HPGe detector with a resolution of 1.8 keV at 1332 keV covering 10 to 3000 keV over 8k channels.

^{238}U	1.67E+4	^{236}U	2.86E+6	^{235}U	5.82E+5	^{234}U	2.53E+7	^{233}U	1.04E+3	^{232}U	7.89E+4
^{234}Th	1.67E+4	^{232}Th	1.41E-3	^{231}Th	5.82E+5	^{230}Th	2.28E+3	^{229}Th	9.85E-1	^{228}Th	7.87E+4
^{234m}Pa	1.66E+4	^{228}Ra	5.92E-4	^{231}Pa	1.23E+2	^{226}Ra	4.93E+0	^{225}Ra	9.80E-1	^{224}Ra	7.87E+4
^{234}Pa	5.50E+1	^{228}Ac	5.92E-4	^{227}Ac	1.76E+1	^{222}Rn	4.91E+0	^{225}Ac	9.76E-1	^{220}Rn	7.87E+4
^{234}U	4.69E-1	^{228}Th	3.72E-4	^{227}Th	1.71E+1	^{218}Po	4.91E+0	^{221}Fr	9.76E-1	^{216}Po	7.87E+4
^{230}Th	2.09E-5	^{224}Ra	3.71E-4	^{223}Fr	2.43E-1	^{214}Pb	4.91E+0	^{217}At	9.76E-1	^{212}Pb	7.87E+4
^{226}Ra	2.99E-8	^{220}Rn	3.71E-4	^{223}Ra	1.72E+1	^{218}At	9.82E-4	^{213}Bi	9.76E-1	^{212}Bi	7.87E+4
^{222}Rn	2.98E-8	^{216}Po	3.71E-4	^{219}Rn	1.72E+1	^{214}Bi	4.91E+0	^{213}Po	9.55E-1	^{212}Po	5.04E+4
^{218}Po	2.98E-8	^{212}Pb	3.71E-4	^{215}Po	1.72E+1	^{214}Po	4.91E+0	^{209}Tl	2.11E-2	^{208}Tl	2.83E+4
^{214}Pb	2.98E-8	^{212}Bi	3.71E-4	^{211}Pb	1.72E+1	^{210}Pb	4.71E-1	^{209}Pb	9.76E-1		
^{218}At	5.95E-12	^{212}Po	2.38E-4	^{211}Bi	1.72E+1	^{210}Bi	4.68E-1				
^{214}Bi	2.98E-8	^{208}Tl	1.33E-4	^{207}Tl	1.72E+1	^{210}Po	4.01E-1				
^{214}Po	2.98E-8			^{211}Po	4.82E-2						
^{210}Pb	2.16E-9										
^{210}Bi	2.15E-9										
^{210}Po	1.76E-9										

Table 4. Isotopes and activities as included in Scenario 7.

Scenario 7 had the potential to reward a thorough analysis with extra information. The presence of isotopes such as ^{236}U (difficult but not impossible) and ^{232}U (via its daughters) could have been established and these would allow one to conclude that the material was reprocessed uranium from a reactor. The efficiency information provided was of course weak given the high density of the sample but there were routes that could be followed. Trying to correct the efficiency curve using mathematical routines or whatever would have been tricky below a 1000 keV or so cutoff but the potential was present to correct the efficiency for the high energy peak of ^{208}Tl (for which the density correction would have been quite small given the energy) and then use ^{208}Tl (which has many peaks) as the basis to establish a rudimentary calibration curve(either in terms of efficiency or just via expressing other nuclides as relative to the ^{208}Tl content) over much of the spectrum. Such an operation would have facilitated further analysis and a good estimate of the enrichment level should have been within grasp (using any of the higher energy ^{235}U peaks and that of ^{234m}Pa). Calculating the age since purification would have been difficult.