IDENTIFICATION OF NUCLEAR MATERIAL WITH HAND-HELD AND PORTABLE GAMMA AND NEUTRON MEASURING DEVICES

M. Risse[1], W. Berky[1], H. Friedrich[1], T. Köble[1], W. Rosenstock[1],
H. Rennhofer[2], B. Pedersen[2],
[1]Fraunhofer-INT P.O. Box 1491, 53864 Euskirchen, Germany,
[2]Joint Research Centre, 21020 Ispra, Italy

1 ABSTRACT

Performing fast measurements in the field at places where suspicious objects were found is essential in the context of nuclear terrorism. Especially if nuclear material is involved, it is necessary to identify small amounts of plutonium or uranium and to gain information concerning isotopic composition. Therefore, measurements at different uranium and plutonium samples were carried out. Samples with different isotopic compositions have been used for the present work. For gamma measurements hand-held and portable devices using different detector materials were investigated. The nuclide identification results of implemented automatic identification routines were compared for the different devices and to the given source information. As hand-held device with germanium detector (Ge) the ORTEC Micro Detective with electrical cooling was used. The identiFINDER-Ultra from ICx was used as an example for a hand-held device and gamma-ray spectrometer with the most common detector material sodium iodide (NaI). Another investigated detection system was the InSpector 1000 from Canberra which contains a lanthanum bromide ($LaBr_3$) crystal. A fourth type of detector material is used by the INTERCEPTOR from Thermo which is equipped with cadmium-zinc-telluride (CZT) crystals. Some of the measurement devices also have neutron detectors but with very small volume and therefore low efficiency. A portable neutron detector with an implemented analysis routine for the discrimination between industrial and nuclear neutron sources is the Fission Meter from ORTEC. The paper presents results obtained with the different measurement systems. The quality of the outcome of the automatic identification routines of the different detection systems varied significantly. These results depended not only on the different detector materials but also on the type of nuclear material. In general identification of uranium was considerably better than the identification of plutonium.

Keywords: Nuclear terrorism, uranium, plutonium, identification, gamma detection, hand-held devices, $LaBr_3$, neutron coincidence measurements, Fission Meter

2 INTRODUCTION

In the context of a possible terrorist threat rapid detection and identification of radioactive material is crucial, especially in the case of nuclear material. In order to evaluate the correctness of measurement results from automatic analysis routines it is essential to have good experience concerning such measurements. Therefore comparable measurements under definite conditions with known sources have to be carried out.

Therefore measurements with different uranium and plutonium samples were performed at the Institute for the Protection and Security of the Citizen (IPSC) at the Joint Research Center (JRC) in Ispra, Italy. Figure 1 shows a typical experimental setup. Each source was positioned in the centre of a circle composed of the gamma detection systems on the left side and the neutron measurement system Fission Meter on the right side. All gamma detectors were located on a table with the crystal centre at the same height; the centre of the Fission Meter, which was

located in front of the table, was on the same height too. Most measurements were done with a source to detector distance of 20 cm for the gamma measurements and a distance of 10 – 40 cm for the Fission Meter. Due to the geometry of the objects and to achieve a practicable count rate a few gamma measurements were done at other distances (from 15 cm up to 170 cm for MOX).

Figure 1: **Experimental setup with a uranium source in the centre of the detectors. The detection systems starting on the right side counter-clockwise are: Fission Meter, INTERCEPTOR, InSpector 1000, Micro Detective and identiFINDER-Ultra. Some detectors are placed on small tables for height compensation.**

Three plutonium, one MOX and seven uranium sources were used. The isotopic composition varies in the case of the plutonium sources from reactor grade (MOX, ^{239}Pu: 66 %) and fuel grade (Pu1: 70 %, Pu2: 84 %) up to weapon grade (Pu3: 93 %). In the case of the uranium sources the enrichment varies from depleted (DU, ^{235}U: 0.31 %) and low enriched (U1: 2.95 %, U2: 4.5 %) up to high enriched (U4: 36 %, uranium plates: 93 %).

3 DETECTION SYSTEMS

3.1 Measurement systems for Gamma Measurements

Table 1 gives an overview of the gamma detection systems seen in Figure 1. The detector crystal material is specified as well as some characteristic values; the outer dimensions of the systems are given also. All detectors feature a different detector crystal which lead to different energy resolution and efficiency. This might lead to different qualities of the results from automatic analysis routines. The germanium detector has by far the best energy resolution, the lanthanum bromide and cadmium-zinc-telluride crystals have similar energy resolutions but very different efficiencies, the poorest resolution of the tested systems has the sodium iodide detector. All systems feature identification modes and gamma spectra can be obtained.

In the case of the InSpector 1000 and the identiFINDER-Ultra the measurement time of the identification mode needs to be set in advance (120 s for the InSpector 1000, 30 s for the identiFINDER-Ultra), the INTERCEPTOR automatically selects the measurement time (typically 60 s), and the Micro Detective‘s identification mode displays continuously actual results and runs until it is manually stopped by the user. With all systems it is possible to obtain a spectrum without a preselected time and to do the identification later by using this spectrum. These facts lead to a greater variety of measurement times. Whenever possible, spectra with

longer measurement times were obtained. To collect as much data as possible also series of identification measurements with shorter times were done.

All detection systems except the Micro Detective yield a “confidence factor” after the analysis has been completed, referring to the degree of certainty the specified nuclide was identified. Not all devices give indications for the isotopic composition of uranium and plutonium: the Micro Detective distinguishes four uranium and three plutonium types; the identiFINDER-Ultra gives two uranium and two plutonium types; the InSpector 1000 gives two plutonium types and the INTERCEPTOR generates no information concerning enrichment and isotopic composition.

Detector, Crystal Material	**Manufacturer**	**Weight of device [kg]**	**Size of Device [cm]**	**Crystal Size [cm]**	**Energy Resolution [keV] at 662 keV**	**Relative Efficiency [%] for ^{60}Co**	**Battery Life [h]**
Micro Detective, HPGe	Ametek / ORTEC	6.9	37.4 x 14.6 x 27.9	3 (Length) / 5 (ø)	1.5	10.7	> 3
InSpector 1000, $LaBr_3$	Canberra	2.4 (Body + Probe)	19 x 16.5 x 6.4 (Body)	3.8 (Length) / 3.8 (ø)	23.2	12.6	9
IdentiFINDER-Ultra, NaI(Tl)	ICx Radiation	1.25	24.8 x 9.4 x 7.6	5.1 (Length) / 3.6 (ø)	45	8.0	8
INTERCEPTOR, CZT	Thermo	0.27	11.2 x 6.1 x 2.5	0.7 x 0.7 x 0.35	19	0.02	10

Table 1: Overview of the gamma detection systems and their specifications for the gamma identification detector. All devices have an identification mode. The relative efficiencies are obtained using the standard measurement procedure in which a ^{60}Co source is placed 25 cm away from the end-cap of the detector.

3.1.1 Micro Detective

The Micro Detective [1] has implemented software with analysis functionality. When its analysis routine has led to a first hint nuclides are listed as “suspected”, when lead to a credible result nuclides are listed as “found” (confidence factor 99.9 % according to the manual). In the case of nuclear material the following relevant results for the degrees of enrichment or isotopic composition are possible:

- Pu, including ^{241}Am: major lines of Pu and high energy lines of ^{241}Am are detected.
- Weapon Grade Pu: major lines of Pu are detected and indication for ^{239}Pu > 90 %.
- Reactor Grade Pu: major lines of Pu are detected and ^{239}Pu < 90 %.
- Highly enriched uranium: major lines of U are detected and indication for ^{235}U > 70 %.
- Depleted uranium: major lines of U are detected and indication for ^{235}U < 0.6 %.
- Natural uranium: major lines of U are detected and indication for ^{235}U ≈ 0.7 %.
- Low enriched uranium: major lines of U are detected and indication for 0.8 % < ^{235}U < 70 %.
- Elevated uranium concentration: peak count rates for major lines of U are significantly higher than background. Can be any enrichment.

It has to be mentioned, that in this device the limit between low enriched uranium and high enriched uranium is set to 70 % in contrast to the generally used value of 20 %.

The information “NORM” indicates natural occurring radioactive material (^{40}K, ^{226}Ra, ^{232}Th, ^{238}U). The other isotopes which will be identified are as follows: ^{57}Co, ^{60}Co, ^{133}Ba, ^{137}Cs, ^{192}Ir, ^{241}Am, ^{75}Se (industrial); ^{18}F, ^{67}Ga, ^{99m}Tc, ^{111}In, ^{123}I, ^{131}I, ^{133}Xe, ^{201}Tl (medical); ^{233}U, ^{235}U, ^{237}Np, ^{239}Pu, ^{252}Cf (nuclear) and ^{235}U, ^{239}Pu (special nuclear material, SNM).

3.1.2 InSpector 1000

The nuclide identification display of the InSpector 1000 [2] lists the isotope, its type (NORM, industrial, medical, SNM) and its correlation with values from the nuclide library as percentage: e.g. Ba-133 ind. 89.071 % or Cs-137 ind. 99.934 %. As preselected by the manufacturer the nuclide library “ANSI_LibCorNid” was used. It contains the following isotopes: ^{241}Am, ^{133}Ba, ^{57}Co, ^{60}Co, ^{51}Cr, ^{137}Cs, ^{67}Ga, ^{123}I, ^{125}I, ^{131}I, ^{111}In, ^{192}Ir, ^{40}K, ^{99}Mo, ^{237}Np, ^{103}Pd, reactor grade plutonium (PuRG), weapon grade plutonium (PuWG), Radium, ^{75}Se, ^{153}Sm, Thorium, ^{99m}Tc, ^{201}Tl, ^{202}Tl, ^{233}U, ^{235}U, ^{238}U, ^{133}Xe.

3.1.3 identiFINDER-Ultra

The nuclear identification mode of the identiFINDER-Ultra [3] displays the results as isotope listing like: 9 Ind Co-60; − Ind Na 22. This has to be understood as follows: The spectrum analysis suggests that the analyzed source contains ^{60}Co, and possibly ^{22}Na. The probability is rated between 1 (unlikely) and 10 (very likely). A very weak indication is displayed as “− “. In general results with indication below 7 are not reliable identified. “Ind” indicates the isotope is classified as industrial, other classifications are “norm” for natural occurring isotopes, “med” for isotopes for medical purpose and “nuc” for isotopes with a nuclear context. As preselected by the manufacturer the standard output of two isotopes was used. For all measurements it is necessary to ensure that the right nuclide library with the right isotopes is selected. For the presented measurements the nuclide library “security” was used, the isotopes in alphabetic order are: ^{241}Am, ^{133}Ba, ^{207}Bi, ^{57}Co, ^{60}Co, ^{51}Cr, ^{134}Cs, ^{137}Cs, ^{152}Eu, ^{67}Ga, ^{123}I, ^{125}I, ^{131}I, ^{111}In, ^{192}Ir, ^{40}K, ^{54}Mn, ^{22}Na, ^{237}Np, ^{240}Pu, reactor grade plutonium (RGPu), weapon grade plutonium (WGPu), ^{226}Ra, ^{75}Se, ^{99m}Tc, ^{232}Th, ^{201}Tl, ^{233}U, ^{235}U, ^{238}U, DU,^{133}Xe.

3.1.4 INTERCEPTOR

In the identification Mode, the INTERCEPTOR [4] acquires a spectrum and attempts to identify a radioactive isotope by comparing the measured spectrum with spectra (templates) stored in the internal library. The output of the INTERCEPTOR is displayed like: 64 % Industrial Co-60, 46 % Medical In-111. The percentage represents the probability of matching to the measured spectrum. According to the manufacturer the confidence levels for the isotope identification are defined as low (40 – 64 %), medium (65 – 84 %) and high (85 – 100 %). All isotopes that the unit can identify in its ID mode in alphabetic order are: ^{241}Am, ^{133}Ba, ^{57}Co, ^{60}Co, ^{137}Cs, ^{152}Eu, ^{67}Ga, ^{123}I, ^{125}I, ^{131}I, ^{111}In, ^{192}Ir, ^{40}K, ^{54}Mn, ^{99}Mo, ^{22}Na, ^{103}Pd, ^{239}Pu, ^{226}Ra, ^{75}Se, ^{153}Sm, ^{99m}Tc, ^{232}Th, ^{201}Tl, ^{233}U, ^{235}U, ^{238}U and ^{133}Xe.

3.2 Measurement System for neutron measurements - the Fission Meter System

The Fission Meter system [5],[6] consists of a hinged detector unit with 30 ^{3}He tubes and a polyethylene layer of approximately 2.5 cm on one side (see Figure 1). Three modes of measurement are available:

- **Static Search Mode**: average count rates
- **Mobile Search Mode**: count rate as a function of measuring time, used for location of neutron sources

- **Characterization Data Collect Mode**: determination of coincident neutrons using multiplicity plots in order to distinguish between industrial neutron sources and fissile material as well as obtaining Feynman plots in order to detect the presence of shielding material

4 RESULTS

4.1 Gamma Energy spectra

In the following figures gamma spectra obtained with the four detector systems are given. Figure 2 gives the result from a measurement of calibration sources ^{133}Ba, ^{137}Cs and ^{60}Co. The main energy lines of the isotopes as well as from the natural ^{40}K and ^{208}Tl are marked in the spectra. The different resolutions and efficiencies of the detector materials are visible as given in Table 1. By comparing the counts it is obvious that the INTERCEPTOR has a considerably lower efficiency. In the spectrum obtained with the Ge-detector all lines are resolved. The resolution in the $LaBr_3$ and CZT spectrum is lower and in the NaI spectra the single lines are smeared out to broad peaks. The spectra are normalized to the INTERCEPTOR spectrum measuring time. The energy calibration of the INTERCEPTOR is shifted to lower energies. Unfortunately it is not possible to change the energy calibration at the device. The energy range of the Micro Detective and the identiFINDER-Ultra are from 0 – approx. 3000 keV, the energy range of the INTERCEPTOR and the InSpector 1000 from 0 up to approx. 1500 keV. In the case of the INTERCEPTOR only with a long measurement time the whole spectrum has data unequal to zero. The present characteristics are preselected by the manufacturer and have not been changed in order to be able to evaluate results obtained with standard settings.

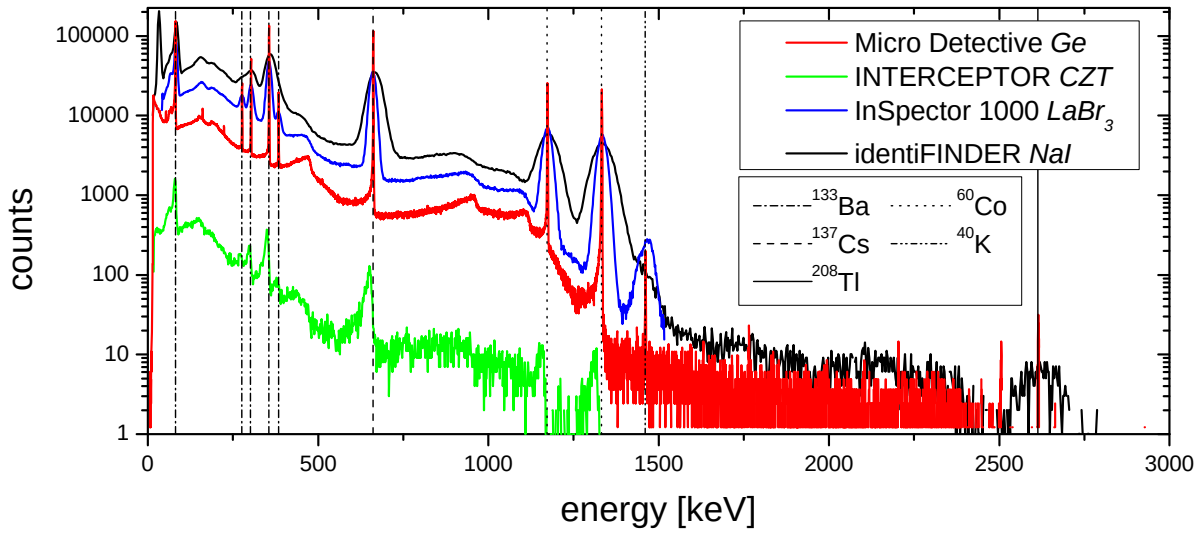


Figure 2: Comparison of spectra obtained with different detection systems using ^{133}Ba, ^{137}Cs and ^{60}Co calibration sources, distance 10 cm. All spectra are normalized to the INTERCEPTOR spectrum measurement time (2161 s) as reference. In addition the characteristic energies of the deployed sources as well as the natural ^{40}K and the natural ^{208}Tl are marked.

In Figure 3 the result of the measurement of the Pu3 source (^{239}Pu: 93 %) without shielding obtained with the different detection systems is shown. All spectra are normalized to the same measurement time (1002 s). In the spectrum obtained with the Ge-detector the main energy lines are clearly resolved, especially in the 400 keV region. In the $LaBr_3$ and CZT spectra the large

number of energy lines are smeared to a smaller number of peaks and in the NaI spectrum they are smeared to one broad peak.

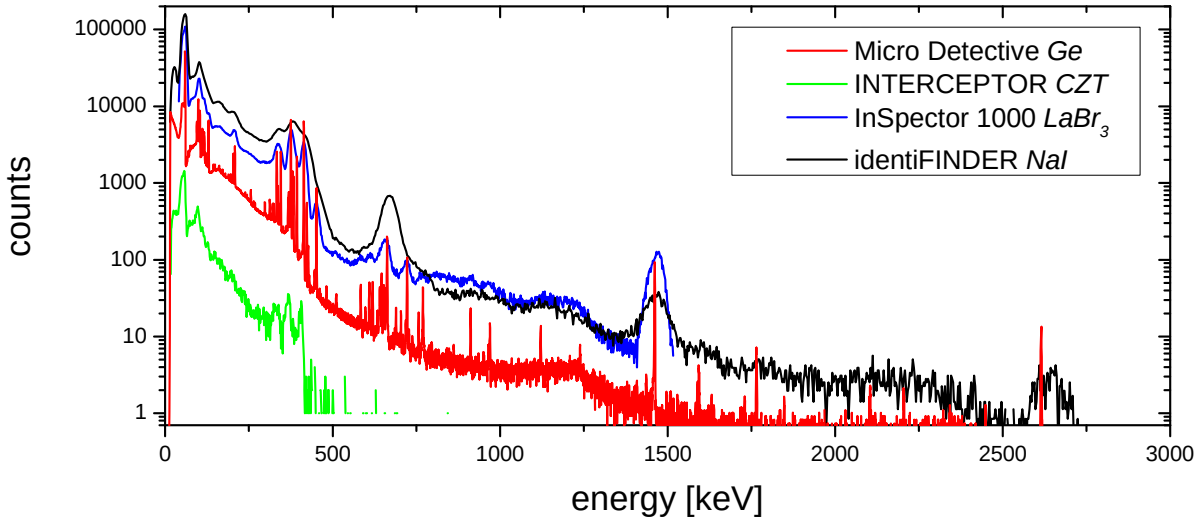


Figure 3: Comparison of spectra obtained with different detection systems using the Pu3 source (^{239}Pu: 93 %), distance 20 cm, without shielding. All spectra are normalized to the INTERCEPTOR spectrum measurement time (1002 s) as reference. The other actual measuring times have been longer.

4.2 Influence of geometry and shielding

The plutonium sources (Pu1, Pu2 and Pu3) consist of PuO_2 pellets with the diameter much larger than the thickness (Ø: 15 mm, thickness: 3.7 mm). Their housing consists of a stainless steel structure with 4 cm diameter with a stable back side and a thin window with a plastic cover on the front side (see photo in Table 2). Due to the self-absorption in the pellet and the different material thicknesses in different emission directions the radiation emission is not isotropic. Table 2 gives examples of measurement results done with the identiFINDER-Ultra with the source lying on the table with the metal back side up. The short time identification (30 s) leads to no result, the longer measurement time of 3600 s gives the result weapon grade plutonium with a low confidence factor. An additional tin shielding of 1 mm in front of the detector reduces the 59 keV energy line of the ^{241}Am. The short time identification (30 s) then gives the result weapon grade plutonium with even a bit higher confidence factor than the long measurement without the tin. A measurement from above the source facing the metal side leads to the same result. Concerning the investigation of an unknown object this means measurements from different sides of the objects can be very helpful. In the case that plutonium is expected, a tin shielding could improve the result as well.

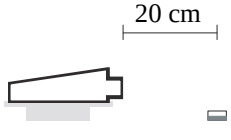
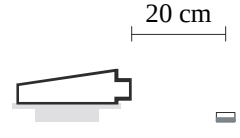
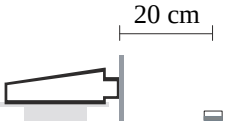
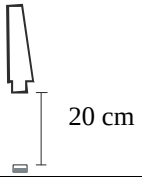
Geometry Pu 3 				
Live time [s]	30	3600	30	30
Shielding	-	-	1 mm tin	-
Identification Result	Nuclid listing: not identified	5 Nuc WGPu - Ind Am 241	6 Nuc WG Pu	6 Nuc WG Pu

Table 2: Results of measurements on the Pu3 source (93 % ^{239}Pu) with identiFINDER-Ultra. Sketches of the measurements with identiFINDER-Ultra, table for leveling and Pu3 source as shown in the photo.

4.3 Uranium Measurements

Table 3 gives an overview of the identification results obtained with uranium samples. All given results are achieved by the later analysis of measured spectra and not in short time identification measurements. For each source the measurement times for the detectors were comparable. Only for the DU different measurement times were applied.

Detector	DU	U1	U2	U4	Uranium plates
Data sheet ^{235}U	0.31 % depleted uranium	2.95 % low enriched uranium	4.5 % low enriched uranium	36 % high enriched uranium	93 % high enriched uranium
Micro Detective	▪ Depleted uranium ▪ Am 241 ▪ Count for > 3 min ▪ K 40	▪ Low enriched uranium ▪ Cs 137 ▪ Th 228 ▪ Th 232 ▪ K 40	▪ Low enriched uranium ▪ Cs 137 ▪ Th 228 ▪ Th 232 ▪ K 40	▪ High enriched uranium* ▪ K 40 ▪ Tl 208	▪ High enriched uranium ▪ Cs 137 ▪ K 40 ▪ Ra 226 ▪ Tl 208
Inspector 1000	(no measure-ment)	▪ U-235 SNM 97.0 % ▪ U-238 SNM 91.4 %	▪ U-235 SNM 98.2 % ▪ U-238 SNM 87.7 %	▪ U-235 SNM 99.5 %	▪ U-235 SNM 99.7 %
identiFINDER-Ultra	▪ 7 ind. DU 238 ▪ 4 NORM K 40	▪ 6 ind. DU 238 ▪ 5 Nuc U 235	▪ 5 Nuc. U 235 ▪ 5 Ind. DU 238	▪ 9 Nuc U 235	▪ 9 Nuc U 235
INTERCEPTOR	▪ 59 % nat. Th-232 ▪ 58 % U-238	▪ 86 % U-235 ▪ 60 % med. In-111	▪ 86 % U-235 ▪ 60 % med. In-111	▪ 86 % U-235 ▪ 60 % med. In-111	▪ 89 % U-235 ▪ 65 % med. In-111

Table 3: Overview of the measurement results obtained with the different uranium sources. The results are displayed like given by the detector (see chapter 3.1). Measurement times for the DU source are (from top to bottom): 445 s, 1712 s, 135 s; U1: ~ 5800 s; U2: ~ 7500 s; U4: ~ 850 s and for the uranium plates: ~ 1400 s. The results are highlighted as follows: in red: false results; in green: correctly identified; blue: uncertain but correct identified; black: natural occurring material and background radiation; *: Micro Detective definition for high enriched ^{235}U > 70 %, therefore the result should be low enriched uranium and is false.

In all cases uranium was identified, partly uncertain. For the devices which give a degree of enrichment those data were incorrect in some cases. According to the Micro Detective manual (see chapter 3.1.1) the U4 source should have been identified as low enriched uranium but was identified instead as high enriched. The identiFINDER-Ultra identified depleted uranium in the case of the U1 and U2 sources with a confidence factor of 6 or 5, respectively. ^{235}U was as well identified with a factor of 5 which leads to the conclusion that results with those confidence factors should not be neglected. In the case of the INTERCEPTOR for all sources (U1 – U5) ^{111}In was identified.

The Micro Detective has reported a variety of additional isotopes besides the uranium. It has to be taken into account, that the measuring times have been rather long and the background in the laboratory is not negligible. The identified ^{137}Cs is also present in the background spectrum. The detection of ^{241}Am in the DU measurement is due to the fact, that the strong MOX source which was deployed for the next measurement was already close to the measurement area.

4.4 Plutonium Measurements

In Table 4 the results of the plutonium measurements are given for all detectors for different measurement times. The Micro Detective identifies plutonium in all cases very fast but gives the wrong isotopic composition for the Pu2 source: weapon grade instead of reactor grade. The InSpector 1000 gives a very poor result and never identifies plutonium, only ^{241}Am is correct identified. The identiFINDER-Ultra identifies the plutonium with a low confidence factor and needs longer measuring times. For the Pu2 it also gives weapon grade instead of reactor grade plutonium but with the lowest significance. The measurement with the INTERCEPTOR leads to good results. Only in the case of a 60 s measurement of the Pu3 wrong isotopes are identified. Compared to the uranium measurements the results of the INTERCEPTOR for plutonium are much better, but not listed with high significance either.

Detector	MOX	Pu1	Pu2	Pu3
Data sheet ^{239}Pu	66 % reactor grade plutonium	70 % reactor grade plutonium	84 % reactor grade plutonium	93 % weapon grade plutonium
Micro Detective	▪ Pu, RG-Pu (20 s) ▪ Elevated uranium concentration, Pu, including Am241 Reactor Grade Pu, Am241, K40 (400 s)	▪ Pu, including Am241, Reactor Grade Pu, Am241, K40, Np237, Cr51, (4000 s)	▪ Found Nucl.Pu (approx. 5 s) ▪ Pu incl. Am 241; WGPu, Am241, Cs137 (25 s) ▪ Pu, incl.Am 241, WGPu, Am241, K40, Ra226, Gd153, W188 (47000 s)	▪ Nuclear Pu WG-Pu (2 s) ▪ Pu, including Am241, Weapons Grade Pu, Am241, K40, Ra226, Cr51, Gd153 (10000 s)
InSpector 1000	▪ Am 241 ind. 91.69 % no Pu (530 s)	▪ Am-241 ind. 94.83 %, Sm-153 ind. 85.04 %, no Pu (100 s) ▪ Am-241 ind. 96.1 % no Pu (6300 s)	▪ No nuclides found (120 s and 580 s)	▪ I-131 87.0 % (120 s) ▪ No nuclides found (3500 s)
identiFINDER-Ultra	▪ 9 Ind Am 241 - Nuc RG Pu (240 s) ▪ 8 Ind Am 241 - Nuc Rg Pu (30 s, 307 cm)	▪ 5 nuc RG Pu 5 Ind Am 241 (30 s) ▪ 7 Nuc RG Pu (7300 s)	▪ 5 Ind Am-241 - Nuc WGPu (1700 s)	▪ Nuclid listing: not identified (30 s) ▪ 5 Nuc WG Pu - Ind Am 241 (3600 s)
INTERCEPTOR	▪ 94 % Ind Am 241 77 % Pu 240 (60 s)	▪ 70 % Ind Am 241 58 % Pu 239 (60 s) ▪ 70 % Ind Am 241 56 % Pu 239 (7700 s)	▪ 69 % Ind Am 241 51 % Pu 239 (60 s)	▪ 73% med I-131 53% med I-123 (60 s) ▪ 59% Ind Am 241 56% Pu 239 (1000 s)

Table 4: Results of measurements with unshielded plutonium sources. In the case of Pu1, Pu2 and Pu3 the source was laying on the table with the metal side upwards (see photo in Table 3). Distances between source and detector are 20 cm for the Pu1, Pu2 and Pu3; MOX: 170 cm, an exception for the identiFINDER-Ultra measurement is marked. The results are highlighted as follows: in red: false results; in green: correct identified; blue: uncertain but correct identified; black: natural occurring material and background radiation.

4.5 InSpector 1000

The results of the InSpector 1000 concerning the plutonium sources are rather poor and in no case plutonium was identified. Figure 4 shows the spectrum of Pu3, obtained from a distance of 20 cm with 1 mm tin in front of the detector. The automatic nuclide identification of the InSpector 1000 identified ^{131}I instead of weapon grade plutonium. The gamma energy spectra with the peaks found by the automatic analysis routine is shown as well as the characteristic energies of ^{131}I and weapon grade plutonium as listed in the nuclide library. A simple comparison leads to the conclusion, that the plutonium lines fit much better than the ^{131}I lines. The energy region around 400 keV with the important lines for the plutonium identification is analyzed in addition with the Genie 2000 Gamma Analysis Software from Canberra afterwards. The result of the fit is in excellent correlation to the data in the nuclide library. The spectrum has a good quality but the analysis routine is not very good.

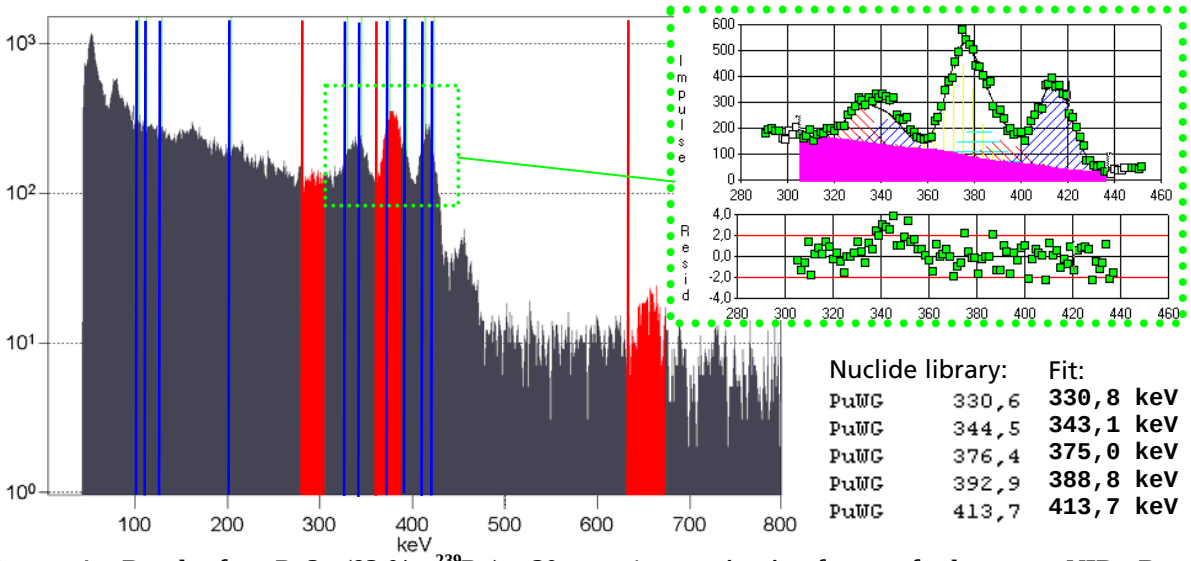


Figure 4: Result for Pu3 (93 % ^{239}Pu), 20 cm, 1 mm tin in front of detector. NID Result: ^{131}I med. 89.269 % <u>Left:</u> gamma spectrum with marked peaks found by automatic analysis routine. Red lines: characteristic energies of the nuclide library used by the InSpector 1000 for ^{131}I , blue: PuWG. <u>Right:</u> Additional analysis with Genie 2000 Gamma Analysis Software from Canberra afterwards and the result.

4.6 Neutron Measurement

Neutron measurements were performed with all uranium and plutonium sources and gave always the indication shielded fissile material present. Unfortunately the same information was given also for the neutron background measurement in the laboratory.

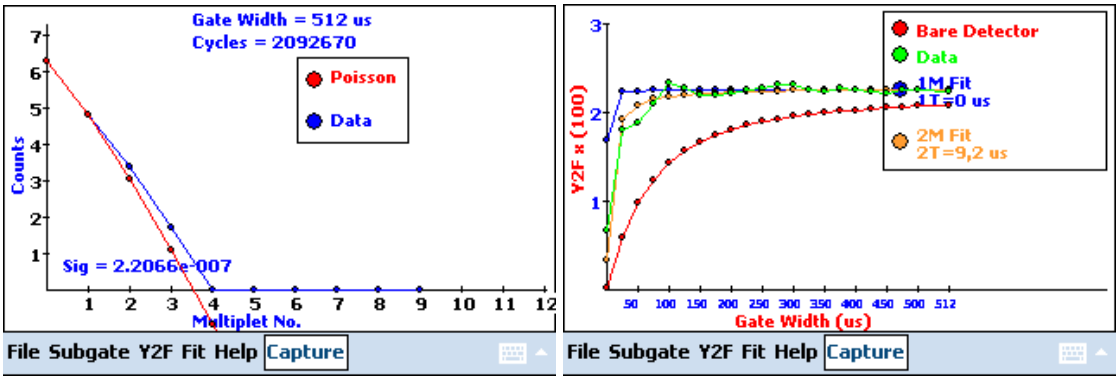


Figure 5: Background measurement. <u>Left:</u> Multiplicity plot; <u>Right:</u> Feynman plot. Measuring time 1074 s.

The neutron background in the laboratory was untypically high. Figure 5 shows the obtained plots for the background measurement. In the background radiation, coincident neutrons were detected which means fissile material is identified. In the multiplicity plot [6] of Figure 5 the observed data and the statistic Poisson distribution are not in agreement which means fissile material is present. In the Feynman variance plot the obtained data and the simulation for the bare detector do not match either which means the source of the background neutrons is surrounded by shielding material.

5 CONCLUSIONS

For the characterization of suspicious objects which may contain nuclear material, hand-held devices should give a clear hint on the existence and the type of such material. In the case of uranium sources all four tested devices gave the information that uranium is present. The enrichment, which is given by the Micro Detective and in the case of DU by the identiFINDER-Ultra, is for the most part correct. The results for plutonium sources are not of the same quality. The InSpector 1000 never identified plutonium. The INTERCEPTOR on the other hand correctly identified plutonium with a similar energy resolution and in spite of its significant lower efficiency. If information on the isotopic composition was given, it was for the most part correct. However, precise information on the isotopic composition will not be given by these automatic analysis routines. This can only be gained from the detailed analysis of gamma spectra obtained with germanium detectors.

An experience with these tests is that repeated measurements with varied geometry and in the case of plutonium with a thin tin shielding should be performed. This may lead to more reliable results. Not only the characteristics of the detector material and the quality of the analysis routine are important, but also the concurrence of these two factors. If the latter is not given, the analysis result may be poor even though the two afore mentioned factors are excellent.

Further measurements with the Fission Meter have to be carried out. In particular the neutron background in the laboratory has to be as low as outside nuclear laboratories and it has to be monitored during the whole period of measurements.

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