Hand-Held Devices for the Detection of Clandestine Nuclear Material On-site

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Abstract

The possible threat of nuclear material out of control has become an increasingly important issue for the international community in the past years. Improvised Nuclear Devices and Dirty Bombs may cost many lives and contaminate vast areas when successfully exploded by terrorists or terrorist groups. Whereas the declared nuclear material within the nuclear fuel cycle generally is under good control by international safeguards it is difficult to cope with undeclared nuclear material. The best detectors and the best practices have to be used to reveal undeclared nuclear material or activities.

Important means for detecting such material are portal monitors and other fixed installations at state boarders and facility limits. In addition mobile measuring systems are of great importance. These fixed installations and mobile measuring systems have to be supplemented by reliable and easy to use hand-held devices for the detection of gamma and neutron radiation emitted by the material. Hand-held devices may not only be used in combination with fixed installations and mobile systems but may also serve policemen or fire fighters to detect radioactive and nuclear material anywhere in the country.

We tested a variety of advanced hand-held devices with respect to reliability, ease of use, quality of the user interface, false alarm rate and the production of misleading results. One other important issue is the necessary skill of the user. As many users will not be specialist in the area of radiation measurement the application of hand-held devices must be really easy and to a great extend fool proof. We investigated gamma dosimeters and pagers as well as spectroscopic devices, gamma devices additionally equipped with a small neutron counter and dedicated neutron devices.

Hand-held devices are an inevitable means for detecting undeclared nuclear material and activities. It is not sufficient to have measuring devices at hand with the best and most advanced technology but it is a least of the same importance to apply them correctly and in the best manner.

1. Introduction

Potential acts of terrorism including the use of nuclear or radioactive material are a severe threat to the safety of the general public. In order to localize and also identify illicit radioactive and nuclear material, sophisticated detection techniques are required [1] [2] [3]. Hand-held detection systems play a key role in that respect as they allow for a search on-site where the illicit material is suspected. If nuclear or radioactive material is localized, an identification of the material will be useful prior to consideration of further actions. Therefore hand-held detectors equipped with identification routines are the best possible choice. Because of the variation in type and size of detector material as well as data analysis, not all of those systems are equally well suited for identifying such material. We investigated the practicability and suitability of several hand-held gamma radiation detectors for the localization and identification of radioactive material in-situ and a portable neutron detection device for the localization of fissile material.

2.1. Search and Identification with Gamma Detectors

We performed search and identification measurements in one of our institutes' labs. The lab's dimensions are: 8 m (length) x 4 m (width) x 2.5 m (height). Figure 1 shows a picture of the lab, taken from the entrance.

Figure 1: Overview of the lab where the radioactive source was hidden.

The hidden radioactive material was a Co-60 source (activity: 350 kBq). Because of its small dimensions (2.5 cm, see figure 2) and transparence it was relatively inconspicuous and difficult to spot.

Figure 2: Co-60 source used for testing the search-qualification of detectors.

For the surveys five detection systems from four different manufacturers were investigated, featuring different crystal materials, sizes, weights, and analysis software. In addition, the dose rate measuring device FH40 which is widely used was investigated for comparison. Figure 3 shows pictures of these detectors. Their relevant specifications are listed in table 1.

Figure 3: Detectors used for this study, from left to right: Micro Detective [4], InSpector 1000 [5], IdentiFINDER [6], Interceptor [7], RadEye PRD [8], FH40 G-L [9].

In order to gain comparable results for each detector we selected hiding spots at four different heights and had test persons searching the hidden source once for every height with each detector. The order of the hiding spots was altered every time. In this way we achieved a high degree of objectivity.

Table 1: Comparison of the relevant data of the devices

Detector	**Micro Detective**	**InSpector 1000**	**IdentiFINDER**	**FH40 G-L**[1]	**RadEye PRD**	**Interceptor**
Manufacturer	Ametek / ORTEC	Canberra	ICx Radiation	Thermo	Thermo	Thermo
Detector Material	HPGe	$LaBr_3$	NaI (Tl)	Gas (Proportional Counter)	NaI (Tl)	CdZnTe
Weight [kg]	6.9	2.4 (Body + Probe)	1.25	0.45	0.16	0.27
Size of Device [cm]	37.4 x 14.6 x 27.9	19 x 16.5 x 6.4 (Body)	24.8 x 9.4 x 7.6	19.5 x 7.3 x 4.2	9.6 x 6.1 x 3.1	11.2 x 6.1 x 2.5
Crystal Size [cm]	3 (Length) / 5 (ø)	3.8 (Length) / 3.8 (ø)	5.1 (Length) / 3.6 (ø)	2.6 (Length) / 2.5 (ø) (Gas Chamber)	3.1 (Length) / 1.8 (ø)	0.7 x 0.7 x 0.35
Identification Mode	yes	yes	yes	no	no[2]	yes
Energy Resolution [keV] at 662 keV	1.5	23.2	48	-	-	19
Relative Efficiency [%]	10.7	12.6	8.0	-	-	0.02
Battery Life [h]	> 3	9	8	> 250	600	10

[1] Dose rate measuring device

[2] The RadEye is equipped with the NBR (Natural Background Rejection) routine which enables the user to distinguish between “high energy” and “low energy” alarms.

The task of the search procedure was to locate the source as fast as possible and then run an identification if the investigated detector featured such a routine. The time needed for locating the source was noted. For two of the detectors an exact runtime for the identification routine had to be set (IdentiFINDER, InSpector 1000), the Interceptor features a routine choosing this time automatically, and the Micro Detective’s identification routine keeps running until it is manually stopped, showing results of identified nuclides during the process.

Each survey started at the lab’s entrance. The directions and walking speed during the survey were chosen by the test persons. Among them were people experienced in handling radiation detectors, but also people who did not know the devices at all before. This way of performing the surveys included several random factors due to the individual habits of the test persons thus creating a more realistic scenario.

2.2. Results

The surveys were performed by seven different test persons. A larger number of people was not available because of the lab's access restrictions. Therefore we had to accept large variations of the measurement's results. These variations occurred because of the different characteristics of the devices as well as the test persons' individual behavior such as search strategy, e.g. walking speed, walking directions, etc., and personal capabilities.

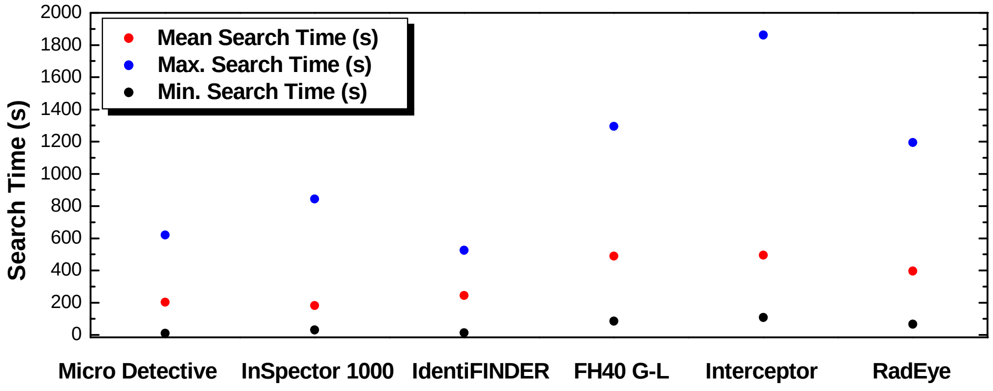

Figure 4: Comparison of mean, minimum, and maximum search times for all detectors and all groups of height. In two cases the source was not found at all; these data were not accounted for in the diagram.

Figure 4 illustrates the results of the mean search times including all search results. The maximum and minimum search times for all detectors are shown as well.

Identification measurements were performed with the IdentiFINDER, the InSpector 1000, the Interceptor, and the Micro Detective. As for the former two, the runtimes for these measurements were set to values considered to be typical by the manufacturers. In the case of the IdentiFINDER, we selected 30 seconds of measuring time. For the InSpector 1000 we chose 120 seconds.

The Micro Detective merely discriminates between two "confidence levels" referring to the fact that a nuclide is "suspected" or "found". If a nuclide is listed as "found", it can be said to be identified with a certainty of 99.9 % according to the manufacturer. As for the other three detectors, a "confidence factor" given in percent is shown after the end of the measurement, specifying the confidence of a nuclide being identified.

A comparison of the detector's runtimes required for the identification of the Co-60 source would not have been informative as some runtimes were set and others were variable (2-144 s). So only the confidence factors given by the detectors were compared. Additionally, we were interested in false identification results given by the systems because in a real situation users have to rely on the fact that the reported nuclide is really present. Figure 5 illustrates the comparison of the mean confidence factors for all four detectors as well as the number of measurements where false identification results were given. The mean confidence factor was calculated from all measurements with each system. Only with the Interceptor false results occurred. This detector also showed the lowest mean confidence factor. Taking into account that the Co-60 source should have been quite easy to identify at close distance the Interceptor's factor of approx. 57 % is very unsatisfactory, but an experienced user can gain further information from the energy spectrum. The three other detectors turned out to be sufficiently reliable and did not show any false identification results.

In general, the Micro Detective, the InSpector 1000, and the IdentiFINDER are significantly superior to the other three detectors in localizing the source, the InSpector 1000 showing the shortest mean search time of all detectors. However, one has to take into account that the detectors are drastically different in weight and size and therefore in handling. The duration of a survey performed with the RadEye can vastly exceed that of a survey done with the Micro Detective because the latter has approximately 40 times the weight of the former (RadEye). On the other hand, the Micro Detective features the option of identifying material with a high degree of confidence which could be immensely valuable in a real scenario. So the best possible choice of detector in case no preliminary knowledge about the material hidden within a certain area would probably be a relatively light-weight detector equipped with an identification mode showing satisfactorily results.

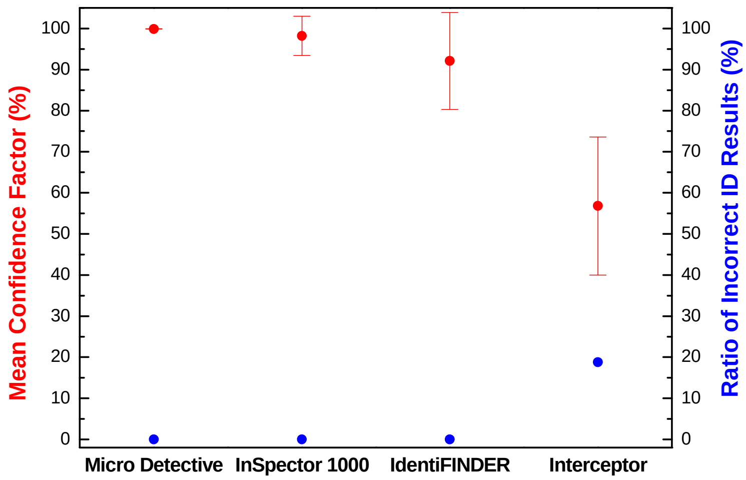

Figure 5: Comparison of mean confidence factors for all detectors featuring an identification mode (red dots) and false identification results (blue dots).

3.1. Search Experiments with the Neutron Detector Fission Meter

In addition to the search experiments with gamma radiation detection systems we also performed search experiments with the neutron detector “Fission Meter” (manufactured by Ametek/ORTEC) [8]. We investigated the option of locating neutron sources (fissile material) by means of a covert search.

The Fission Meter system 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 6 on the left). The measured data are transferred to a control unit (“Ranger” pocket PC) via serial cable on which they are computed and displayed. The Ranger’s screen was displayed on a notebook computer for convenience (see figure 6 on the right). During the search experiments, the detector unit was placed inside a trolley (see figure 7). In this way we performed measurements very similar to a covert search at places of interest such as airports or train stations.

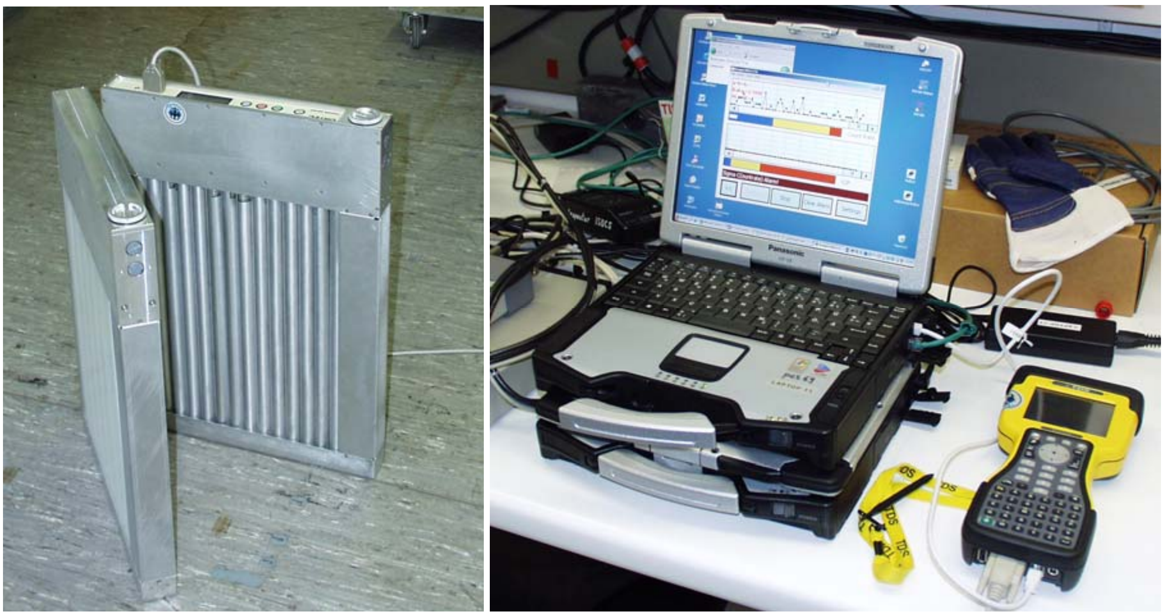

Figure 6: Fission Meter system with detector unit on the left and pocket PC / notebook computer for displaying the measured data on the right.

We performed experiments both inside a lab and outdoors with Cf-252, Am/Li, and Am/Be sources of various activities and neutron emission rates.

Figure 7: Detector unit strapped inside a trolley (setup for search experiments).

3.2. Results of the neutron measurements

Figure 8 shows the measured count rate with an Am/Li source, activity of $4.4 \cdot 10^{10}$ Bq and emission rate of $5.5 \cdot 10^{4}$ n/s. The source was passed by with the trolley (detection unit inside) at distances of 20 cm to 1 m. The source was located clearly at all distances. The same holds for a Cf-252 source (representing fissile material) with an activity of $1.9 \cdot 10^{5}$ Bq and an emission rate of $2.2 \cdot 10^{4}$ n/s and an Am/Be source with an activity of $3.5 \cdot 10^{9}$ Bq and an emission rate of $2 \cdot 10^{6}$ n/s.

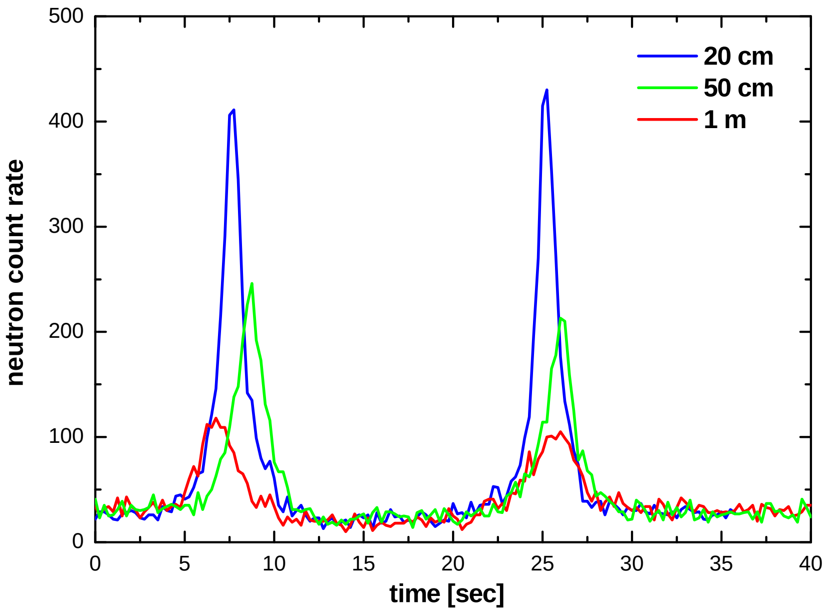

Figure 8: Localization of the Am/Li source in the lab at different distances.

We also investigated the detection system's abilities of locating the neutron sources outdoors up to a distance of 4 m. Figure 9 shows the count rate values for several distances to the Cf source mentioned above. The source's position is marked in this figure. The source could be located up to a distance of 2 m at least; at a distance of 4 m the count rate did not rise considerably above the background so the detection limit was reached for this neutron intensity.

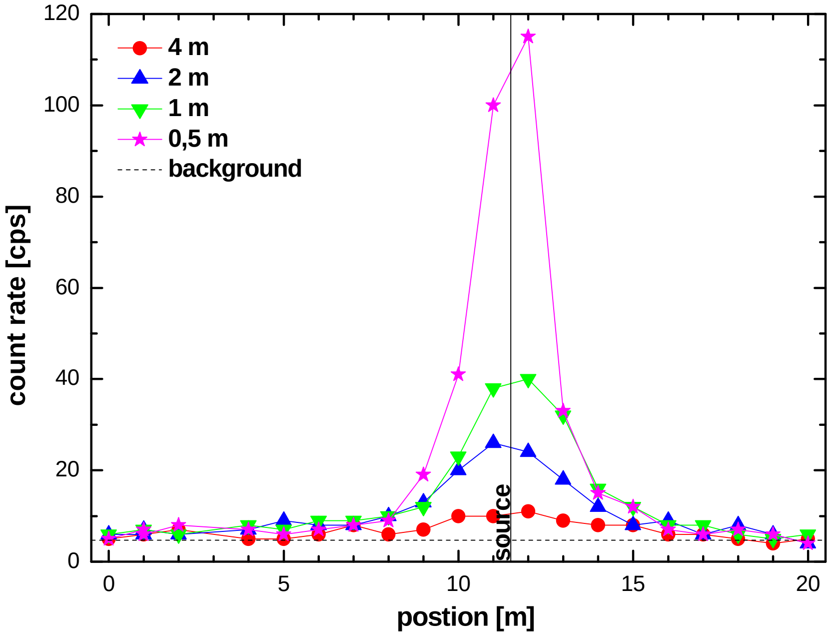

Figure 9: Localization of the Cf-252 source outdoors at different distances to the detector (count rate values taken from the static search mode in this case).

4. Conclusions

Various detection systems for locating and identifying radioactive or nuclear material in-situ are available on the market. However, their adaptation for fast and reliable operation in a real on-site environment is of varying quality. Therefore, the suitability of a number of Gamma and neutron detection systems was investigated concerning to the localization and identification of such material during on-site surveys. Most gamma detectors proved to be useful at locating the radioactive material within a reasonable period of time, only the dose rate meter FH40 G-L, which was not designed for this kind of task, was difficult to handle and failed to produce satisfactory results. All the detection systems which are equipped with an identification routine successfully identified the source at close distance except for the Interceptor, but mainly due to a inaccurate energy calibration of the device. The neutron detector system Fission Meter proved to be reliable at locating the neutron sources Cf-252, Am/Li, and Am/Be we used for these experiments at close distances. The mobile detection systems turned out to be reliable and will be useful in a real scenario as well as in an on-site inspection.

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