Comparison of dose rate measurements of commercially available hand-held gamma detectors with radiation protection dose meter

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Abstract. The control of rooms and areas where nuclear or radioactive material is stored or used is often performed with the use of commercially available hand-held gamma detectors using their dose or dose rate measurement capability. These devices are also often used by policemen or firemen. Reliable dose rate values are of great importance for the personal safety of the user in case of an elevated radiation field or generally for a first estimation of the threat generated by the radiation source. Therefor dose rate measurements were performed at Fraunhofer INT with the available hand-held gamma detectors under identical conditions. Seven hand-held gamma detectors of different type and size were investigated. The results of the dose rate measurements were compared among each other. For an assessment of the quality of the dose-rate measurements with hand-held gamma detectors a comparison with a calibrated dose rate measuring device for radiation protection FH 40 was made. It was seen that each hand-held gamma detector gave reproducible results for the gamma dose rate. However, the measured mean of the dose rate measurements with each hand-held device differed considerably, at a maximum by a factor of 3. Normally the measurement values were in the same order of magnitude. Except one all devices were not calibrated for radioprotection purposes. Taking into account that in Germany even for devices intended for radioprotection purposes only a precision of the dose rate of +/- 30 % is required the measurement results with hand-held devices can be regarded as reasonable good. Dose rate measurements with hand-held gamma detectors should be handled with care but in general the values obtained are good enough for personal safety and a first threat estimation although in general first responders would be required to carry a special radiation protection dosimeter in addition.

KEYWORDS: Hand-held gamma detector; dose rate; comparison.

1 INTRODUCTION

The control of rooms and areas where nuclear or radioactive material is stored or used is often performed with the use of commercially available hand-held gamma detectors using their dose or dose rate measurement capability. These devices are also often used by policemen or firemen. Reliable dose rate values are of great importance for the personal safety of the user in case of an elevated radiation field or generally for a first estimation of the threat generated by the radiation source.

Therefor dose rate measurements were performed at Fraunhofer INT with the available hand-held gamma detectors under identical conditions. Seven hand-held gamma detectors of different type and size were investigated. The results of the dose rate measurements were compared among each other. For an assessment of the quality of the dose-rate measurements with hand-held gamma detectors a comparison with a calibrated dose rate measuring device for radiation protection FH 40 was made.

2 HAND-HELD GAMMA DETECTORS

Tab. 1 shows the basic characteristics like detector type and crystal size of the hand-held gamma detectors which were tested. We included devices which are primarily intended to measure dose and dose rate as well as devices which are intended for identification of nuclides. Detectors with different types and sizes of scintillators and low resolution semiconductors as well as proportional counters which are in common use were selected for testing. The FH 40 radiation protection dose rate meter was used as reference instrument.

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Table 1: Basic characteristics of the hand-held gamma detectors

Detector Name	Manufacturer	Detector Type	Crystal Size [mm]
FH 40	Thermo	Proportional Counter	-
InSpector 1000	Canberra	$LaBr_3(Ce)$	38 (Ø) x 38 (Length)
RadEye PRD	Thermo	NaI(Tl)	18 (Ø) x 31 (Length)
IdentiFINDER	FLIR	NaI(Tl)	36 (Ø) x 51 (Length)
Interceptor	Thermo	CZT	7 x 7 x 3.5
Raider	FLIR	CZT	Eight Crystals: each has size of 1 cm^3
STORA-TU	Ecotest	Proportional Counter	-
TERRA	Ecotest	Proportional Counter	-

According to the manufacturer's data sheet information the used gamma detectors were designed for the following purposes. The FH 40 is a digital survey meter designed for radiation protection measurements. It is a stand-alone unit with an internal proportional detector [1]. The InSpector 1000 is a hand-held $LaBr_3(Ce)$ spectrometer with a built in GM detector (high dose rate) for use primarily in first responder, customs, homeland security, and health-physics applications [2]. The RadEye PRD is a NaI(Tl)-detector designed for detection and localization of radiation sources and for dose rate measurements conducted by security forces, steel and recycling industry or first responders [1]. The IdentiFINDER is a hand-held digital gamma spectroscopy and dose rate system with an integral NaI(Tl) scintillation detector and a GM detector. It is suited for homeland security, industrial, medical, nuclear power generation and nuclear fuel cycle applications. The main features are nuclide identification, spectrum analysis, dose and dose rate calculation, and source finding [3]. The Interceptor is a Spectroscopic Personal Radiation Detector (SPRD) with a large volume CZT detector. It is an instrument for personal safety, screening for nuclear materials, for localization of sources and is capable of categorizing and identifying of radionuclides [1]. The Raider is a hand-held high resolution semiconductor CZT radiation detector and identification unit designed for rapid identification and verification of radioactive materials [3]. The STORA-TU detector is a hand-held proportional counter designed for measurement of gamma and X-ray radiation equivalent dose rate [4]. The TERRA hand-held detector has a built-in gamma, beta sensitive Geiger-Muller counter for the measurement of gamma and X-ray radiation equivalent dose and equivalent dose rate [4].

3 MEASUREMENT SETUP

The measurements were carried out with calibrated test sources. The sources were positioned in a distance of 10 cm from the reference point of the detector as indicated by the manufacturer. For each measurement the device was restarted and the reading of the display was recorded 60 sec after the restart to take care of the integration time which some of the detectors use. For each device and source five measurements were performed and mean and variance calculated. Fig. 1 shows the devices and the principle set-up. The sources used for the measurements are listed in Tab. 2.

Figure 1: Measurement setup with hand-held gamma detectors

Table 2: Used Sources

Source name	Isotope	Activity [kBq]
Cs1	^{137}Cs	249.8
Cs2	^{137}Cs	42.0
Co1	^{60}Co	206.1
Co2	^{60}Co	2.0
Ba1	^{133}Ba	76.7
Eu1	^{152}Eu ^{154}Eu ^{155}Eu	5.2 3.3 2.0
U1	^{238}U	460.0

4 RESULTS

As an example the results for all detectors under test with the ^{137}Cs source No. 1 are shown in Fig. 2. The reference dose rate obtained with the FH 40 is drawn as a solid line. The reference dose rate obtained with the FH 40 is drawn as a solid line. Taking into account the error bars the measured values of all detectors agree with the +/- 30 % range around the FH 40 reference value indicated by the dashed lines. It should be noted that the +/- 30 % for the reference instrument has to be regarded as a possible systematic deviation, not as a statistical one.

Figure 2: Results for the source Cs1

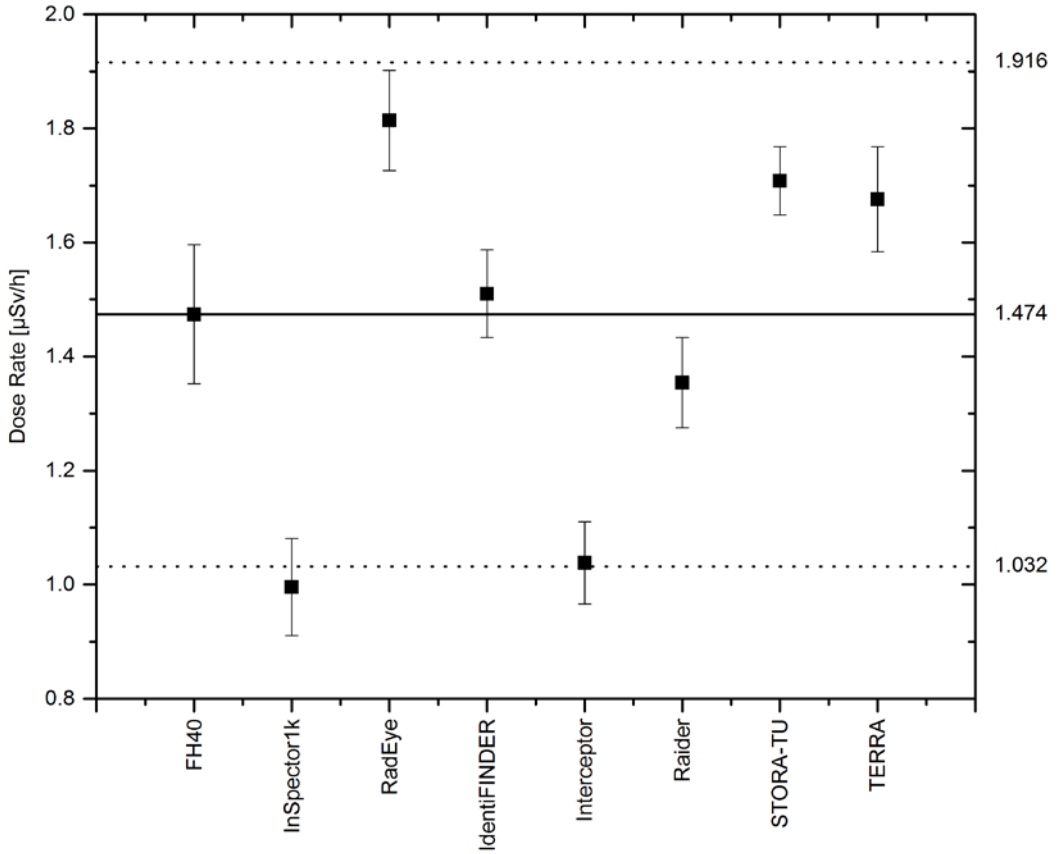
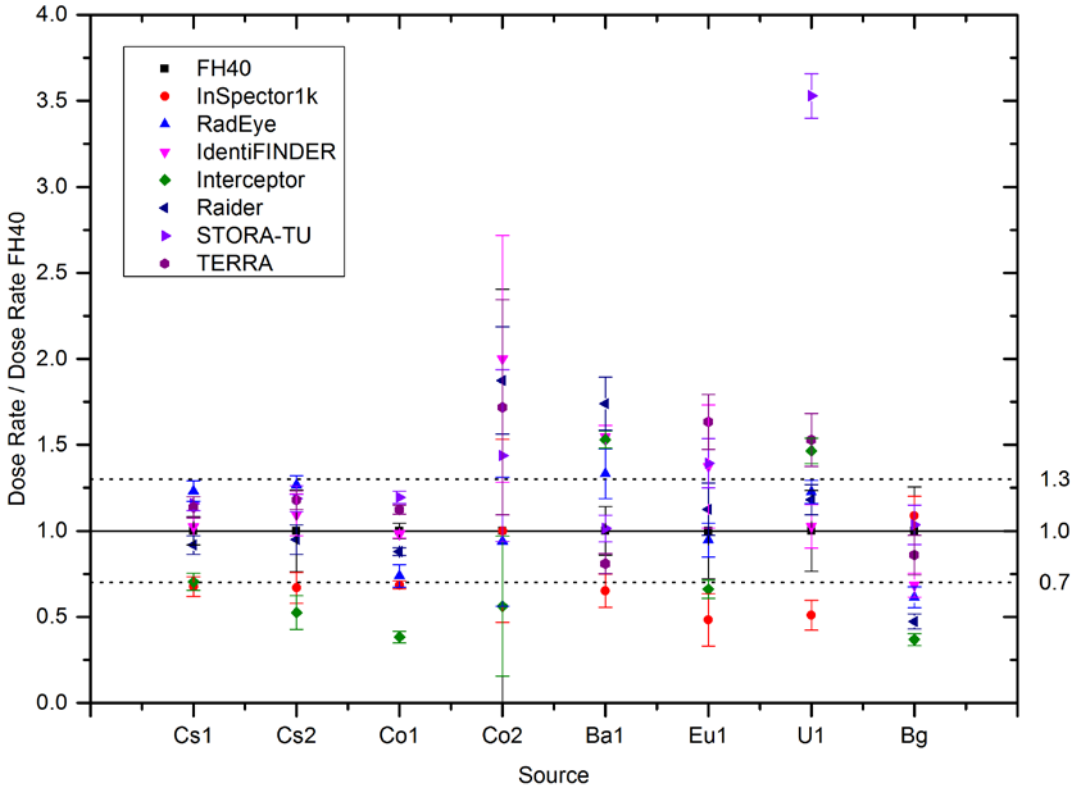


Figure 3: Dose rate results for different detection systems depending on used sources



In Fig. 3 the measurement results of all detectors and all sources are shown together with measurements of the ambient background. All measurement results were normalized to the FH 40 reference measurements after subtracting the background. In general the variations of the measurements of a single device for each source are small although the confidence intervals for different detectors for the same source in general do not overlap well. The confidence interval in general also does not overlap well with the confidence interval of the reference instrument FH 40. If the possible deviation of +/- 30 % from the true value of the dose rate allowed for radioprotection instruments in German legislation is also take into account most of the measurement results for the detectors are acceptable. Exceptions are for the Interceptor and Inspector1k results which are tending to be systematically low and one not understood large outlier for the STORA-TU for Uranium.

5 DISCUSSION

It was seen that each hand-held gamma detector gave reproducible results for the gamma dose rate. However, the measured mean of the dose rate measurements with each hand-held device differed considerably, at a maximum by a factor of 3. Normally the measurement values were in the same order of magnitude. Except one all devices were not calibrated for radioprotection purposes. Taking into account that in Germany even for devices intended for radioprotection purposes only a precision of the dose rate of +/- 30 % is required the measurement results with hand-held devices can be regarded as reasonable good. This compares well to results Pebida et. al. [5] found in their tests of radiation detectors used in homeland security applications where hand-held radiation detectors were directly compared to calibrated air-kerma rates according to the ANSI N42.34 standard which requires also +/- 30 % for ^{137}Cs.

6 CONCLUSION

Seven hand-held gamma detectors with different detector types not primarily intended for dose rate measurements for radiation protection purposes were tested with common sealed radioactive sources and compared to the dose rate determined by the dose rate meter FH40. For the hand-held devices tested the indicated dose rate values can be regarded as reasonable. However, dose rate measurements with hand-held gamma detectors should be handled with care. Although in principle the values obtained are good enough for personal safety and a first threat estimation in general first responders would be required to carry a special radiation protection dosimeter in addition.

7 REFERENCES

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