Application Note AN9677
Waste identification at Futura S.p.A., a company of IREN S.p.A., in Grosseto

Grosseto

January 31st, 2023

Introduction

RadHAND 600 Pro [**1**] and DiscoveRAD [**2**] are two hand-held systems made by CAEN S.p.A. for the localization and identification of radioactive material. Measurements have been made with the two instruments of radionuclides contaminated Municipal Solid Waste (MSW) at the Futura's MSW Treatment Plant located in Grosseto (Italy). The plant, serving a 280.000 inhabitants area, receives residual MSW, and source separated Organic Fraction of MSW and Green Waste. The outputs of the plant are a secondary solid fuel from the residual MSW, as well as a high quality compost from organic materials.

Currently, there is no specific regulation for waste disposal produced by citizens who received a medical exposure as part of their own medical or dental diagnosis or treatment with some radionuclides. As a consequence, the citizens put their waste contaminated by radioactive secretions (e.g. handkerchiefs, sanitary pads, etc) in the residual MSW bin, without any specific bag, nor tag. The contaminated waste must be then identified among the non-contaminated one, separated, placed in a controlled area, and flagged with the correct time after which the waste presumably will be no more radioactive.

All the trucks transporting waste, arriving or leaving the plant, are first checked by a fixed portal, which alarms when the truck contains radioactive material with gamma emission. In case of alarm, the Radiation Protection Expert (RPE) checks the source position with a portable instrument (called "reference instrument" hereafter) and label it in the truck wall.

The waste is discharged up to the label position, then the RPE locates the contaminated waste thanks to the reference instrument. Once located, the contaminated waste is put in a bag and placed in a controlled area. The radioisotopes contained in the bag are then identified (typical contaminated MSW usually contains medical isotopes); measuring the count rate and knowing the source decay time, the RPE can fix a settling time. The identified waste must remain in the controlled area and checked again after the settling time. If its radioactivity is at the level of the natural background (with a tolerance of 1.5 $\times$ the background level), it is then disposed as non-radioactive waste. **Fig. 1** shows the sequence of operations done for the localization and identification of radioactive waste.

Measurements at the waste treatment plant

RadHAND and DiscoveRAD were used together with the reference instrument to locate the source position and identify the source type. The main differences between the two devices are the active detectors, NaI(Tl) and BGO respectively; the possibility to read/write rad tolerant RFID tags, to make pictures of the samples, and connect all data in a remote database (called RadBASE) for RadHAND; the possibility to detect neutrons with DiscoveRAD. More details can be found in [**1**] and [**2**], respectively.

A preliminary background measurement has been made to verify the background level, and let the devices set the alarm thresholds automatically. The background level was quite low and the results were similar for the two devices, 0.018 µSv/h and about 50 cps.

The two devices were used for a preliminary scan of the truck walls. Having the same detector type, the RadHAND was used to verify the count rate with respect to the reference instrument of the RPE giving always comparable counts. DiscoveRAD gave always smaller counts, probably due to the different detector.

The waste was located thanks to the count increase with respect to the background. Three types of radiological waste were localized:

1. sanitary pads;
2. various material where the source was sprinkled (not categorized material);

Fig. 1: (1) Localization on the truck wall of the radioactive source; (2) Localization of the radioactive waste among the non-radioactive one; (3) Identification of the radiological source type with RadHAND; (4) Increase of count rate recorded by DiscoveRAD when put close to the source.

3. incontinence diapers.

In the case of not categorized material, we used the function "EasyFinder" of DiscoveRAD, which related the count rate with the internal accelerometer to find the direction where the source came from.

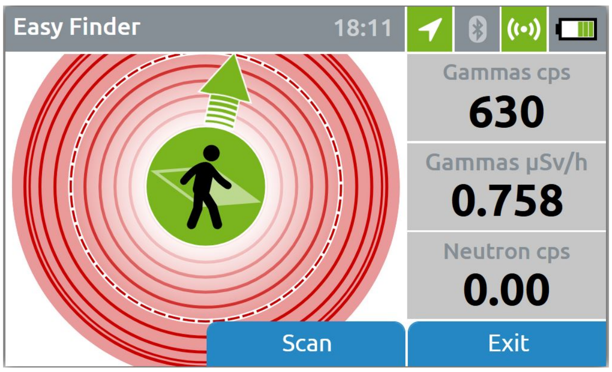

Fig. 2: EasyFinder function of DiscoveRAD.

Once the waste was localized, the identification algorithm was applied, and the result was I-131 for the three waste types.

Since data was saved into the DiscoveRAD internal memory, we report below the results with DiscoveRAD. Similar results were obtained with RadHAND too. Both devices were able to measure the dose rate of the contaminated waste, and identify the I-131 radioisotope (see **Tab. 1** and **Fig. 3**). The sensitivity of both instruments with a ^{137}Cs source is 1850 cps/µSv/h. For a comparison of the performances of the two instruments with respect to a ^{137}Cs source see **Appendix: Comparison between RadHAND and DiscoveRAD**.

Waste Type	Dose rate (μSv/h)	Identified radionuclide
Sanitary pads	∼ 0.084	I-131
Not categorized material	∼ 1.350	I-131
Incontinence diaper (single)	∼ 22.730	I-131
Incontinence diapers (total)	∼ 99.780	I-131

Tab. 1: Dose rate of the identified radionuclides of the each measured waste type.

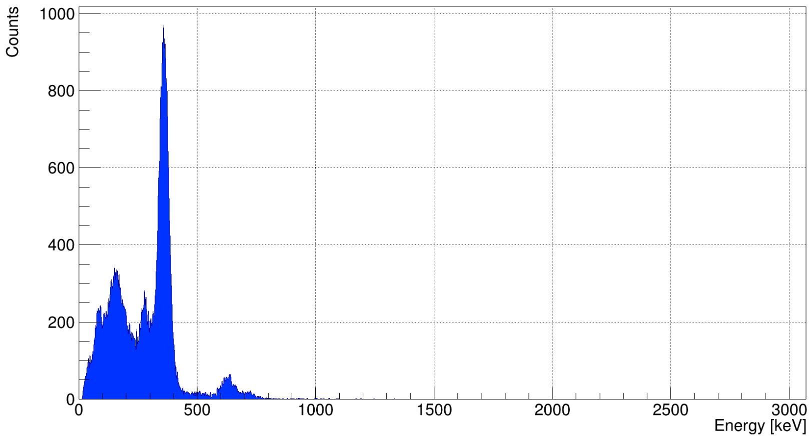

Fig. 3: Energy spectrum in the range 0-3 MeV acquired with DiscoveRAD with the incontinence diapers sample. Iodine-131 peaks are clearly visible at 284.3, 364.5, and 636.9 keV.

Conclusions

We tested the possibility to successfully perform waste localization and identification with RadHAND and DiscoveRAD. The devices correctly alarmed in presence of the sources, giving comparable results with the reference instrument. The devices identified the emitting source, created the energy spectrum for further analysis, calculated the dose and counts per second with higher full scale range than the reference instrument. To further improve the devices, we plan to add a metal rod to perform measurements at 1-2 meter far from the waste.

Appendix: Comparison between RadHAND and DiscoveRAD

Comparison tests between RadHAND and DiscoveRAD were performed at CAEN S.p.A. laboratory to verify the consistency of the measured values with respect to expected ones and between the two instruments.

Nominal values are taken from the web page "RadProCalculator" [**3**], which calculates the dose-rate from a point gamma source, emitting isotopes at any distance. The reverse calculation, determining the activity of a source from a known dose-rate may also be performed, as well as the possibility to add a radiation shielding, though not used in this application. The calculation takes into account the formula of the exposure rate $\dot{X} = \Gamma_\delta \frac{\alpha}{d^2}$ **[4]**, where Γ_δ is the exposure rate constant (Gamma constant), α is the activity of the source, and d is the distance. The constant is equal to 3.214 $(R{\cdot}cm^2)/(hr{\cdot}mCi)$ for ^{137}Cs; this value considers that the X-rays of ^{137}Cs do not arrive at the detector and they are therefore not included in the final calculation. Final dose rate values are reported in µSv/h by using the following conversion for gammas in air: 1 Roentgen = 0.877 rad, then 1 Roentgen = 0.877 rem and 1 Roentgen = 0.00877 Sieverts.

For the measurement, we used a ^{137}Cs source of 8.88 MBq (0.240 mCi) of activity placed at several distances from the instruments and we recorded the values shown on the two screens. For each distance, we took 10 measures and calculated the mean and RMS value as statistical error to take into account for variations of the instantaneous measured dose rate. The environmental background dose was measured in the same way and resulted in 0.045 ± 0.001 µSv/h and 0.047 ± 0.001 µSv/h for RadHAND and DiscoveRAD, respectively. Values reported in **Tab. 2** are background subtracted. Minimum and maximum acceptable values correspond to $\pm$ 10% of the nominal value.

Distance (cm)	Nominal dose rate value [µSv/h]	Min acceptable value [µSv/h]	RadHAND value background subtracted [µSv/h]	DiscoveRAD value background subtracted [µSv/h]	Max acceptable value [µSv/h]
50	2.721	2.449	2.743 ± 0.047	2.629 ± 0.032	2.992
100	0.679	0.611	0.725 ± 0.012	0.705 ± 0.011	0.747
200	0.169	0.152	0.184 ± 0.003	0.182 ± 0.004	0.186
300	0.075	0.673	0.082 ± 0.002	0.079 ± 0.002	0.082

Tab. 2: Comparison of RadHAND and DiscoveRAD dose rate values at several distances from the source.

Tab. 3 reports the relative discrepancies between RadHAND and DiscoveRAD with respect to the expected value from RadProCalculator. The discrepancy is defined as $(v_{meas} - v_{exp})/v_{exp}$, where v_{meas} is the value measured by the instrument and v_{exp} is the expected value from RadProCalculator. Discrepancies are all below 10%.

Distance (cm)	Discrepancy RadHAND vs Nominal	Discrepancy DiscoveRAD vs Nominal
50	1%	-3%
100	7%	4 %
200	9%	7%
300	10%	5%

Tab. 3: Comparison of RadHAND and DiscoveRAD dose rate values with expected values.

Compatible values are measured by the two instruments and in agreement with expectations. At the distance of 3 m, the recorded dose is about 2 times the background level, making possible the source location and identification even at that distance. **Fig. 4** shows the setup and the instantaneous measured values.

Fig. 4: RadHAND and DiscoveRAD measuring a ^{137}Cs source with $8.91 \cdot 10^6$ Bq of activity at (1) 50 cm, (2) 100 cm, (3) 200 cm, and (4) 300 cm.

References

[1] https://www.caen.it/products/radhand-600/.

[2] https://www.caen.it/products/discoverad/.

[3] http://www.radprocalculator.com/Gamma.aspx/.

[4] G. F. Knoll. *Radiation detection and measurement*. Ed. by J. Wiley and sons. IV ed.

Application Note AN9677 - Waste identification at Futura S.p.A., a company of IREN S.p.A., in Grosseto rev. 0 - January 31st, 2023

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