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Title: Evaluation of Handheld Isotope Identifiers

Author(s):
J.M. Blackadar, NIS-6
J.A. Bounds, NIS-6
P.A. Hypes, NIS-5
D.J. Mercer, NIS-5
C.J. Sullivan, NIS-6

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Evaluation of Handheld Isotope Identifiers

Purpose

A variety of commercial hand-held isotope identifiers has been used to obtain spectra of several radioisotopes and to test identification accuracy. This report describes the acquisition conditions and chronicles the results of the instruments' automatic radionuclide identification. It should be noted that the measurements reported herein were initially undertaken for purposes other than an evaluation of the identification ability of these instruments. Consequently, the methodology employed may not be ideal; however, the disturbingly poor performance of automatic identification software is worthy of mention.

It is a difficult problem to automate an identification algorithm that can analyze a broad range of radionuclides. Many factors such as acquisition time, calibration drift, temperature changes, changes in background radiation levels, etc., complicate the challenge. False positive and false negative identifications are common, particularly for spectra collected under realistic field conditions. Furthermore, an instrument can only identify isotopes that it has been programmed to recognize. For practical reasons the developers of instruments are forced to limit the number of isotopes in the libraries used for identification. No effort has yet been made to quantify the number of failed identifications reported herein that are the result of the radioisotope simply not being included in the library of a particular instrument.

Instruments

The instruments used in this evaluation included, a Berkeley Nucleonics Corp. SAM 935 with firmware version 02.07.02, a Quantrad Sensor Ranger with firmware version 3.12, an Exploranium GR-130 with firmware version 5.15, an Exploranium GR-135 with firmware version 1.16, a SAIC Radsmart with firmware version E, a Bicron FieldSPEC with firmware version 3:826A, and a CZT Palm Pilot Spectrometer (CZT-PP) with firmware version 1.1a. The Radsmart is a CsI-based instrument, the CZT-PP is a CZT-based instrument, the GR-135 had both NaI and CZT detectors, and all of the other instruments are NaI detectors. All of these detectors are off-the-shelf models with the exception of the CZT-PP that is not yet in full commercial production and so the detector used in these tests was a demonstration unit provided by the developers.

Some instruments calibrate each time the instrument is turned on, while others rely on the user to decide to perform a calibration. Some instruments contain a calibration source so that there is always a reference peak in the data, while others do not. Some use a fixed region-of-interest (ROI) method in their algorithm, while others try to fit the peaks and identify them.

Experiment

SETUP

Generally, the data from all of the detectors using a specific source were acquired simultaneously with the detectors arrayed around the source on a horizontal table. The

data for all of the detectors was acquired for the same period of time and at the same distance. Generally, the acquisition time was 5 minutes of live time and the source-to-detector distance was 20 cm. For a few sources the time or the distance was different than above, but they were the same for all of the detectors used for that source. For the detectors that do not have the ability to set a preset acquisition time, every effort was made to stop the acquisition when the other instruments stopped. It should be noted that these results do not necessarily represent the optimal performance of these instruments for identifying isotopes.

EVALUATION

At the conclusion of the data acquisition period, the spectral data were saved and the instrument's isotope identification was recorded. Categorizing an instrument's identification as being correct or not is a complex task. Although an ANSI standard for handheld isotope identifiers is under development, the authors are unaware of an accepted and appropriate means of performing this task. Five categories were defined and each identification was assigned to one of them. The term "most abundant isotope(s)" (MAI) was defined as the radioisotope(s) that is(are) present with an atomic abundance of at least ~10%.

- The category of "correct" (C) means the instrument correctly identified at least one MAI present as the isotope identified with the most confidence or with confidence less than only a minor daughter (see definition below), or in the case of background it means it identified either nothing or only ^{40}K (which is naturally in the environment).
- The category of "conditionally correct" (CC) means at least one MAI present was correctly identified, but with less confidence than something that was not present or could not be identified.
- The category of "minor daughter" (MD) means that a daughter or parent of a MAI was identified, but the instrument failed to identify a MAI or it identified a radioisotope known to be present with less than 10% abundance. For example, identifying ^{226}Ra when the source was ^{238}U, or identifying the not-present natural grandparent ^{232}Th when the source was ^{228}Th.
- The category of "false negative" (FN) means the instrument gave no identification other than ^{40}K when a radionuclide was in fact present.
- The category of "false positive" (FP) means the instrument identified one or more radionuclides that were not present as being present without making any correct identification other than ^{40}K.

Because the Ranger does not give any confidence ranking when in the multiple isotope mode, its identifications were classified as "correct" if an MAI was present in its list of identifications. A false negative often means the spectrum had insufficient statistics for an identification to be made, or that the radioisotope was not in the instrument's library.

The results presented herein suggest that some skepticism is warranted when using the isotope identification provided by these instruments.

IMPROVEMENTS

As discussed above, there are several shortcomings of this work. For example, data for some of the detector-source pairs is missing; detector calibrations were not closely watched; no consideration was given for the presence or absence of a particular isotope in an instrument's library; and neither the acquisition time nor the distance were adjusted for the source activity. The authors believe first responders in the field may not be able to closely control these variables either. To better represent the ability of the detectors to make identifications, the above shortcomings should be addressed. However, it is believed that these early results demonstrate both the difficulty of the problem and the general ability of commercial instruments to address it.

Results

Because of possible sensitivities, the results from individual instruments are not being reported. Figures 1-4 show combined results from all of the detectors.

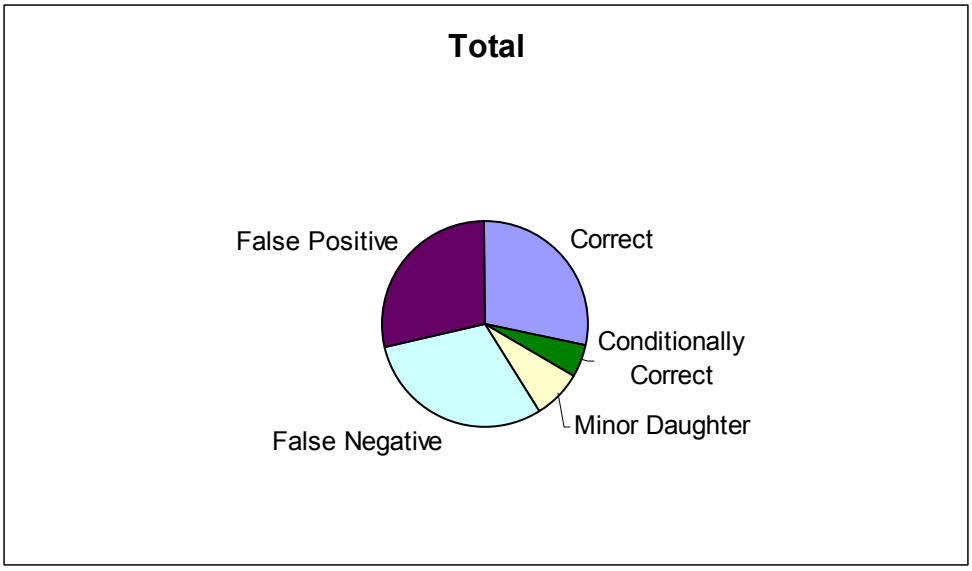


Fig. 1. Breakout of identification results for all of the detectors and data combined (7 instruments, 443 measurements).

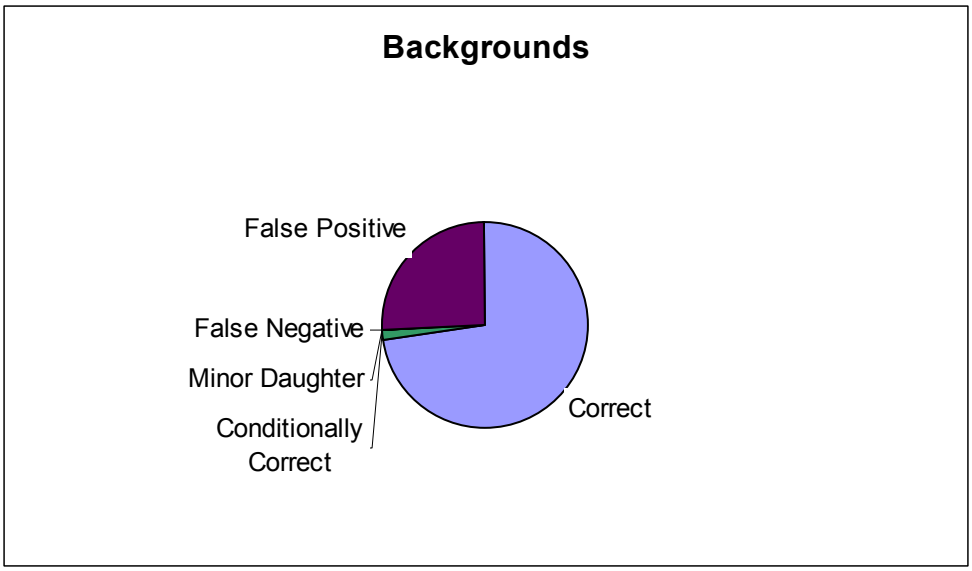


Fig. 2. Breakout of identification results for only the 58 background measurements.

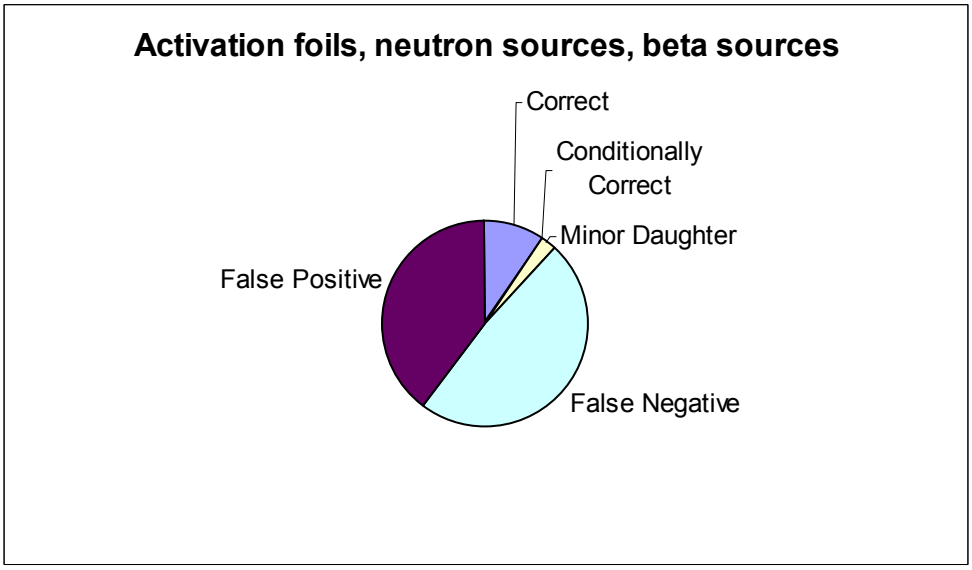


Fig. 3. Breakout of the identification results for activation foils, neutron sources, and beta sources (75 measurements). These have been separated out because the instruments were not designed to identify neutron or beta radioactivity, and the activation foils represent exotic radionuclides that are not likely to be found in the field.

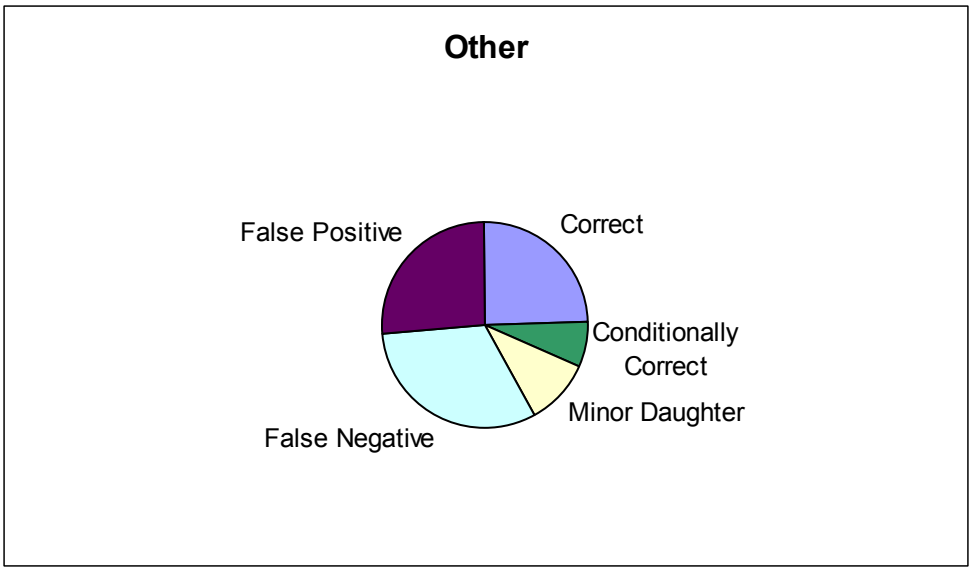


Fig. 4. Breakout of the remaining identification results (representing 310 measurements) that are not represented in Figures 2 or 3.

The following table shows the matrix of sources and detectors used in this work. The "X"s represent the cases for which a spectrum was acquired and an identification was recorded. The cases with two "X"s indicate that two independent spectra were acquired and identifications recorded.

SAM	Ranger	GR130	GR135	GR135 CZT	Radsmart	FieldSPEC	CZT-PP	Source Isotope	Activity (μCi)	Distance (cm)
	X							background on small table		
	X						X	background on big table		
X	X				X		X	Na-22	0.35	20
X	X				X		X	Am-241	9.99	20
X	X				X	X	X	Cs-137	2.8	20
X	X				X		X	Cm-244	9.19	20
	X							U-233		20
	X							Pu foil	0.22 g	20
	X							U-235	0.062 g	20
	X							U-depleted	1.19 g	20
	X							U-highly depleted	18.6 g	20
X	X				X		X	lantern mantles		20
X	X				X		X	U-ore, Rn-222		20
X	X				X		X	Th-ore, Rn-220		20
	X							U-natural		20
X	X				X	X	X	background		20
X	X		X		X	X	X	Ra-226	1.34	20
X	X		X		X	X	X	Eu-152	2.5	20
X	X		X		X	X	X	Co-60	0.95	20
X	X		X		X	X	X	Ba-133	1.2	20
X	X		X		X	X	X	Eu-154, Sb-125, Eu-155		20

SAM	Ranger	GR130	GR135	GR135 CZT	Radsmart	FieldSPEC	CZT-PP	Source Isotope	Activity (μCi)	Distance (cm)
X	X		X		X		X	Ho-166m	9.96	20
X	X		X		X	X	X	Bi-207	0.86	20
	X		X				X	background		20
	X		X					AmB w/ Pb	96126.33	20
	X		X					AmC w/Pb	119211.70	20
	X		X					Cf-252	63.25	20
	X		X					Cf-252 w/poly	63.25	20
	X		X					AmLi	13459385.04	20
	X							AmF noPb	14312.58	20
	X		X					AmF w/Pb	14312.58	20
	X		X					AmBe	953.20	20
	X		X					Ce-139	6.27E-05	20
	X	X	X		X			background		0
	X	X	X		X	X		Au-198		0
	X	X	X		X	X		Fe-59, Mn-54, Mn-56		0
	X	X	X		X	X		Cu-64		0
	X	X	X		X	X		In-116m		0
	X	X	X		X			Na-24		0
			X					In-116m		0
			X					In-116m		0
			X					all foils		5
	X	X	X		X	X	X	background		20
X	X	X	X		X, X	X	X	Th-228	5.90	20
	X	X	X		X	X	X	Ba-133	1.21	20
	X	X	X		X	X		Ce-139	5.67E-05	20
	X	X	X		X	X		Eu-154, Sb-125, Eu-155		20
X	X	X	X		X, X	X	X	Th-228	0.28	20
	X	X	X		X	X		Background		20
	X	X	X		X	X		U-233	15 g	20
	X	X	X		X	X		U-233	15 g	50
	X	X	X		X	X		Np-237	1 g	20
	X	X	X		X	X		Np-237	1 g	50
	X	X	X		X	X		Background		
	X	X	X	X	X	X		U-233	15 g	200
	X	X	X	X	X	X		U-233	15 g	100
	X	X		X	X	X		Background		50
	X	X		X	X	X		Cs-137	2.76	50
	X	X		X	X	X		Pm-147	0.048	50
	X	X		X	X	X		C-14	0.13	50
	X	X		X	X	X		Tc-99		50
	X	X		X	X	X		Cl-36	14.50	50
	X	X		X	X	X		Pb-210	7.00	50
X	X	X		X	X, X	X	X	Sr-90	0.068	50
	X			X	X	X		Background		50
	X			X	X	X		HEU	99 g	50
	X	X		X	X	X	X, X	U-235 & 238		50

SAM	Ranger	GR130	GR135	GR135 CZT	Radsmart	FieldSPEC	CZT-PP	Source Isotope	Activity (μCi)	Distance (cm)
	X	X		X	X	X	X	U-235 & 238		50
	X	X	X	X	X	X	X	U-235 & 238		50
	X		X	X	X	X		U-235 & 238		50
	X	X	X		X	X		Natural U		50
	X	X	X		X	X		Np-237	98 g	50
	X	X	X		X	X	X	Np-237	98 g	150
	X	X	X	X	X	X		MOX rods		200
	X	X	X	X	X	X	X	LEU rods		100
	X	X	X	X	X	X		PuO_2	204 g	50
	X	X	X		X	X	X	Background		50
	X	X	X	X	X	X	X	PuO_2	615 g	50
	X	X	X	X	X	X	X	PuO_2	615 g	150
	X	X	X	X	X	X	X	PuO_2	877 g	150
	X	X		X, X	X	X	X	Pu	4.484 kg	150
	X	X		X, X	X	X	X	Pu w/ 0.5" Fe	4.484 g	150
	X	X	X	X	X	X	X	Pu w/ 0.25" Pb	4.484 kg	150
	X	X	X	X	X	X	X	Pu w/ 0.5" Pb	4.484 kg	150
	X	X	X	X	X	X	X	Pu w/ 4" poly	4.484 kg	150
	X	X	X	X	X	X	X	U-235 & 238		50
	X	X	X	X	X	X	X	U-235 & 238		50
	X	X	X	X	X	X	X	U-235 & 238		50
		X	X					Background		
		X	X	X				Pu w/ 4" poly	4.484 kg	~140
		X						U-233		50
		X						Background		
	X		X			X		Background in Hospital Lobby		
	X		X			X		Tc-99 patient sitting 18" from shoulder		18"
	X		X			X		I-123 patient 10" from neck		10"
	X		X			X		Background in I-123 exam room		
	X		X			X		Background in Treadmill room		
	X		X			X		full Tc-99 syringe Cs bkg for Ranger & GR-135		90" for Fieldspec, 57" for GR-135, 56" for Ranger
	X		X			X		full Tc-99 syringe in 0.25" Pb pig Cs bkg for Ranger & GR-135		90" for Fieldspec, 57" for GR-135, 56" for Ranger
	X		X, X					Cs-137 source in car		~1 ft.
					X		X	Co-57		20
					X		X	Ra-226		20

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