CHARACTERIZATION VIA THE RADHAND DEVICE INTEGRATED INTO THE REACh™ SYSTEM FOR A LOW-COST IN-SITU WASTE CHARACTERIZATION OF NUCLEAR WASTE

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ABSTRACT: A key aspect involving both operational activities as well as radioprotection in NPP is the management of nuclear waste. Providing efficient and reliable real-time radionuclide concentrations contributes invaluable information while processing nuclear waste as it can in turn reduce costs with packaging, transportation, and disposition for NPPs. Typical NPPs procedures involve characterizing nuclear waste by using HPGe-based systems to determine the radionuclide concentrations and the individual isotope abundances. Often, this requires NPPs to be equipped with a laboratory on site as well as radiological experts and immense amounts of time and effort to obtain the results for well-defined gamma-emitting radionuclides which are easily detectable. Current characterization practices involve obtaining waste stream specific distributions which are then applied to all waste packages of the same waste stream type. This type of analysis is typically performed by HPGe detectors whom the main drawbacks are the typical long measurement times, the time for post process analysis, and the typical high entry cost (around 100kEuro). Due to the integration of software and hardware technologies in the smart era, CAEN SpA and WMG Inc. developed a faster and more user-friendly waste package characterization toolkit, named the REACh™ Detector System, which represents a step change in the way LLRW is characterized and classified. It is intended for all waste packages for open geometry measurements by providing a low-cost detection technology with an easily transportable device. The REACh™ Detector System directly measures gamma dose rates and gamma emitting activity by radionuclide for packaged radioactive material. It is equipped with the RadHAND device used for the gamma measurement and data digitalization via RFID technology and a software database for data storage and management. The system can track in every moment the uniquely identified WP using the attached RFID tag and restore the WP characterization history using the developed database. This presentation will show some results for tests made with the RadHAND device which measured real package radioactive waste from NA commercial power plants to evaluate its performances in fixed geometry configuration. The feasibility to substitute the old typical procedure based on HPGe characterization with this new system will be analyzed.

The Challenge

Current methods of characterizing LLRW are gross approximations which tend to yield overly conservative results which can significantly increase packaging, transport, and disposal costs. The inaccuracies of these methods involve the underestimation of short-lived radionuclides typically found in LLRW. When dose-to-curie conversion techniques are used and hard-to-detect radionuclides are estimated using scaling factors relative to Co-60 and/or Cs-137, underestimating the short-lived gamma emitters results in overestimating the hard-to-detect nuclides as well as Co-60 and Cs-137 since most of the dose rate is attributed to these two radionuclides. Providing efficient and reliable real-time radionuclide concentrations provides invaluable information while processing nuclear waste at NPP. More accurate results can be achieved by directly measuring the gamma emitting activity in the packaged LLRW. However, this is typically done using HPGe detectors, which are not easily portable, require significant data processing, and a subject matter expert to interpret the detector results.

The Solution: The REACh™ Detector System

The **REACh™ Detector System** is a two-part system: part hardware and part software. The **part hardware** is composed by an innovative handheld, the **RadHAND**, designed to perform both spectroscopic radiation measurements and UHF RFID tagging of radiological objects. It embeds a 2"x2" NaI(Tl) crystal inside which is integrated with electronics to provide both measured dose rates and identified gamma emitting radionuclides on the detector's onboard display. The radionuclide identification process is completed by an automated pulse processing algorithm. The RadHAND utilizes RFID technology to digitize all info acquired during the characterization process. RFID tags can be attached to packages and have their package-specific information such as spectral acquisition data (e.g., identified radionuclides and measured dose rate) and "logistics" data (e.g., date, time and location where the measurement was taken, a picture of the container configuration/type, and reading distance) saved to the tag memory.

The **part software** performs peak processing by use of the **GAMON™ algorithm**. This algorithm uses the automated radionuclide information obtained from the **RadHAND** to perform isotope-specific dose rate evaluations to calculate the identified radionuclides' concentrations. The **REACh™ software** incorporates self-shielding correction factors as a function of energy, geometry, material type, and reading distances.

Test and Results

The in-field testing consisted of performing gamma scans for twenty-nine real packages of radioactive waste varying in size from 55-gallon drums, B-25 Metal boxes, and 20' intermodal containers. Waste forms included ion exchange resin, routine dry active waste (DAW), contaminated and activated metals, and Fly Ash. Comparative results for Fly Ash Drums are presented hereinafter.

Fly Ash Drum Comparison Summary

Radionuclides of interest	REACh uCi	Percent Abundance	HPGe	GCD	REACh/HPGe	REACh/GCD
Ag-108m	0.00E+00	0.00%	7.25E+01	0.00E+00	0.00	
Ag-110m	7.06E+01	0.32%	1.36E+02	6.56E+02	0.52	0.11
Am-241	3.91E+01	0.18%	0.00E+00	3.71E+01		1.05
Ba-133	5.92E+00	0.03%	0.00E+00	6.97E+00		0.85
C-14	3.11E+01	0.14%	0.00E+00	3.83E+01		0.81
Ce-141	0.00E+00	0.00%	8.33E+00	0.00E+00	0.00	
Cm-243	2.30E+01	0.10%	1.08E+02	2.18E+01	0.21	1.05
Cm-244	2.30E+01	0.10%	0.00E+00	2.16E+01		1.06
Co-57	5.40E+01	0.24%	1.16E+02	2.89E+02	0.47	0.19
Co-58	0.00E+00	0.00%	9.38E-01	2.31E+00	0.00	0.00
Co-60	**1.83E+03**	8.23%	**1.93E+03**	**2.09E+03**	**0.94**	**0.87**
Cr-51	0.00E+00	0.00%	0.00E+00	4.14E-02		0.00
Cs-134	7.04E+00	0.03%	4.25E+00	9.01E+00	1.66	0.78
Cs-137	**4.69E+03**	21.25%	**4.01E+03**	**4.45E+03**	**1.17**	**1.05**
Fe-55	1.50E+03	6.79%	0.00E+00	1.61E+03		0.93
Ge-68	3.83E+03	17.33%	5.31E+03	8.33E+03	0.72	0.46
Lu-177m	0.00E+00	0.00%	2.99E+01	6.98E+01	0.00	0.00
Mn-54	3.69E+01	0.17%	3.82E+00	3.29E+01	9.66	1.12
Nb-94	1.20E+01	0.05%	0.00E+00	1.44E+01		0.83
Nb-95	1.69E+02	0.77%	6.70E-01	7.67E+00	**	22.06
Ni-63	4.85E+03	21.96%	0.00E+00	5.97E+03		0.81
Pu-238	1.26E+01	0.06%	0.00E+00	1.20E+01		1.05
Pu-239	5.40E+01	0.24%	0.00E+00	5.19E+01		1.06
Pu-240	5.40E+01	0.24%	0.00E+00	5.19E+01		1.04
Pu-241	0.00E+00	0.00%	0.00E+00	4.54E-01		0.00
Pu-242	7.89E+00	0.04%	0.00E+00	7.14E+00		1.10
Rh-101	3.47E+01	0.16%	0.00E+00	3.84E+01		0.90
Sb-124	0.00E+00	0.00%	0.00E+00	6.29E+00		0.00
Sb-125	4.60E+02	2.08%	7.51E+01	1.08E+02	**	4.24
Sn-113	0.00E+00	0.00%	0.00E+00	1.23E+00		0.00
Sr-90	1.30E+03	5.89%	0.00E+00	1.23E+03		1.05
Tc-99	2.92E+03	13.20%	0.00E+00	2.81E+03		1.04
Th-227	0.00E+00	0.00%	0.00E+00	4.34E-03		0.00
Zn-65	6.22E+00	0.03%	6.24E+01	6.85E+01	**	0.09
Zr-95	8.07E+01	0.37%	0.00E+00	2.30E+01		3.51
Totals	2.21E+04			2.81E+04		0.787
Total gammas	1.12E+04		1.19E+04	1.60E+04	0.941	

Fly Ash Drum Experimental Setup

20' Intermodal Experimental Setup

The characterization results from REACh™ were compared with the activities of the gamma emitters found with the HPGe detector as well as available generator characterization data (GCD) for each representative package and for the total of the 21 Fly Ash Drums which gamma scans were performed on.

The Fly Ash Drums were compared on the aggregate relative to both the HPGe results and the GCD. The total calculated activity for the 21 Fly Ash Drums is summarized to the left. As shown in the table, the gamma emitters are within 6% of the results obtained with the HPGe detector and the total activities are about 22% lower than the available GCD

Conclusions & Perspectives

The results of the field testing were in good agreement with those found with a HPGe detector and the total gamma emitters found were within 10%. The final characterization results from the REACh™ Detector System, including hard to detector isotopes from the RADMAN™ Interface, were over 20% lower than the results provided by the waste generators on the average.

The REACh™ Detector has the capability to detect gamma emitters very quickly with a dynamic count time that is completed in a matter of seconds. Dynamic count times ranged from 1 to 19 seconds with all but 2 packages analyzed in less than 10 seconds. One final test which was completed was a "walk-around" scan of a 20' intermodal container with 6 individual readings. The "walk-around" was completed in roughly 1 minute and the results were within 4% of those obtained using fixed detector locations and count times totaling over 20 minutes.

Application of the REACh^{TM} Platform to perform logistic and characterization procedures in the Waste Nuclear Management (WNM)

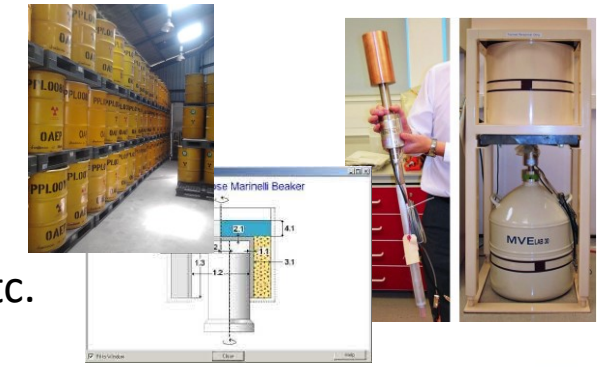
The system offers:

- via RadHAND an integration of Dosimetric and Spectroscopic radiation measurements with UHF RFID technology to easily track any type of radioactive waste
- Integration in a database of specific analysis algorithm to perform isotope-specific dose rate evaluations to calculate the identified radionuclides' concentrations
- Database and RadHAND system accessed only by authorized personnel

The Challenge..

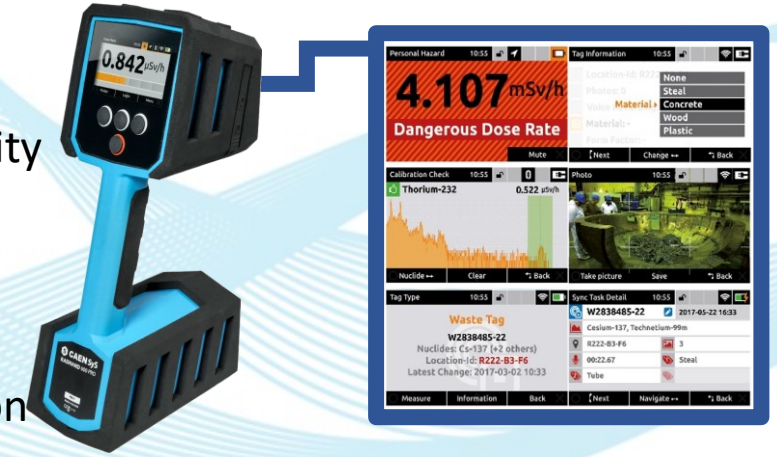
Current characterization methods for LLRW

- Gross approximations which tend to yield overly conservative results
  - E.g., Periodic swipe sampling of DAW every two years (10 CFR Part 61, USA regulation)
- Compositing swipes over time underestimates short-lived radionuclides which results in overestimating hard-to-detect nuclides as well as Co-60 and Cs-137
- Estimating package specific gamma-emitting activity is typically done via HPGe detectors
  - Not easily portable, significant data processing, liquid nitrogen cooled, cost prohibitive, etc.



..and the Solution

- REACh™ system allows a technician to directly measure gamma emitting activity for LLRW, via RadHAND with quick on-the-fly results
- The REACh™ Software uses package specific radionuclide information with package specific dose rates to perform waste characterization and classification



Test Results & Conclusion

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Co-58	0.00E+00	0.00%	9.38E-01	2.31E+00	0.00	0.00
Co-60	**1.82E+03**	8.23%	**1.92E+03**	**2.09E+03**	**0.94**	**0.87**
Cr-51	0.00E+00	0.00%	0.00E+00	4.14E-02		0.00
Cs-134	7.04E+00	0.03%	4.25E+00	9.01E+00	1.66	0.78
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Pu-242	7.89E+00	0.04%	0.00E+00	7.14E+00		1.10
Rh-101	3.47E+01	0.16%	0.00E+00	3.84E+01		0.90
Sb-124	0.00E+00	0.00%	0.00E+00	6.29E+00		0.00
Sb-125	4.60E+02	2.08%	7.51E+01	1.08E+02	**	4.24
Sn-113	0.00E+00	0.00%	0.00E+00	1.23E+00		0.00
Sr-90	1.30E+03	5.89%	0.00E+00	1.23E+03		1.05
Tc-99	2.92E+03	13.20%	0.00E+00	2.81E+03		1.04
Th-227	0.00E+00	0.00%	0.00E+00	4.34E-03		0.00
Zn-65	6.22E+00	0.03%	6.24E+01	6.85E+01	**	0.09
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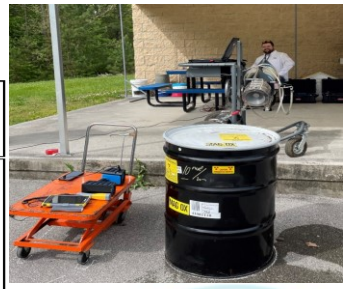

- Good agreement between REACh and HPGe detector (the total gamma emitters found were within 10%).
- The final characterization results were over 20% lower than the results provided by the waste generators on the average
- One final test which was completed was a “walk-around” scan of a 20’ intermodal container. It was completed in roughly 1 minute and the results were within 4% of those obtained using fixed detector locations and count times totaling over 20 minutes
- Next in-field test are coming soon