RADIONUCLIDE SOFTWARE INSTALLATION AT THE US NATIONAL DATA CENTER

Daniel J. Robbins, Joel Rynes, and Kendra Foltz Biegalski

Veridian

ABSTRACT

Two recently developed radionuclide software systems developed through the US Defense Threat Reduction Agency will be installed at the US National Data Center. These are the Radionuclide Monitoring System (RMS) Release 3 Upgrade (R3U) software and the Forensic Event Tool (FET) application software. Development of the software, including the algorithms and the commercial off the shelf software (COTS) used are described. The RMS software suite, which supports an automated data pipeline, has been developed by Veridian within the Center of Monitoring Research (CMR) for use the with International Monitoring System (IMS) data over the last five years. The most recent revision of the software suite, R3U, includes improvements and bug fixes to several tools to optimize high throughput radionuclide data management and analysis. The *rms_analyze* and *rms_xanalyze* tools automatically analyze gamma-ray spectra and three-dimensional (3-D) beta-gamma coincidence spectra, respectively. *Inspectra* provides the user the capability to interactively analyze spectra from gamma-ray detectors, while *Coriant* does the same with 3-D beta-gamma coincidence spectra. *Trendvue* provides graphical display of a detector's performance history, state of health, and station meteorology. The *Analyst Work Area* (AWA) displays station-operating conditions. *Multiple Analyst Review* (MAR) organizes the interactive review of data by a team of analysts and *Workflow* displays received data. The increase in functionality and other improvements made to each of these tools and the supporting database as part of the R3U is described in detail.

The RMS software suite was enhanced with Cascade Summing Correction (CSC) software. Multiple gamma-rays are sometimes emitted per decay and can be measured simultaneously in the detector. This effect can lead to inaccurate radionuclide activity concentrations (over a factor of two in some cases). The CSC software requires the detector to have a total efficiency calibration. Because this calibration is not typically performed at the radionuclide stations, the Monte Carlo N-Particle program was used to model the total efficiency of typical high-purity gamma-ray detectors.

The FET software suite includes the *Nuclear Sources and Assets Database – Geographical Information System* (NUSAD - GIS) as well as the *Radionuclide Ratio Analysis Tool* (RRAT). NUSAD is a special purpose database, which includes all known potential sources of fission products that might be detected by environmental atmospheric sampling along with the known monitoring assets that can detect fission products in the atmosphere. The NUSAD – GIS incorporates a geographical information display in which NUSAD spatial data are converted to "shapefiles" and are viewable by ESRI compatible products such as ArcView. The RRAT is an analytical tool used for evaluating the concentration ratios of radioactive fission products in environmental samples. Analysis of these ratios via the RRAT can be used to determine possible sources of the measured radionuclides.

OBJECTIVE

This paper describes Version 5 of the Radionuclide Monitoring System (RMS) software developed at the Center for Monitoring Research (CMR) and is scheduled to be installed at the United States National Data Center (NDC) in the summer of 2002. RMS 5.0 includes the RMS Release 3 Upgrade (R3U) software that was delivered to the International Data Centre (IDC) in December 2001 and is scheduled to be installed at the Russian Federation NDC during the summer of 2002; several significant enhancements to the baseline RMS software including the addition of Cascade Summing Correction (CSC) software; and the addition of Forensic Event Tools (FET) to the RMS suite. The FET software suite includes the *Radionuclide Ratio Analysis Tool* (RRAT) and the *Nuclear Sources and Assets Database* (NUSAD). The US NDC currently uses RMS Release 3 (R3) software. In the following sections the new components of the RMS software will be described and the differences between the R3U and R3 software will be summarized. To keep this paper at a reasonable length, the functions of the software will be discussed only at a high level.

RESEARCH ACCOMPLISHED

Forensic Event Toolbox

The Forensic Event Toolbox (FET) currently consists of two software applications, the *Radionuclide Ratio Analysis Tool* (RRAT) and the *Nuclear Sources and Assets Database* (NUSAD) *Geographic Information System* (GIS). Both applications continue to be developed. They are described in turn.

Radionuclide Ratio Analysis Tool

Background

It was plain several years ago that a decisive method for proving that radioactive debris emanates from a nuclear detonation was needed. Anthropogenic radionuclides in the atmosphere can originate from many sources including a controlled or accidental release at a nuclear reactor or a fuel reprocessing facility. The rate of production for various fission products is dependent on the fissioning species (either ^{235}U, ^{239}Pu or other fissionable isotope) and the energy of the neutron that initiates the fission. Nearly all nuclear reactors operate with neutron energies that follow a Maxwellian distribution having a mean at the energy corresponding to the operating temperature of the reactor, about 0.025 eV. They also produce fissions almost exclusively in ^{235}U. Nuclear weapons, on the other hand, rarely have any significant moderation so that the energy distribution of the neutrons is nearly the same as that for the energy distribution at the time of fission. This distribution is non-Maxwellian, has a mean energy of about 2 MeV and has peak energy of 6 MeV. The fissioning species may be either ^{235}U or ^{239}Pu. In addition, the fissions in a nuclear detonation all occur almost instantly, while a nuclear reactor produces fission products over a lengthy period up to over a year long. Many of the fission products decay away or are transfigured by the absorption of neutrons. The result of these processes is that the mix of fission products that come from a nuclear weapon are decidedly different from the mix that comes from a nuclear reactor.

Nuclear scientists working at the CMR looked for a way to use the difference in fission product inventories to distinguish between radioactive debris from a nuclear reactor and that from a nuclear detonation. The method they chose was to compare the ratios of concentration of several prominent fission product pairs. The ratios of these fission product pairs are strongly indicative of the source, reactor or bomb, of the fission products.

Analytical Approach

From the enormous list of fission products available, 25 were chosen as nuclides of interest (NOI) because they had moderate half-lives (several hours to several years), high specific activity and relatively large fission product yields. This set of attributes makes them the most likely fission products to be detected following an attempted clandestine nuclear test. From these fission products eight pairs were selected to ratio. The radio-xenon pairs were selected because they were made up of the three xenon isotopes more likely to be detected and measured. The particulate fission product pairs were selected following the suggestion of Doctor Yehuda Finkelstein[1]

Table 1 Nuclides of Interest and Default Ratios for the Radionuclide Ratio Analysis Tool.

Nuclides of Interest		Default Ratios
Sr-89	Xe-131	Xe-135/Xe-133
Y-91	Xe-133m	Xe-133m/Xe-133
Y-93	Xe-133	Mo-99/Nd-147
Zr-95	Xe-135	Ce-143/Zr-95
Zr-97	Cs-137	Nd-147/Ce-141
Mo-99	Ba-140	Nd-147/Zr-95
Ru-103	La-140	Ce-143/Nd-147
Rh-105	Ce-141	Mo-99/Ce-141
Sn-125m	Ce-143	
Te-127	Pr-143	
Sb-128	Nd-147	
Te-129	Pm-149	

The total activity of each nuclide of interest was calculated at the end of irradiation for a pressurized water reactor using ORIGEN/SCALE[2] for two operating scenarios, a normal run between refueling of 365 days and a run ended prematurely after 3 days at full power. The total activity of each nuclide was also calculated using the England and Rider Fission Product Tables[3] for each ^{235}U and ^{239}Pu exposed to fission spectrum neutrons. These values were taken to be representative of the relative production of fission products produced in basic nuclear weapons using each of the two species as fuel.

An algorithm, based on the Bateman decay equation, was written and encoded to decay each fission product species from the time of release, specified by the user, to a future collection time, also specified by the user. It is postulated that in use the time of release will come from SHI information or another source indicating that a suspect nuclear detonation has occurred. The collection time will come from the collection stop time in the Radionuclide Monitoring System database for samples that the user is trying to determine a source for.

Another algorithm was written to compare the activity ratios of the sample to the activity ratios of the possible sources: reactor long operation, reactor short operation, uranium fueled bomb and plutonium fueled bomb. The algorithm selects the scenario ratio set with greatest similarity to the sample ratio set and identifies that scenario as the most likely source of the debris in the sample. This algorithm takes the ratio of each selected pair of nuclides in each sample and divides it by the activity concentration ratio of the same pair of nuclides from each scenario, per Equation 1. It takes the absolute value of the natural log of this ratio. The result is called the Disparity. A perfect fit will result in a ratio of 1.0 and a natural log of zero, so the value closer to zero is chosen.

$$Disparity = \left| \ln\left(R_{sample} / R_{scenario} \right) \right|$$ **Equation 1**

Data Entry

The user enters the initial information on the **Sample Id Tab**, shown in Figure 1. After selecting an Event Date and Hour and the number of days to extend the query, the user selects the station codes of the stations likely to have collected samples during the period of interest, then presses the "Query Samples" button. The tool populates the "Sample Ids of Interest" window with all samples collected at the selected stations during the period of interest. The user can then review the summary of radionuclides detected in the samples and decide which to keep for analysis.

Next the user selects the **NOI Tab**. The user must select one reactor scenario and one weapon scenario for the tool to compare the sample results to. The user may accept the default NOI Pair List or delete any or all of them. The user may also select any nuclide from the list of NOI to use as a numerator and any other nuclide from the list as a denominator in a custom ratio pair. The user then selects "Submit Config" to launch the analysis. The user will then select the **Reports Tab** or the **Plots Tab** to view the results
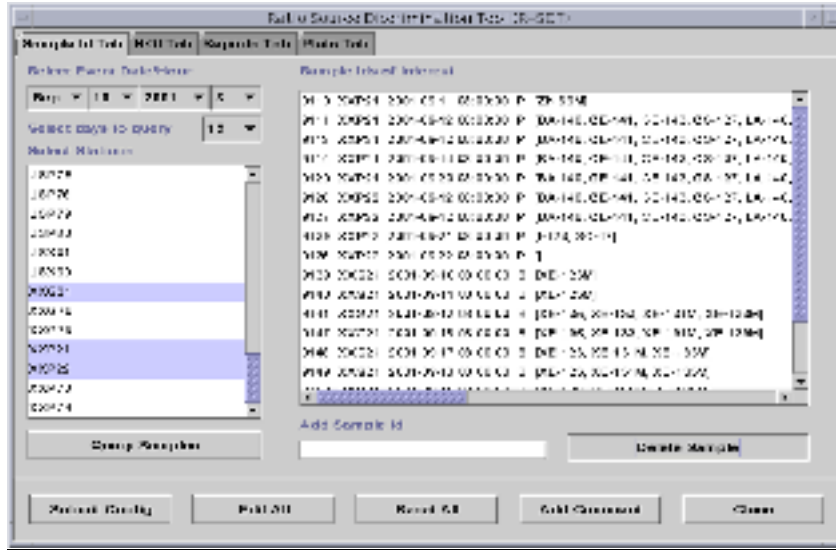
Figure 1 Sample Id Tab from the Radionuclide Ratio Analysis Tool.

Result Reporting

In the **Reports Tab**, the tool averages the results of Equation 1 over all values or separates the results by ratio pair, sample, or collection site at the user's discretion. The overall average minimizes the uncertainty in the results. Allowing the results to be viewed and averaged by ratio pair, sample and collection site give the user tools to identify the source of errant data and to selectively reject that data to improve the overall certainty of the results.
In addition to sorting and averaging the results, the tool permits plotting of the ratios by NOI pair in the **Plots Tab**, as shown in Figure 2. The user selects the NOI pair for plotting and then selects "Graph Pair." The tool will plot the ratio of the selected NOI pair over time for each of the scenarios selected on the **NOI Tab** and will plot the sample ratios for the same NOI pair. It will do a correlation of the sample ratios against each of the scenarios and will list the coefficient of determination, the square of the correlation coefficient, for each case. This provides additional analytical information to the user as well as a visual presentation of the analytical results.
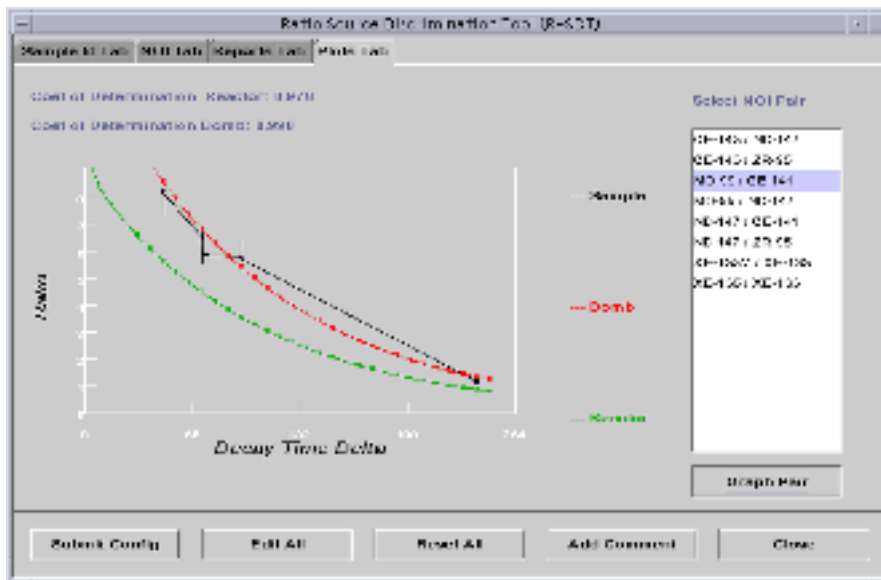

Figure 2 Plots Tab from the Radionuclide Ratio Analysis Tool.

Future Work

Two major efforts are needed to improve the capabilities of the RRAT, one in the baseline data and one in the analytical tools.

Currently there are only two reactor scenarios available, a normal duration run and a very short period of operation of a pressurized water reactor. Boiling water reactors would probably not produce significantly different results for the same length of operating period. However, some reactors, in particular the Canadian Deuterium Reactor or CANDU and the Russian designed RBMK, refuel online so that the period of irradiation for the fuel may be quite short and the initial fission product activity ratios may be quite different from light water reactors. Also, some reactors, in particular fast breeder reactors, have a much more energetic neutron spectrum than light water reactors and this probably results in initial fission product activity ratios that are significantly different. Both type of reactors need to be modeled using ORIGEN and the scenarios need to be added to the options in the RRAT.

Currently, the RRAT performs a crude averaging of the ratio of ratios of NOIs. This is augmented by correlation of selected ratios over time. However, improved analytical techniques are desired. One method that shows high promise is multi-variant analysis. This will entail expanding the correlation approach to comparing several NOI pair ratios to each other. This appears to be possible only by using a common denominator and an effort to develop an algorithm to perform this analysis should be a goal for the near future.

Nuclear Assets and Sources Database

Database

The *Nuclear Assets and Sources Database* (NUSAD) is an Oracle-based database that contains information on sources of nuclear debris in the environment and the assets that might detect that debris. It has been described in detail in a previous SRR[4]. A source is any facility that could potentially release radionuclides and an asset is any device that can detect radionuclides. These data can be used to help determine the source of radionuclides found in data at the NDC, or to identify additional assets that might provide data confirming or refuting data on file.

NUSAD contains three broad classes of data: assets, sources and geographical. Information on each reference is included in the database, including the title, publication details, author, and how the data were used in the NUSAD. The NUSAD database schema contains approximately 40 database tables and is available upon request. The NUSAD Geographical Display Tool has been upgraded to two new tools.

Data Entering Tool

NUSAD data are stored on an Oracle database. The *Data Entering Tool* (DET) was created to provide easy access to the NUSAD data, without requiring users to have substantial knowledge of SQL and the NUSAD schema. The DET includes a graphic user interface (GUI) written with Java. It provides an interface that permits authorized users to easily enter, delete, modify, and view data. The NUSAD DET allows data to be accessed either through a browser or editor window.

Geographical Information System

To aid in future visualization, the NUSAD – *Geographical Information System* (NUSAD – GIS) was provided to the NDC. Software has been installed that converts NUSAD spatial data to *shapefiles*. *Shapefiles* are the file format that can be viewed by commercial-off-the-shelf (COTS) software from the ESRI Corporation called ARCView, ARCIMS, and ARCExplorer. The NUSAD – GIS comprises two programs, the first collects data from a NUSAD table or view and writes these data to a text file stored on the file server. The second program reads this text file and creates the *shapefile*.

These additions to the NUSAD greatly enhance the potential to visualize, interpret and present analyses of data from environmental collection of fission and activation products. In addition, the visualization tools aid the analyses themselves.

<u>*Radionuclide Monitoring System, Release 3 Upgrade*</u>

The Radionuclide Monitoring System (RMS) Release 3 Upgrade (R3U) includes several software tools to aid analysts in processing the large throughput of data from global arrays of environmental radionuclide sensors and to aid managers in monitoring the performance of automated equipment. The software has been described elsewhere[5], so this paper will describe enhancements to the existing suite.

Rms_analyze

Rms_analyze launches automatically when the data import routine recognizes an incoming pulse-height data message, although it can be called to execute manually by a user. It uses the data in the Radionuclide Monitoring System (RMS) Database. After receiving spectral data, the program locates peaks, determines peak area, and updates the calibration metrics of the detector. Following the calibration update, it performs a second peak location and peak area measurement. *Rms_analyze* then identifies and quantifies radionuclide activity concentrations, calculates the minimum detectable concentrations (MDC) for nuclides of interest, calculates parent, daughter activity relationships and performs several quality control tests. The output can then be used by automated routines to prioritize the sample for analyst review, notify analysts, notify subscribers of unusual events and send out an Automated Radionuclide Report (ARR).

Two improvements have been made to *rms_analyze*:
> The warning and error messages have been enhanced.
> The on-line help manual has been enhanced.
> Bug fixes were carried out.

Rms_xanalyze

Rms_xanalyze[6] functions similarly to *rms_analyze*, except that it operates on 3-D beta-gamma coincidence spectral data from noble gas stations. *Rms_xanalyze* determines net counts in predefined regions of interest (it is consequently very dependent on reported calibration information), identifies the presence of ^{131m}Xe, ^{133}Xe, ^{133m}Xe, ^{135}Xe and radon daughters by comparing net counts to the counting limit, and calculates activity concentrations and MDCs for the identified radioxenon isotopes. The output is used the same way as the output from *rms_analyze*.
The following enhancements have been made to *rms_xanalyze*:
> A reanalysis capability has been added through the command line.
> An automatic control check on the xenon sample volume has been added.
> Linear and quadratic energy versus channel regressions (ECR) have been made available for analysis.
> The timing of reading from and writing to the database has been improved.
> The interference counts algorithm has been modified so that all nuclides with a potential to interfere with counting are now included, with their associated uncertainties, in calculating the corrected activity of the nuclide of interest.

Inspectra

Like the programs above, *Inspectra* has been described in detail previously[5]. It provides a means for the user to manually evaluate sample pulse-height spectra and override the automated decisions of *rms_analyze*.
The following enhancements were added to Inspectra for R3U:
> The ability to edit general comments and support for a predefined list of general comments were added.
> The capability to undo the remove nuclide command was provided.
> The "WP224" label was changed to NOI (Nuclide of Interest).
> Peak search sensitivity vs. peak significance scatter plot option was added.
> 3-D beta-gamma coincidence samples are now filtered from the **Open Sample Dialog**
> The Role indicator was added to the main *Inspectra* window
> The display of real half-lives and half-lives used by *rms_analyze* in the **Nuclide Library Dialog** was added so that the user is aware of artificialities created for processing some natural radionuclides. It was found to be necessary to create these artificial half-lives to avoid over-correction for decay and consequent over correction for background counts.

The capability to perform sample reprocessing using resolution versus energy regression (RER) pair data was added.

Cross-hairs on graphs to facilitate data interpretation were added to the display.

New timeliness flags are displayed (particulate samples only).

Several bugs were eliminated.

Coriant

Coriant[6] provides for the manual review of 3-D beta-gamma spectra from noble gas stations. The following enhancements have been added to *Coriant* in the Release 3 Upgrade:

A new **Reanalysis Dialog** facilitates modification of:
- o Number of Compton background channels used in net region of interest (ROI) area determination.
- o ECR coefficients.
- o Turn on/off detector and gas background subtractions.

Graph coordinates are now displayed in **Histogram Tab**.

ROIs in 2-D beta-gamma spectra are now highlighted

The *Multiple Analyst Review* (MAR) Tool has been linked to *Coriant*:
- o Release without categorization option has been added.
- o Permissions are now checked for adding comments and releasing spectra.

General improvements in data display were made to the **Isotope Tab Dialog** and the **ROI Dialog**.

Bugs were eliminated.

Trendvue

Trendvue has been described in detail in reference 5. The application allows the user to visualize various parameters of radionuclide sensors over time in order to recognize trend development. The following enhancements were added to Trendvue for the RMS R3U:

The ability to create log plots was added.

The ability to plot status of health (SOH) data was added.

Swing COTS was added to provide a capability to create wind plots.

The ability to plot larger number on xy-Graph was provided.

Updated y-axis hash mark function was added.

The ability to query on released samples only for some parameters was added.

Analyst Work Area

The *Analyst Work Area* (AWA) provides the user the ability to graphically view the status of reports from radionuclide sensors in the IMS. It has been described in reference 5. No changes were made to the AWA for RMS Release 3 upgrade.

Multiple Analyst Review

The *Multiple Analyst Review* (MAR) is described in reference 5. The tool permits a user to manage the assignment of data to analysts to review. The following enhancements have been added to the MAR for Release 3 Upgrade:

The ability to add, delete, and modify users' default roles has been provided.

The MAR was integrated into the database;
- o The assignment of permissions for the MAR and the database (controls database read and write access) were combined.
- o The creation of roles for the MAR and the database were combined.

An Exit button was added.

Rms_categorize

Rms_categorize[5] is used to automatically prioritize both particulate and noble gas samples based on the amount and types of radionuclides identified. The results of the prioritization step are stored in the database and alert messages

are sent to subscribers based on the results. Previously, the Exponentially Weighted Moving Average (EWMA) method was the only prioritization algorithm available. In R3U two separate algorithms on a per station and a per nuclide basis can now be chosen to prioritize samples. These are the EWMA and the Recent Distribution Categorization (RDC) algorithms.
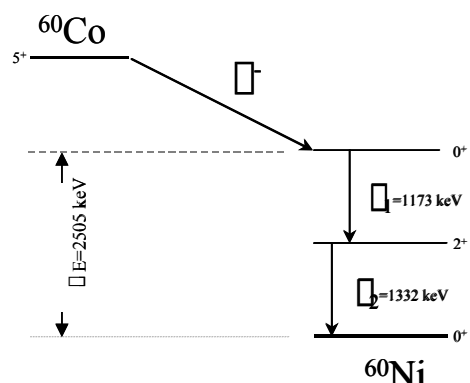
The RDC algorithm works by comparing the current activity measurement with the last ten activity measurements for that nuclide at that station. If the difference between the current measurement and the mean measurement is greater than a configurable number of standard deviations (default two), then the sample is anomalous. In addition, if there are not ten previous measurements or if the nuclide has not been detected at least three times in the past thirty days at that station, then the sample is anomalous. The RDC algorithm, unlike the EWMA algorithm, is not dependent on the order in which the samples are received. The RDC algorithm is typically better for radionuclides detected on an occasional basis whereas the EWMA algorithm typically is better for frequently detected radionuclides.

Baseline Software Enhancements

Cascade Summing Correction

One of the difficulties in measuring radioisotopes with gamma ray detection is cascade summing. Typically, nuclides of the isotope being counted decay to the excited state of another isotope. This excited state quickly decays to the ground state by the emission of gamma rays. Many of the radioisotopes that are measured emit multiple gamma rays of different energy. On occasion, two or more of these gamma rays enter the detector nearly simultaneously and are counted as one gamma ray having an energy equivalent to the sum of the energies of all the gamma rays.

A good example is ^{60}Co as shown in Figure 3. Cobalt-60 decays to ^{60}Ni by the emission of a beta particle. The excited ^{60}Ni nucleus emits two principle gamma rays to reach its ground state, one at 1.173 MeV and one at 1.332 MeV. Usually these gamma rays will be counted separately, but sometimes they are counted as one gamma ray with energy of 2.505 MeV resulting in an erroneously high count of photons at that energy and an erroneously low count of photons at the other two energies.

Figure 3 Decay scheme of ^{60}Co.

The inaccuracies introduced by coincidence summing, as much as a factor of two, carry over to cause inaccuracies in other tools such as the RRAT. It is important that corrections are calculated and a more accurate value for the activities of these radioisotopes be found. The cascade summing correction (CSC) was developed to do this.

The CSC was integrated into the radionuclide analysis software (*rms_analyze*) so that it executes after the nuclides are identified. It requires decay specific correction coefficients and both the peak and total detector efficiency. The decay specific coefficients were obtained from the Evaluated Nuclear Structure Data File (ENSDF). The RMS current formats and protocols allow the total efficiency to be stored in the sample data file. However, because this calibration is not typically performed at the stations, the Monte Carlo N-Particle (MCNP) code, developed by Oak Ridge National Laboratory, was used to model total efficiency for typical detector systems.

The activity correction factor is, therefore, both decay and detector specific. Table 2 below shows the activity correction factors for a typical HPGe detector for the key-line activity of all fission and activation products in the CMR radionuclide library that are subject to cascade summing effects. The isotopes with the largest and smallest correction coefficients are highlighted in the table. These correction coefficients do not include x-ray effects. Consideration should be given to researching the impact of x-rays on counting accuracy and entering correction factors for them in the analysis software if their impact is significant.

Table 2 CSC ratios for activation and fission products in R3U library.

Nuclide	Type	Halflife	Ratio	Nuclide	Type	Halflife	Ratio
AG-106M	activation	8.460 D	1.794	K-42	activation	12.360 H	1.004
AG-108M	activation	127.000 Y	1.507	LA-140	fission (p)	1.678 D	1.263
AG-110M	activation	249.760 D	1.521	MO-99	fission (p)	2.748 D	1.268
AG-111	fission (p)	7.450 D	0.994	NA-24	activation	14.959 H	1.123
AS-74	activation	17.770 D	1.000	ND-147	fission (p)	10.980 D	1.012
AS-76	activation	1.097 D	0.850	NP-239	activation	2.357 D	1.017
AU-196	activation	6.183 D	1.053	PB-203	activation	2.161 D	1.007
AU-196M	activation	9.700 H	1.663	PD-112	fission (p)	21.030 H	1.101
AU-198	activation	2.694 D	1.001	PM-149	fission (p)	2.212 D	1.000
BA-133	activation	10.520 Y	1.137	PM-151	fission (p)	1.183 D	0.866
BA-136M	fission (p)	0.308 S	1.533	PR-144	fission (p)	17.280 M	1.033
BA-140	fission (p)	12.752 D	1.073	RB-84	activation	32.770 D	1.001
BR-77	activation	2.377 D	1.018	RH-102	activation	207.000 D	1.072
CD-115M	fission (p)	44.600 D	0.996	RH-105	fission (p)	1.473 D	1.000
CE-143	fission (p)	1.377 D	1.147	RU-103	fission (p)	39.260 D	0.999
CE-144	fission (p)	284.894 D	0.941	RU-106	fission (p)	1.023 Y	1.208
CO-57	activation	271.800 D	1.025	SB-120	activation	5.760 D	2.077
CO-58	activation	70.820 D	1.216	SB-122	activation	2.700 D	1.009
CO-60	activation	5.271 Y	1.170	SB-124	activation	60.200 D	1.144
CR-51	activation	27.702 D	1.002	SB-125	fission (p)	2.730 Y	1.080
CS-132	activation	6.479 D	1.025	SB-126	fission (p)	12.400 D	2.161
CS-134	activation	2.062 Y	1.245	SB-127	fission (p)	3.850 D	1.005
CS-136	fission (p)	13.160 D	1.452	SB-128	fission (p)	9.010 H	2.631
EU-152	activation	13.542 Y	1.218	SC-46	activation	83.810 D	1.181
EU-152M	activation	9.274 H	1.236	SE-75	activation	119.779 D	1.228
EU-155	fission (p)	4.680 Y	0.981	SM-153	fission (p)	1.928 D	1.057
EU-156	fission (p)	15.190 D	1.175	SM-156	fission (p)	9.400 H	1.061
EU-157	fission (p)	15.180 H	1.112	SN-125	fission (p)	9.640 D	1.175
FE-59	activation	44.496 D	1.012	SR-91	fission (p)	9.630 H	0.996
GA-72	activation	14.100 H	1.210	TE-129	fission (p)	1.160 H	1.051
HG-203	activation	46.612 D	1.007	TE-129M	fission (p)	33.600 D	1.000
I-123	activation	13.200 H	1.003	TE-131M	fission (p)	1.250 D	1.388
I-130	fission (p)	12.360 H	1.617	TE-132	fission (p)	3.204 D	1.112
I-131	fission (p)	8.040 D	0.973	TM-168	activation	93.100 D	1.704
I-132	fission (p)	2.295 H	1.453	U-237	activation	6.750 D	1.241
I-133	fission (p)	20.800 H	1.006	W-187	activation	23.720 H	0.932
I-135	fission (p)	6.570 H	1.030	Y-88	activation	106.650 D	1.169
IR-190	activation	11.780 D	1.878	Y-93	fission (p)	10.100 H	1.054
IR-192	activation	73.831 D	1.325	ZN-65	activation	243.900 D	1.066

Trendvue

Further improvements were made to *Trendvue* in addition to the enhancements included in the R3U software. These enhancements include:

> A new plot was added to the pull down menu that plots nuclide concentrations reported in the IDC-generated Automatic Radionuclide Report (ARR) and Reviewed Radionuclide Report (RRR).
> A second Y-axis was added to the *Trendvue* graph. Right-clicking the plot legend opens a dialog box that allows the user to choose the axis on which the graph will be plotted.
> A pop-up dialog box has been added that allows users to specify the minimum and maximum values for the X-axis and both Y-axes.
> Users are now able to choose the format in which the time and date are displayed in *Trendvue*.
> *Trendvue* can now plot data from flat files. The software uses description files that have information about the number of columns and column names for parsing flat files. The description files give *Trendvue* the flexibility to handle new formats in the future.
> Right-clicking the mouse on the legend of a plot gives the user the ability to change the color of the plot.

CONCLUSIONS AND RECOMMENDATIONS

The software suites described are effective and robust. It is recommended that the RMS 5.0 software enter into operational use at the NDC and that work continue on developing further capabilities and applications of the RMS software especially in the area of the newly developed RRAT.

REFERENCES

[1] Fission Product Isotopic Activity Ratios as Event Characterization Tools, Draft Technical Report prepared for the Provisional Technical Secretariat, Y. Finkelstein, February 2000.

[2] Oak Ridge Isotope Generation/Standardized Computer Analyses for Licensing Evaluation, Version 4.4a, Oak Ridge National Laboratory – Radiation Safety Information Computational Center, 2000.

[3] Yields Evaluated and Compiled for Los Alamos report LA-UR-94-3106 (ENDF-349), T.R. England and B.F. Rider October, 1994

[4] Nuclear Sources and Assets Database (NUSAD) Development, J. C. Rynes and D. Leussing, 23rd Annual DoD/DOE Seismic Research Symposium Proceedings, 2001

[5] IDC Processing of Radionuclide Data, Documentation for the International Data Center, K.M.F. Biegalski and H. Magyar, December 2001.

[6] Automatic And Interactive Analysis Software For Beta-Gamma Coincidence Systems Used In CTBT Monitoring, J. Rynes, K.M.F. Biegalski, and P. Donohoe, 22nd Annual DoD/DOE Seismic Research Symposium Proceedings, 2000