A Comparison of Select USDOE and USEPA Risk and Dose Assessment Tools Utilized at Two FUSRAP Projects – 17388

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ABSTRACT

The US Army Corps of Engineers (USACE) utilizes several computer programs and models to conduct risk and dose assessments at Formerly Utilized Sites Remedial Action Program (FUSRAP) projects. In the past, the USACE has primarily relied on the US Department of Energy (USDOE)'s Argonne National Lab (ANL) RESidual RADioactivity (RESRAD) computer code for performing dose and risk assessments involving radiological contamination in onsite soils and the US Environmental Protection Agency (USEPA) Preliminary Remediation Goal (PRG) and Dose Compliance Calculator (DCC) for radiological contamination in ground water. Recent USEPA guidance requires use of USEPA calculators for all media at National Priority List sites, which includes some FUSRAP sites. The USACE recently utilized both RESRAD and the USEPA PRG and DCC calculators in assessments at two FUSRAP projects for all media in order to evaluate differences in the models and determine adjustments to potentially resolve differences. The two projects involve soil and groundwater assessments and address typical FUSRAP contaminants such as uranium, radium, thorium and their progeny. This paper discusses differences between the models, lessons learned, and methods used to address stakeholder and other concerns regarding these assessments. The paper's discussions are useful for anyone performing risk or dose assessments for radiological contamination and especially those using RESRAD and the PRG and DCC calculators.

INTRODUCTION

The United States Government, thru the US Department of Energy (USDOE) and the US Army Corps of Engineers (USACE), addresses legacy sites from the nation's early atomic energy program through the Formerly Utilized Sites Remedial Action Program (FUSRAP). The USDOE and the USACE have both had roles in program administration and execution since the FUSRAP began in 1974. The USACE follows the investigation and response framework of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended, and the National Oil and Hazardous Substances Pollution Contingency Plan while executing the FUSRAP. Some FUSRAP sites are also US Nuclear Regulatory Commission (USNRC) licensed and some are National Priority List (NPL) sites regulated by the US Environmental Protection Agency (USEPA). Several sites have all four of the above mentioned federal agencies involved and all have state agency involvement as well. Given that federal and state agencies have developed or adopted different computer models to determine risk and/or dose from residual radioactivity at a site, selection of the proper model to use is complicated at best.

Accordingly, the USACE utilizes several computer programs and models to conduct risk and dose assessments at FUSRAP sites. In the past the USACE has primarily relied on the USDOE Argonne National Lab RESidual RADioactivity (RESRAD) computer code for dose and risk assessments involving radiological contamination in onsite soils and the US Environmental Protection Agency (USEPA) Preliminary Remediation Goal (PRG) and Dose Compliance (DCC) calculators for radiological contamination in ground water. The USACE has also used hand calculations, the New Jersey Department of Environmental Protection (NJDEP)'s RASOR model, CAPP 88, COMPASS, and other RESRAD family of codes for these assessments. Recent EPA guidance [1] requires initial use of EPA calculators for all media at NPL sites, which includes some FUSRAP sites.

DESCRIPTION

The USACE recently utilized both RESRAD and the USEPA PRG and DCC calculators in assessments at two FUSRAP projects for all media in order to evaluate differences in the models and determine adjustments to potentially resolve differences. The two projects involve soil and groundwater assessments and address typical FUSRAP contaminants such as uranium, radium, thorium and their progeny.

Projects

Project one is a former landfill contaminated with natural uranium in equilibrium with its progeny. The media of primary concern are soils and groundwater. The USACE is at the CERCLA Remedial Investigation (RI) phase of this project and conducted a Baseline Risk and Dose Assessment (BLRDA) as part of the RI. The exposure scenarios evaluated included resident, maintenance worker, indoor worker, trespassers, and recreational use.

Project two is a former uranium metallurgy and machining plant utilizing enriched, natural, and depleted uranium. The media of primary concern are soils and groundwater. The USACE is at the CERCLA RI phase of this project and conducted a BLRDA as part of the RI. The exposure scenarios evaluated included resident, maintenance worker, indoor worker, trespassers, and recreational use.

Neither project is licensed by the USNRC, and project two is part of a regional groundwater NPL site. Both projects present excellent opportunities to compare RESRAD and the USEPA PRG and DCC calculators.

Models

The RESRAD family of codes is a suite of software tools developed by the USDOE to evaluate radiologically contaminated sites. The codes can be used to derive cleanup criteria or Derived Concentration Guideline Levels (DCGLs) and estimate radiation dose or risk from residual radioactive material under various scenarios using appropriate parameters. The RESRAD code calculates both radiological dose and risk. [2] DCGL development was not an aspect of the BLRDA, as criteria for remediation is determined in the Feasibility Phase or CERCLA.

The USEPA has separate codes for risk and dose calculations. The Preliminary Remediation Goals (PRG) calculator presents risk-based PRGs calculated using default input parameters and the latest toxicity values using the USEPA Risk Assessment Guidance for Superfund: Volume I, Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals) (RAGS Part B). Typically PRGs are risk-based, conservative screening values to identify areas and contaminants of potential concern (COPCs) that may warrant further investigation. [3]

DISCUSSION

Modeling

The authors caution the reader against reification. Reification is when an abstraction (the model) is treated as if it were a real true entity. In fact, all models are approximations. Accuracy determination or verification is not the intent of this paper. Usefulness is a key aspect of models as illustrated by statistician George Box in stating “All models are wrong, some are useful” [4] or as stated by statistician Thaddeus Tarpey “All models are right, most are useless”. [5] Since both the USEPA and USDOE models have been widely used and both have been verified by various agencies, both models are obviously useful.

Both RESRAD and the USEPA models have significant uncertainty associated with their results. While the determination of this uncertainty is outside the scope of this paper, the State of New Jersey discusses modeling uncertainty as significant enough that there is actually no difference between 150 and 250 microsieverts/year (uSv/yr) [15-25 mrem/yr] dose standards. [6] The recent USEPA guidance stating 120 uSv/yr (12 mrem/yr) is an appropriate evaluation of a regulatory standard [7] certainly falls well within the uncertainty of modeling results as well. RESRAD does provide modeling options to assist in understanding model input uncertainty and the uncertainty can vary significantly (orders of magnitude).

While both USEPA and USDOE models are easily used, both require a significant understanding of risk and dose assessments as well as an understanding of how the model uses the input values and the modeling assumptions.

Model Selection

Choosing the best model to use for a project can be a challenge but is best decided with project regulator input, especially if the agency has a preference for a model. USEPA guidance requires the initial use of USEPA models on NPL sites. One noteworthy justification for doing so is the use of USEPA models for chemical risk assessment. These chemical models are similar to the PRG calculator and widely accepted and used. Since total site risk is of concern on NPL sites, using similar models for chemical and radiological risk estimates in order to combine site risks only makes sense. Likewise use of the USEPA models may not be warranted if a site is regulated under the Atomic Energy Act and not on the NPL. The USNRC and Agreement States may accept either the USDOE or USEPA models or may have their own dose assessment models (e.g. COMPASS or NJDEP's RASORS).

The model user should also consider the data needs for each model. Both the USEPA calculators and RESRAD have default inputs and can function with minimal site specific inputs. Arguably, the fewer inputs required the less site specific the assessment may be and vice-versa.

Additionally, the model user should consider the purpose of the modeling effort. Project planning, public discussions, CERCLA documentation, or demonstrating compliance with regulations all may be accomplished with different models. As an example, on a FUSRAP project in New Jersey, the USACE uses NJDEP RASORS for project planning assessments, CAPP-88 for demonstrating Clean Air Act compliance, RESRAD for DCGL derivation, USEPA calculators for chemical risks and disposal facility selection, and hand calculations of dose and risk estimates.

Running different models and comparing results may also provide useful information for the model user as well as may mitigate regulator concerns over model choice. Should differences in model results be insignificant, the user may choose to use a less complex or more readily accepted model.

Previous Model Comparison

A comparison of the USEPA and USDOE models was presented in *RESRAD for Radiological Risk Assessment: Comparison with EPA CERCLA Tools – PRG and DCC Calculators* [8]. The report found differences in dose estimations between the models from 10% to 3 orders of magnitude depending on modeled scenario, pathways, and isotope. The report compared final PRG to a final goal calculated from RESRAD output. For key FUSRAP isotopes (Ra-226, Th-230, U-238) the differences reported were generally 1 order of magnitude but up to 3 orders of magnitude for Ra-226.

Key differences noted in the report include:

- RESRAD employs fate and transport simulation to track the environmental distributions of radionuclides over time whereas the USEPA PRG Calculator models radiation exposures starting at current time (time = 0).

- The USEPA PRG Calculator does not have the ability to model the variation in radionuclide concentration as a function of time, therefore the model is static. RESRAD incorporates parent radionuclide decay and progeny ingrowth during the entire exposure duration, as well as during transport through the environment. In the USEPA calculators, longer-lived daughters can be entered as separate inputs using either measured concentrations or the concentration of the parent radionuclide if the daughter is assumed to have reached equilibrium with the parent.

- RESRAD allows consideration of the shape and size of the contaminated area, rather than assuming the area is circular. The USEPA PRG calculator does not make any such accommodation regarding the shape of the contaminated area, it assumes the area is circular.

- RESRAD, unlike the USEPA PRG Calculator, incorporates the contribution to overall cancer risks from short-lived progenies with half-lives of up to 100 years by including cancer slope factors for those progenies in the risk calculations.

The USEPA models have undergone revision since the 2015 comparison report, and data presented herein is based on the versions current at the date of comparison. It should be noted that the last significant update to the USEPA models was after these comparisons (December 2016).

USACE Comparison Results

RESRAD is downloaded to and ran from the user's computer. Each run can be saved, edited, and various reports printed. USEPA calculators are online only and run from the USEPA website. Output files can be saved in various formats; however, each run of the model cannot be saved. Both approaches come with pros and cons. As an example, access to the internet may be an issue for the USEPA calculators and calculator runs cannot be saved; however, being able to run from any computer is a plus for the user with stringent security policies on their company's computer. The authors have significant issues having any program installed on their computers.

RESRAD and the USEPA calculators use somewhat different modeling approaches and input parameter sets. Efforts were made to select input parameter values for the two calculators that describe the various exposure scenarios as consistently as possible; however, it was not always possible to achieve perfect concordance in the inputs for the two models.

One difference between the two approaches is that RESRAD estimates both cancer risk and radiation dose in a single model run using exactly the same models and input parameters for both calculations, whereas the USEPA uses its PRG calculator to estimate cancer risk and its DCC calculator to estimate doses. The USEPA PRG and DCC calculators use essentially the same set of input parameters, but since they operate independently, they require separate setups. Nevertheless, the same sets of input values were used for both USEPA calculators so the risk and dose estimates obtained from the two USEPA calculators reflect the same scenario/receptor combinations. Another difference is that RESRAD provides a library of dose conversion factors that can be selected; the USEPA DCC calculator does not. Additional differences between RESRAD and the USEPA PRG Calculator modeling approaches are described in RESRAD for Radiological Risk Assessment: Comparison with EPA CERCLA Tools – PRG and DCC Calculators [8] and are not repeated herein.

Model output comparisons are presented in the following tables. No effort was made to evaluate outliers in the comparison.

Project 1 Calculated Risk Comparison

A comparison of Risks calculated using both models is presented in Table I.

TABLE I. Project 1 Calculated Risk Comparison

Scenario - Soil / Groundwater	**Receptors**	**Risk estimates**		
		RESRAD	PRG Calculator	RESRAD/ PRG
1. Current	Adult recreational/trespasser	1.64E-05	2.23E-05	0.73
	Adolescent recreational/trespasser	8.16E-06	1.17E-05	0.70
	Worker Outdoor	6.62E-05	7.71E-05	0.86
	Worker Indoor	2.71E-04	1.40E-04	1.93
2. Construction/ Utility Worker	Construction/ Utility Worker	6.11E-06	5.30E-06	1.15
3. Resident	Child	3.09E-04	3.84E-04	0.81
	Adult	1.44E-03	1.34E-03	1.08
4. Background Soil	Adult recreational/trespasser	4.45E-06	4.38E-06	1.01
	Adolescent recreational/trespasser	2.18E-06	2.32E-06	0.94
	Worker Outdoor	1.80E-05	1.46E-05	1.23
	Worker Indoor	7.33E-05	2.67E-05	2.75
	Construction/ Utility Worker	1.35E-06	8.28E-07	1.63
	Child Resident	6.38E-05	6.39E-05	1.00
	Adult Resident	2.86E-04	2.80E-04	1.02
			Minimum	0.70
			Maximum	2.75
			Mean	1.20

Results of the comparison demonstrates that results compare very well on average with an average difference factor of 1.2. RESRAD results in approximately 3 times the risk estimate, compared to the USEPA PRG calculator for the indoor worker and the background data set. RESRAD results for the recreational/trespasser and outdoor worker receptors were less than that of the USEPA calculator.

It should also be noted that Project 1 was divided into six Areas of Concern (AOC). Comparisons of the other five AOC Exposure Point Concentrations (EPCs) with the same pathways and scenarios in Table I resulted in a similar range and average of difference ratios (RESRAD/PRG).

Project 1 Calculated Dose Comparison

A comparison of dose results calculated using both models is presented in Table II.

TABLE II. Project 1 Calculated Dose Comparison

Scenario - Soil/ Groundwater	Receptors	Dose Estimates (µSv/yr)		
		RESRAD	DCC Calculator	RESRAD/ DCC
1. Current	Adult recreational/trespasser	8.98E+00	1.24E+01	0.72
	Adolescent recreational/trespasser	8.20E+00	1.53E+01	0.54
	Worker Outdoor	3.43E+01	4.01E+01	0.85
	Worker Indoor	1.55E+02	7.38E+01	2.09
2. Construction/ Utility Worker	Construction/ Utility Worker	7.70E+01	7.43E+01	1.04
3. Resident	Child	7.98E+02	1.74E+03	0.46
	Adult	9.65E+02	1.24E+03	0.78
4. Background Soil	Adult recreational/trespasser	2.42E+00	2.57E+00	0.94
	Adolescent recreational/trespasser	1.89E+00	3.34E+00	0.56
	Worker Outdoor	1.01E+01	7.67E+00	1.32
	Worker Indoor	4.14E+01	1.43E+01	2.90
	Construction/ Utility Worker	1.69E+01	1.16E+01	1.46
	Child Resident	1.56E+02	3.14E+02	0.50
	Adult Resident	1.75E+02	2.21E+02	0.79
			Minimum	0.46
			Maximum	2.90
			Mean	1.07

Results of the comparison demonstrates that results compare very well on average with an average difference factor of 1.1. Results of the comparison demonstrates that RESRAD results in approximately 2-3 times the dose estimate, compared to the USEPA DCC, for the indoor worker scenario. It should also be noted that RESRAD results for the recreational/trespasser and future resident receptors were less than that of the USEPA calculator.

The other five AOC EPCs resulted in similar difference ratios (RESRAD/DCC) as those presented in Table II. The differences between the models did not result in any changes to the project approaches or the chemicals of potential concerns for Project 1.

Project 2 Calculated Risk Comparison

A comparison of risks calculated using both models is presented in Table III.

TABLE III. Project 2 Calculated Risk Comparison

Scenario - Soils	**Receptors**	**Risk estimates**		
		RESRAD	PRG Calculator	RESRAD/PRG
1. Current - External Exposures	Worker Indoor	8.38E-06	2.78E-05	0.30
	Child Visitor Indoor	7.75E-08	7.40E-08	1.05
	Trespasser- outdoor	2.36E-07	1.28E-07	1.84
2. Construction/ Utility Worker	Construction/Utility Worker	1.99E-06	1.30E-06	1.53
3a. Site redeveloped for alternate use Soil 0-2 feet	Workers(Composite Indoor/Outdoor)	7.30E-05	6.46E-06	11.30
	Child Visitor -Indoor	1.09E-06	1.03E-06	1.06
	Adolescent Trespasser	2.62E-06	5.38E-07	4.87
3b. Site redeveloped for alternate use Soil 0-10 feet	Workers(Composite Indoor/Outdoor)	4.33E-05	3.94E-06	10.99
	Child Visitor	6.49E-07	3.02E-07	2.15
	Adolescent Trespasser	1.55E-06	3.18E-07	4.87
4a. Future Recreational use Soil 0-2 feet	Integrated Child/Adult Recreational User	1.27E-05	7.17E-06	1.77
	Child Recreational	2.75E-06	2.34E-06	1.18
4b. Future Recreational use soils 0-10 feet	Integrated Child/Adult Recreational User	7.52E-06	4.21E-06	1.79
	Child Recreational	1.63E-06	1.38E-06	1.18
5. Current - External Exposures Background soils	Worker Indoor	4.57E-06	1.43E-05	0.32
6. Site redeveloped for alternate use Soil 0-2 feet - background soils	Workers(Composite Indoor/Outdoor)	3.55E-07	2.66E-06	0.13
			Minimum	0.13
			Maximum	11.30
			Mean	2.90

Results of the comparison demonstrates that RESRAD results in approximately 3 times the risk estimate, on average, compared to the USEPA PRG calculator. The Composite indoor and Outdoor Worker scenario results in the most significant differences at one order of magnitude. It should also be noted that with the

Composite Worker values removed, the average difference between the models is a factor of 1.8.

Project 2 Calculated Dose Comparison

A comparison of doses calculated using both models is presented in Table IV.

TABLE IV. Project 2 Calculated Dose Comparison

Scenario - Soils	Receptors	Dose Estimates (µSv/yr)		
		RESRAD	DCC	RESRAD/DCC
1. Current - External Exposures	Worker Indoor	3.50E-00	1.80E+01	0.19
	Child Visitor Indoor	1.50E-01	1.69E-01	0.89
	Trespasser-outdoor	2.40E-01	1.69E-01	1.42
2. Construction/ Utility Worker	Construction/Utility Worker	1.08E+01	2.27E+01	0.48
3a. Site redeveloped for alternate use Soil 0-2 feet	Workers(Composite Indoor/Outdoor)	3.70E+01	7.55E+00	4.90
	Child Visitor	2.40E+00	3.66E+00	0.66
	Adolescent Trespasser	2.95E+00	1.04E+00	2.84
3b. Site redeveloped for alternate use Soil 0-10 feet	Workers(Composite Indoor/Outdoor)	2.12E+01	4.66E+00	4.55
	Child Visitor	1.51E+00	2.29E+00	0.66
	Adolescent Trespasser	1.75E+00	6.51E-01	2.69
4a. Future Recreational use Soil 0-2 feet	Integrated Child/Adult Recreational User	6.17E+00	5.33E+00	1.16
	Child Recreational	5.94E+00	6.68E+00	0.89
4b. Future Recreational use soils 0-10 feet	Integrated Child/Adult Recreational User	3.65E+00	3.22E+00	1.13
	Child Recreational	3.73E+00	4.06E+00	0.92
5. Current - External Exposures Background soils	Worker Indoor	1.92E+00	9.79E+00	0.20
6. Site redeveloped for alternate use - background soils	Workers(Composite Indoor/Outdoor)	1.89E+01	2.36E+00	8.02
			Minimum	0.19
			Maximum	8.02
			Mean	1.97

Results of the comparison demonstrates that RESRAD results in approximately 2 times the dose estimate, on average, compared to the USEPA DCC. The Composite Worker scenario and Indoor Worker scenario results in the maximum differences at less than one order of magnitude. RESRAD dose results for the child receptors were less than that of the USEPA calculators. It should also be noted that with the Composite Worker values removed, the average difference between the models is a factor of 1.1.

The differences between the models did not result in any changes to project approaches or the chemicals of potential concerns for Project 2.

RESULTS

Maximum differences in results between the models, with input values set as similar as possible, were an order of magnitude. Average differences in results between the models, with input values set as similar as possible, were less than a factor of 3 for each project and likely well within each model's uncertainty.

The differences between the models did not result in any changes to project approaches or the chemicals of potential concerns for either project.

This study focused on actual assessments rather than hypothetical comparisons. Results are for typical FUSRAP site contaminants (U-238, Ra-226, Th-232, U-235 and their associated daughter products), actual contaminant concentrations, and for scenarios stated in Tables 1-3. Other contaminants, scenarios, and concentrations may produce different results.

CONCLUSIONS

The USACE's comparison of the USDOE's RESRAD and the USEPA's PRG/DCC calculators across 2 projects and multiple exposure scenarios demonstrates that both modeling approaches are useful tools for estimating risk and dose from radiological contamination. Regulator preference, data needs, purpose, and model uncertainty should be considered when selecting the model to best represent estimated project risks and doses.

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