Verification Study of the Preliminary Remediation Goals for Radionuclides (PRG) Electronic Calculator

February 15, 2017 – April 3, 2017

CONTENTS:

[1] Additional comments are provided as separate documents: Jannik Calculations_Construction Worker , Jannik Calculations_Farmer, Jannik Calculations_Groundwater, Jannik Calculations_Indoor&Outdoor Workers, Jannik Calculations_Recreator, Jannik Calculations_Resident_(manual), Jannik Calculations_Resident, Jannik_Calulator Output_Construction_Worker, Jannik_Calulator Output_Farmer_2017(sheep_goat), Jannik_Calulator Output_Indoor Worker_2017, Jannik_Calulator Output_Soil to Groundwater, Jannik_Calulator Output_Outdoor Worker_2017, Jannik_Calulator Output_Recreator, and Jannik_Calulator Output_Resident_manual

Verification Study Charge for:

U.S. Environmental Protection Agency (EPA), "Preliminary Remediation Goals for Radionuclides" (PRG) electronic calculator http://epa-prgs.ornl.gov/radionuclides/

Background:

EMS, Inc., under contract EP-W-13-016 with EPA's Office of Solid Waste and Emergency Response, has been asked to conduct a second external, independent verification study of the "Preliminary Remediation Goals for Radionuclides" (PRG) electronic calculator. The PRG calculator provides information on establishing PRGs for radionuclides at CERCLA sites with radioactive contamination. The PRG electronic calculator presents standardized exposure parameters and equations that should generally be used for calculating radionuclide PRGs for residential, commercial/industrial, and agricultural land use exposures, tap water and fish ingestion exposures, and migration of radionuclides through the unsaturated zone.

The first verification study was conducted in September 2015 by G. Timothy Jannik (Savannah River National Laboratory) and William Thomas Pentecost (Colorado Department of Public Health and Environment, retired). EPA responded made changes to the calculator based on their comments, and made subsequent updates, which are documented at https://epa-prgs.ornl.gov/radionuclides/whatsnew.html.

Updates made later in December 2016 and January 2017, documented below and at https://epa-prgs.ornl.gov/radionuclides/whatsnew.html, are the subject of this verification study:

- New inhalation Risk and Dose Coefficients are available for Rn-222, Rn-220, Bi-212, Bi-214, Pb-212, Pb-214, and Po-218.
- The secular equilibrium (SE) PRG calculation has been revised. An unexpected error occurred in the SE PRGs when the ability to select more than one isotope was provided. The results have been restored to their initial values prior to the ability to select more than one isotope for SE PRG calculation.
- The +D and +E isotopes have been removed from the selection list. Now, a user may select the 'Include daughters' checkbox to see PRG output for the entire chain.
- In the resident, farmer, and indoor worker soil external exposure equations, a new variable has been added (GSF_b) to account for the gamma shielding provided by clean soil cover under a building. It is combined with GSF_i, the shielding provided by the building, to reduce exposures to receptors inside a building which is on top of clean soil over contaminated soil.
- Previously, produce intake rates were based on general fruit and vegetable consumption rates. Now, the produce intake rates are derived from 22 individual produce items, found in the 2011 Exposure Factors Handbook, that contribute to the overall produce ingestion PRG. Mass loading factors (MLFs) were also improved,

from a single MLF that was applied to all produce, to 22 individual MLFs that correspond with the 22 individual produce items that make up the new produce intake rates. In site-specific mode, users will now able to select additional animal products including Goat Milk, Sheep Milk, Goat Meat, and Sheep Meat, which are not included in the default animal product PRGs. Users will also be able to select Rice and Grains, which are not included in the default produce PRG. Formerly, the transfer factors used in this risk assessment tool were specific to element only. Now, the transfer factors are element, climate zone, soil type, and produce specific. For more detailed information, Biota Modeling in EPA's Preliminary Remediation Goal and Dose Compliance Concentration Calculators explains where these new intake rates, MLFs, and transfer factors were sourced and how they will be applied to the PRG calculator. This file is engineered for 2 sided printing.

- The MCL document was modified to remove +D and +E isotopes.

Charge:

According to EPA's Guidance on the Development, Evaluation, and Application of Environmental Models (2009), *verification* refers to activities designed to confirm that the mathematical framework embodied in the module is correct and that the computer code for a module is operating according to its intended design so that the results obtained compare favorably with those obtained using known analytical solutions or numerical solutions from simulators based on similar or identical mathematical frameworks.

The purpose of this verification study is to ascertain that the computer code pertaining to the new updates has no inherent numerical problems with obtaining a solution and that the code performs according to design specifications. In addition, the study will ensure that the equations are programmed correctly and that sources of error, such as rounding, are minimal. **The equations used in the calculator are listed at** http://epa-prgs.ornl.gov/radionuclides/equations.html.

We are enlisting two subject matter experts for this verification study. Your comments and recommendations will be used to revise the December updates, as needed, so that the final version will reflect sound technical information and guidance.

As an independent tester of the PRG electronic calculator, we ask you to examine the numerical technique in the computer code for consistency with the conceptual model and governing equations.

When your verification study is complete, e-mail your comments to EMS's Project Manager (Jennifer Rando, jennifer.rando@emsus.com) on or before **April 3, 2017**. Please submit your comments in Microsoft Word and reference each comment to a specific step in the calculator and equation (http://epa-prgs.ornl.gov/radionuclides/equations.html). For specific comments or text edits on the user's guide, you may copy and paste text into Microsoft Word and indicate edits or comments using track changes or the comments feature. *Please do not hand write your comments.*

<u>How to Use the Calculator:</u>

The PRG calculator is available at http://epa-prgs.ornl.gov/radionuclides/, and the User's Guide is available at http://epa-prgs.ornl.gov/radionuclides/prg_guide.html. To summarize,

<u>Step 1</u> Select an exposure scenario. The PRG calculator has nine exposure scenarios:

1. Resident
2. Composite Worker
3. Outdoor Worker
4. Indoor Worker
5. Construction Worker - Standard Unpaved Road Vehicle Traffic (Site-specific only)Farmer
6. Construction Worker - Wind Erosion and Other Construction Activities (Site-specific only)
7. Recreator
8. Farmer
9. Soil to Groundwater

Some of these exposure scenarios have multiple media choices; other scenarios will only involve one media so a choice will not appear.

<u>Step 2</u> Select either "Generic" (in which case the runs use a pre-determined set of default input parameters) or "Site-Specific" (in which case the user can change some of the input parameters).

<u>Step 3</u> Select if you want to get estimates of the cancer risk posed by radionuclides at your site, in addition to the target risk-based concentrations that will be provided as PRGs.

<u>Step 4</u> Choose to have your results in either picocuries per gram, which are the units usually used in the United States, or in bequerels per gram which most of the rest of the world uses.

<u>Step 5</u> Select one or more radionuclides for which you want to develop PRGs. Some of the radionuclides and radioactive decay chain products are designated with the suffix "+D" to indicate that cancer risk estimates for these radionuclides include the contributions from their short-lived decay products, assuming secular equilibrium.

The decay chain for +D radionuclide ends in 100 years.

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SRNL-STI-2017-00203

March 29, 2017

To: EDG File, 999W-312

From: B. H. Stagich, 999W

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G. T. Jannik, Technical Reviewer

Verification of EPA's "Preliminary Remediation Goals for Radionuclides" (PRG) electronic calculator

Introduction

The U.S. Environmental Protection Agency (EPA) requested an external, independent verification study of their "Preliminary Remediation Goals for Radionuclides" (PRG) electronic calculator. The calculator provides information on establishing PRGs for radionuclides at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites with radioactive contamination (Verification Study Charge, Background). These risk-based PRGs set concentration limits using carcinogenic toxicity values under specific exposure conditions (PRG User's Guide, Section 1). The purpose of this verification study is to ascertain that the computer codes has no inherit numerical problems with obtaining solutions as well as to ensure that the equations are programmed correctly. To verify the calculator, all equations for each receptor type (resident, construction worker, outdoor and indoor worker, recreator, farmer and composite worker) were hand calculated using the default parameters. The same eleven radionuclides (Am-241, Bi-212, Bi-214, Co-60, H-3, Pb-212, Pb-214, Po-218, Pu-238, Rn-220, and Rn-222) were used for each calculation to keep consistency throughout.

Concerns

There were a number of problems found in the latest updates of the PRG calculator. Each issue will be addressed by receptor type.

Resident

All calculations using the default parameters for the resident receptor type were correct; the problems found with this receptor came from using the manual parameter option for the Tapwater calculations. The λ_i value given in the PRG outputs were not the same as the values calculated, affecting the λ_B and λ_E values as well (Table 1). Only when the manually inputted TR value (2.00E-03) was replaced with the default TR value (1.00E-06) in the hand calculation did the λ_i better match PRG (Table 2).

Another issue in this set of calculations was the calculated Irr_{res} values were approximately 17% less than PRG's output after the λ values were altered to match PRG (Table 2). A reason for this was not determined.

Farmer

The farmer calculations were performed through the manual parameter option in order to use the newly added goat and sheep calculations, but all other values were left as the default values. Starting with the direct consumption of agricultural products calculations, the ingestion rates for poultry, eggs, beef, milk, swine and fish were different values in the PRG input than were on the equation and variable sheets (Figure 1). After changing these values to match PRG, all of the consumption values matched.

However, in the direct consumption back calculated to water calculations, the $PRG_{far\text{-}beef\text{-}ing}$ value for H-3 used by PRG (7.32E+00) is not the value calculated in direct consumption (3.31E+00). Another issue found was the $PRG_{wat\text{-}far\text{-}tot}$ calculation does not calculate correctly. It was found that to equal the PRG output, the calculation could only use ingestion, fruits and vegetables, beef and milk, but this does not include Pb-212 and Pb-214 (Table 3 & Table 4). The calculation for the totals of these two radionuclides has not been found. The final issue found in this set of calculations was the values for Sheep Milk and Goat Milk not calculating correctly and the reasons have not been determined (Table 5).

In the direct consumption back calculated to soil and water calculations, PRG uses a y-intercept for H-3 (4.10E-01) that is not the direct consumption calculated value (1.86E-01). The PRG output contains a duplicate Sheep slope column in place of the Sheep Milk slope column and because of this, the values from the hand calculations and the PRG calculations cannot be compared. Also, the Sheep Milk y-intercept and x-intercept are switched (Figure 2).

Conclusions

After running through all the calculations, EPA's PRG electronic calculator appears to be mathematically correct in most scenarios using the default parameters; however, the calculator is displaying many issues with correctly calculating scenarios using manually input parameters.

References:
PRG User's Guide. Section 1 "Introduction"

EPA's PRG Verification Study Charge.

cc: J. J. Mayer, 999W-322
K. L. Dixon, 773-42A

Table 1. For resident, tapwater calculations, the λ_i, λ_B, and λ_E values calculated using the manually inputted TR value (2.00E-03) were approximately 5% different from PRG for Bi-212.

Bi-212			
	Calculated	PRG	% Differ.
Ingestion	7.49E+04	7.49E+04	0.1%
Inhalation	N/A	N/A	N/A
Immersion	3.44E+08	3.44E+08	-0.1%
Lambda i	1.73E+01	1.65E+01	4.9%
Lambda B	1.73E+01	1.65E+01	4.9%
Lambda E	1.74E+01	1.65E+01	5.2%
Irr(res)	7.05E-07	8.80E-07	-22.0%
Irr(dep)	4.24E-02	4.45E-02	-4.9%
F & V	1.45E+06	1.38E+06	5.2%
Total	7.13E+04	7.11E+04	0.2%

Table 2. For resident, tapwater calculations, the λ_i, λ_B, and λ_E values calculated using the default TR value (1.00E-06) were approximately 0.2% different from PRG for Bi-212.

Bi-212			
	Calculated	PRG	% Differ.
Ingestion	7.49E+04	7.49E+04	0.1%
Inhalation	N/A	N/A	N/A
Immersion	3.44E+08	3.44E+08	-0.1%
Lambda i	1.65E+01	1.65E+01	0.1%
Lambda B	1.65E+01	1.65E+01	0.1%
Lambda E	1.65E+01	1.65E+01	0.3%
Irr(res)	7.41E-07	8.80E-07	-17.2%
Irr(dep)	4.45E-02	4.45E-02	0.0%
F & V	1.39E+06	1.38E+06	0.4%
Total	7.11E+04	7.11E+04	0.0%

Figure 1. For farmer, direct consumption of agricultural products calculations, the ingestion rates provided on EPA's PRG website for poultry, eggs, beef, milk, swine and fish do not match the input values used by PRG (provided in the output sheets).

$$PRG_{far\text{-}poultry\text{-}ing}\,(pCi/g) = \frac{TR}{SF_f\left(\frac{risk}{pCi}\right)\times IFP_{far\text{-}adj}\,(1{,}318{,}100\ g)\ \times CF_{far\text{-}poultry}\,(1)}$$

where:

$$IFP_{far\text{-}adj}\,(1{,}318{,}100\ g) = \left(\begin{array}{l}\left(EF_{far\text{-}c}\left(\frac{350\ days}{year}\right)\times ED_{far\text{-}c}\,(6\ years)\times IRP_{far\text{-}c}\left(\frac{23.6\ g}{day}\right)\right)+\\\left(EF_{far\text{-}a}\left(\frac{350\ days}{year}\right)\times ED_{far\text{-}a}\,(34\ years)\times IRP_{far\text{-}a}\left(\frac{106.6\ g}{day}\right)\right)\end{array}\right)$$

16	$IRP_{far\text{-}a}$ (poultry ingestion rate - farmer adult) g/day	107.4
17	$IRP_{far\text{-}c}$ (poultry ingestion rate - farmer child) g/day	46.9
18	$IFP_{far\text{-}adj}$ (age-adjusted poultry ingestion factor) g	1376550

$$PRG_{far\text{-}egg\text{-}ing}\,(pCi/g) = \frac{TR}{SF_f\left(\frac{risk}{pCi}\right)\times IFE_{far\text{-}adj}\,(658{,}455\ g)\ \times CF_{far\text{-}egg}\,(1)}$$

where:

$$IFE_{far\text{-}adj}\,(658{,}455\ g) = \left(\begin{array}{l}\left(EF_{far\text{-}c}\left(\frac{350\ days}{year}\right)\times ED_{far\text{-}c}\,(6\ years)\times IRE_{far\text{-}c}\left(\frac{10.95\ g}{day}\right)\right)+\\\left(EF_{far\text{-}a}\left(\frac{350\ days}{year}\right)\times ED_{far\text{-}a}\,(34\ years)\times IRE_{far\text{-}a}\left(\frac{53.4\ g}{day}\right)\right)\end{array}\right)$$

19	$IRE_{far\text{-}a}$ (egg ingestion rate - farmer adult) g/day	59.6
20	$IRE_{far\text{-}c}$ (egg ingestion rate - farmer child) g/day	31.7
21	$IFE_{far\text{-}adj}$ (age-adjusted egg ingestion factor) g	775810

$$PRG_{far\text{-}beef\text{-}ing}\,(pCi/g) = \frac{TR}{SF_f\left(\frac{risk}{pCi}\right)\times IFB_{far\text{-}adj}\,(2{,}202{,}410\ g)\ \times CF_{far\text{-}beef}\,(1)}$$

where:

$$IFB_{far\text{-}adj}\,(2{,}202{,}410\ g) = \left(\begin{array}{l}\left(EF_{far\text{-}c}\left(\frac{350\ days}{year}\right)\times ED_{far\text{-}c}\,(6\ years)\times IRB_{far\text{-}c}\left(\frac{40.1\ g}{day}\right)\right)+\\\left(EF_{far\text{-}a}\left(\frac{350\ days}{year}\right)\times ED_{far\text{-}a}\,(34\ years)\times IRB_{far\text{-}a}\left(\frac{178.0\ g}{day}\right)\right)\end{array}\right)$$

22	$IRB_{far\text{-}a}$ (beef ingestion rate - farmer adult) g/day	165.3
23	$IRB_{far\text{-}c}$ (beef ingestion rate - farmer child) g/day	62.8
24	$IFB_{far\text{-}adj}$ (age-adjusted beef ingestion factor) g	2098950

$$PRG_{far\text{-}dairy\text{-}ing}\,(pCi/g) = \frac{TR}{SF_f\left(\frac{risk}{pCi}\right)\times IFD_{far\text{-}adj}\,(6{,}036{,}590\ g)\ \times CF_{far\text{-}dairy}\,(1)}$$

where:

$$IFD_{far\text{-}adj}\,(6{,}036{,}590\ g) = \left(\begin{array}{l}\left(EF_{far\text{-}c}\left(\frac{350\ days}{year}\right)\times ED_{far\text{-}c}\,(6\ years)\times IRD_{far\text{-}c}\left(\frac{349.5\ g}{day}\right)\right)+\\\left(EF_{far\text{-}a}\left(\frac{350\ days}{year}\right)\times ED_{far\text{-}a}\,(34\ years)\times IRD_{far\text{-}a}\left(\frac{445.6\ g}{day}\right)\right)\end{array}\right)$$

25	$IRD_{far\text{-}a}$ (dairy ingestion rate - farmer adult) g/day	676.4
26	$IRD_{far\text{-}c}$ (dairy ingestion rate - farmer child) g/day	994.7
27	$IFD_{far\text{-}adj}$ (age-adjusted dairy ingestion factor) g	10138030

$$PRG_{far\text{-}swine\text{-}ing}\,(pCi/g) = \frac{TR}{SF_f\left(\frac{risk}{pCi}\right) \times IFSW_{far\text{-}adj}\,(1{,}203{,}860\ g)\ \times CF_{far\text{-}swine}\,(1)}$$

where:

$$IFSW_{far\text{-}adj}\,(1{,}203{,}860\ g) = \left[\begin{array}{l}\left(EF_{far\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{far\text{-}c}\,(6\ years) \times IRSW_{far\text{-}c}\left(\frac{18.5\ g}{day}\right)\right) + \\ \left(EF_{far\text{-}a}\left(\frac{350\ days}{year}\right) \times ED_{far\text{-}a}\,(34\ years) \times IRSW_{far\text{-}a}\left(\frac{97.9\ g}{day}\right)\right)\end{array}\right]$$

28	$IRSW_{far\text{-}a}$ (swine ingestion rate - farmer adult) g/day	92.5
29	$IRSW_{far\text{-}c}$ (swine ingestion rate - farmer child) g/day	33.7
30	$IFSW_{far\text{-}adj}$ (age-adjusted swine ingestion factor) g	1171520

$$PRG_{far\text{-}fish\text{-}ing}\,(pCi/g) = \frac{TR}{SF_f\left(\frac{risk}{pCi}\right) \times IFFI_{far\text{-}adj}\,(10{,}078{,}180\ g)\ \times CF_{far\text{-}fish}\,(1)}$$

where:

$$IFFI_{far\text{-}adj}\,(10{,}078{,}180\ g) = \left[\begin{array}{l}\left(EF_{far\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{far\text{-}c}\,(6\ years) \times IRFI_{far\text{-}c}\left(\frac{85.6\ g}{day}\right)\right) + \\ \left(EF_{far\text{-}a}\left(\frac{350\ days}{year}\right) \times ED_{far\text{-}a}\,(34\ years) \times IRFI_{far\text{-}a}\left(\frac{831.8\ g}{day}\right)\right)\end{array}\right]$$

43	$IRFI_{far\text{-}a}$ (fish ingestion rate - farmer adult) g/day	831.8
44	$IRFI_{far\text{-}c}$ (fish ingestion rate - farmer child) g/day	57.4
45	$IFFI_{far\text{-}adj}$ (age-adjusted fish ingestion factor) g	10018960

Table 3. For direct consumption back calculated to water calculations, the total for most of the radionuclides (except H-3, Po-218, Rn-220, Rn-222) were over 100% different from the PRG value.

	Calculated	PRG	% Differ.
Am-241	2.98E-03	7.75E-02	**-185.2%**
Bi-212	5.69E+00	4.18E+01	**-152.1%**
Bi-214	2.17E+01	1.57E+02	**-151.5%**
Co-60	5.17E-02	4.23E-01	**-156.5%**
H-3	4.41E+00	4.41E+00	**0.0%**
Pb-212	1.02E-01	1.07E+00	**-165.3%**
Pb-214	7.54E+00	8.51E+01	**-167.5%**
Po-218	1.81E+13	1.81E+13	**-0.2%**
Pu-238	2.81E-05	6.12E-02	**-199.8%**
Rn-220	6.71E+00	6.71E+00	**0.1%**
Rn-222	3.39E+00	3.39E+00	**-0.1%**

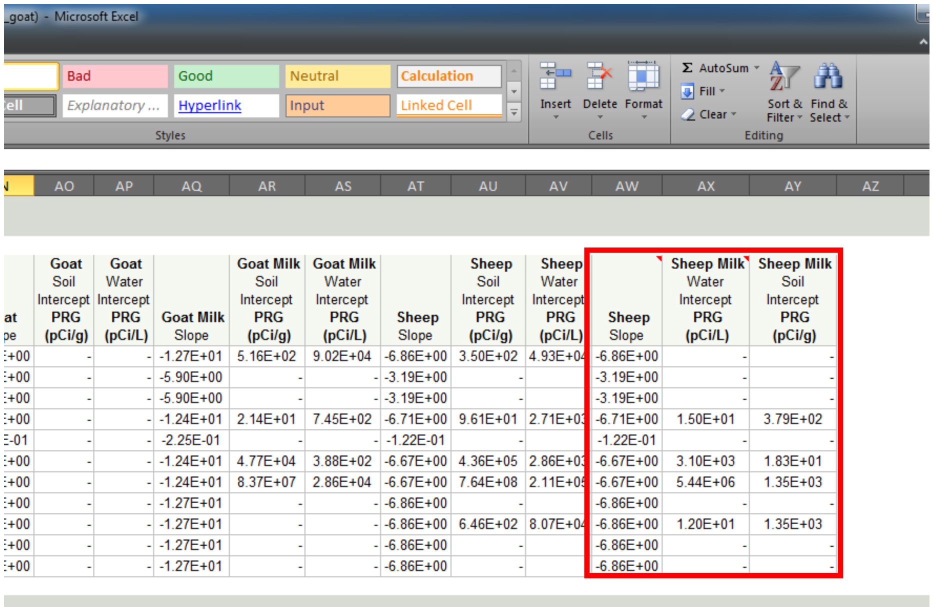
Table 4. For direct consumption back calculated to water calculations, only using the ingestion, fruits and vegetables, beef and milk totals in the final total for each radionuclide; the difference moved closer to 0% (except for Pb-212 and Pb-214).

	Calculated	PRG	% Differ.
Am-241	7.73E-02	7.75E-02	**-0.3%**
Bi-212	4.18E+01	4.18E+01	**0.1%**
Bi-214	1.58E+02	1.57E+02	**0.4%**
Co-60	4.26E-01	4.23E-01	**0.7%**
H-3	4.41E+00	4.41E+00	**0.0%**
Pb-212	1.13E+00	1.07E+00	**5.8%**
Pb-214	9.12E+01	8.51E+01	**6.9%**
Po-218	1.81E+13	1.81E+13	**-0.2%**
Pu-238	6.14E-02	6.12E-02	**0.2%**
Rn-220	6.71E+00	6.71E+00	**0.1%**
Rn-222	3.39E+00	3.39E+00	**-0.1%**

Table 5. For direct consumption back calculated to water calculations, the values for goat and sheep milk ranged from 60 to 200% different than PRG for all applicable radionuclides.

		Calculated	PRG	% Differ.
Am-241	Goat Milk	4.03E+04	4.06E+01	**200%**
	Sheep Milk	N/A	N/A	N/A
Bi-212	Goat Milk	N/A	N/A	N/A
	Sheep Milk	N/A	N/A	N/A
Bi-214	Goat Milk	N/A	N/A	N/A
	Sheep Milk	N/A	N/A	N/A
Co-60	Goat Milk	3.34E+02	7.68E+02	**-79%**
	Sheep Milk	8.78E+01	3.90E+02	**-126%**
H-3	Goat Milk	N/A	N/A	N/A
	Sheep Milk	N/A	N/A	N/A
Pb-212	Goat Milk	1.74E+02	4.00E+02	**-79%**
	Sheep Milk	9.27E+01	1.88E+01	**133%**
Pb-214	Goat Milk	1.28E+04	2.94E+04	**-79%**
	Sheep Milk	6.83E+03	1.39E+03	**132%**
Po-218	Goat Milk	N/A	N/A	N/A
	Sheep Milk	N/A	N/A	N/A
Pu-238	Goat Milk	N/A	N/A	N/A
	Sheep Milk	2.62E+03	1.39E+03	**61%**
Rn-220	Goat Milk	N/A	N/A	N/A
	Sheep Milk	N/A	N/A	N/A
Rn-222	Goat Milk	N/A	N/A	N/A
	Sheep Milk	N/A	N/A	N/A

Figure 2. In the PRG output spreadsheet, the Sheep Milk slope column is replaced with a duplicate of the Sheep slope column and the Sheep Milk intercepts are switched.



at pe	Goat Soil Intercept PRG (pCi/g)	Goat Water Intercept PRG (pCi/L)	Goat Milk Slope	Goat Milk Soil Intercept PRG (pCi/g)	Goat Milk Water Intercept PRG (pCi/L)	Sheep Slope	Sheep Soil Intercept PRG (pCi/g)	Sheep Water Intercept PRG (pCi/L)	Sheep Slope	Sheep Milk Water Intercept PRG (pCi/L)	Sheep Milk Soil Intercept PRG (pCi/g)
E+00	-	-	-1.27E+01	5.16E+02	9.02E+04	-6.86E+00	3.50E+02	4.93E+04	-6.86E+00	-	-
E+00	-	-	-5.90E+00	-	-	-3.19E+00	-		-3.19E+00	-	-
E+00	-	-	-5.90E+00	-	-	-3.19E+00	-		-3.19E+00	-	-
E+00	-	-	-1.24E+01	2.14E+01	7.45E+02	-6.71E+00	9.61E+01	2.71E+0	-6.71E+00	1.50E+01	3.79E+02
E-01	-	-	-2.25E-01	-	-	-1.22E-01	-		-1.22E-01	-	-
E+00	-	-	-1.24E+01	4.77E+04	3.88E+02	-6.67E+00	4.36E+05	2.86E+0	-6.67E+00	3.10E+03	1.83E+01
E+00	-	-	-1.24E+01	8.37E+07	2.86E+04	-6.67E+00	7.64E+08	2.11E+0	-6.67E+00	5.44E+06	1.35E+03
E+00	-	-	-1.27E+01	-	-	-6.86E+00	-		-6.86E+00	-	-
E+00	-	-	-1.27E+01	-	-	-6.86E+00	6.46E+02	8.07E+04	-6.86E+00	1.20E+01	1.35E+03
E+00	-	-	-1.27E+01	-	-	-6.86E+00	-		-6.86E+00	-	-
E+00	-	-	-1.27E+01	-	-	-6.86E+00	-		-6.86E+00	-	-

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Position: Principal Technical Advisor

Education/Qualification:

- Bachelors of Science, 1977: Villanova University, Mechanical Engineering
- Masters of Science, 1988: Georgia Institute of Technology, Health Physics

Relevant Experience:

Tim Jannik is a Principal Technical Advisor at the Savannah River National Laboratory (SRNL). He has over 35 years of experience in the nuclear industry, 26 of which have been at the Savannah River Site. Mr. Jannik is the technical lead of the Environmental Dosimetry Group at SRNL and he specializes in 1) environmental dosimetry and radioecology, 2) effluent monitoring and environmental surveillance, and 3) human health risk analyses.

Employment and Professional History:

1995 to present, ***Savannah River National Laboratory***
Savannah River Nuclear Solutions/WSRC

Principal Technical Advisor

- Technical Lead of the SRNL Environmental Dosimetry Group
- Savannah River Site (SRS) subject matter expert for human health risk and environmental dose assessments
- Technical Advisor for the Environmental Monitoring Section

1989-1995, ***Westinghouse Savannah River Company***

Principal Engineer/Scientist

- Subject matter expert for Environmental Monitoring (1991-1995)
- Effluent Monitoring System Engineer for Reactors (1990-1991)
- Start-up Engineer for Defense Waste Processing Facility (1989-1990)

1977-1989, **Project/Construction Engineer**

- Georgia Power Company (Plant Vogtle) (1984-1989)
- Newburg/Marble Hill (1983-1984)
- Bechtel Power Corporation (1982-1983)
- Tennessee Valley Authority (1979-1982)

- Martin Marietta Corporation (1978-1979)
- Rutgers University (Research Assistant) (1977-1978)

Technical Accomplishments:

60+ Technical Reports, Publications, and Presentations
Peer Reviewer for Health Physics Journal

Professional Affiliations:

Health Physics Society (HPS), Member since 1992

Awards and Honors:

Pi Tau Sigma (Mechanical Engineering Honor Society)
1998 Westinghouse Savannah River Company Vice-President's Award
2003 and 2004 Savannah River National Laboratory Directors Award

Other:

Active DOE 'Q' Clearance

Selected Publications:

1. E.B. Farfan and **G.T. Jannik,** (editors), *Radiation Monitoring and Radioecology Research in the Chernobyl Exclusion Zone – 25 Years After the Accident,* Special Issue of the Health Physics Journal, ISSN 0017-9078, Vol. 101, No. 4, October 2011.
2. **G.T. Jannik**, M.H. Paller, and P.D. Fledderman, *Effective Dosimetric Half-Life of Cs-137 Soil Contamination,* Published in the Proceedings of the 2008 ANS Annual Meeting, 2008.
3. M.H. Paller, **G.T. Jannik**, and P.D. Fledderman *Changes in Cs-137 Concentrations in Soil and Vegetation on the Floodplain of the Savannah River Over a 30 Year Period,* Journal of Environmental Radioactivity, ISSN 0265-931X, Vol. 99. No. 8, pp 1302-1310, 2008.
4. P.D. Fledderman, **G.T. Jannik**, and M.H. Paller, *An Overview of Cs-137 Contamination in a Southeastern Swamp Environment,* Operational Health Physics-The Radiation Safety Journal, Vol. 93, Sup. 3, 2007.
5. M.H. Paller, **G.T. Jannik**, and L.D. Wike, *Concentration Ratios for Small Mammals Collected from the Exposed Sediments of a Cs-137 Contaminated Reservoir,* Journal of Environmental Radioactivity, ISSN 0265-931X, Vol. 90. No. 3, pp 224-235, 2006.
6. **G.T. Jannik**, P.L. Lee, T.O. Oliver, J.L. Roach, Jr., and A.A. Simpkins. *Risk-Based Radionuclide Derived Concentration Guideline Levels for an Industrial Worker Exposed to Concrete-Slab End States at the Savannah River Site."* Proceedings of the 2005 ANS Topical Meeting on Decommissioning, Decontamination, and Reutilization. "The Transition to Closure and Legacy Management." ANS Order No. 700315, ISBN 0-89448-689-6, La Grange Park, IL, August, 2005.

7. **G.T. Jannik** and P.D. Fledderman, *Risk-Based Radioactive Liquid Effluent Monitoring Requirements at the U.S. Department of Energy's Savannah River Site,* Operational Health Physics-The Radiation Safety Journal, Vol. 82, Supplement 1, February 2002.
8. **G.T. Jannik**, *Critical Radionuclide/Critical Pathway Analysis for the U.S. Department of Energy's Savannah River Site,* Risk Analysis-An International Journal, Vol. 19, No. 3, 1999.
9. W.H. Carlton, C.E. Murphy, **G.T. Jannik**, and A.A. Simpkins *Radiostrontium in the Savannah River Site Environment,* Health Physics-The Radiation Safety Journal, Vol. 77, Number 6, December 1999.

Conflict of Interest Certification

Verification Study: U.S. Environmental Protection Agency (EPA), "Preliminary Remediation Goals (PRG) for Radionuclides Electronic Calculator"

A conflict of interest or lack of impartiality exists when the proposed reviewer personally (or the reviewer's immediate family), or his or her employer, has financial interests that may be affected by the results of verification study; or may provide an verification study may be impaired due to other factors. When the Reviewer knows that a reasonable person with knowledge of the facts may question the reviewer's impartiality or financial involvement, an apparent lack of impartiality or conflict of interest exists.

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- Have you made any public statements (written or oral) on the issue? ☒ No ☐ Yes
- Have you made any public statements that would indicate to an observer that you have taken a position on the issue under consideration? ☒ No ☐ Yes
- Do you, your family, or your employer have any financial interest(s) in the matter or topic under review, or could someone with access to relevant facts reasonably conclude that you (or your family or employer) stand to benefit from a particular outcome of this verification study? ☒ No ☐ Yes

With regard to real or apparent conflicts of interest or questions of impartiality, the following provisions shall apply for the duration of this verification study:

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Signature Date

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G. T. JANNIK

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Verification Study for Preliminary Remediation Goals for Radionuclides (PRG)
Mark G. Hogue, CHP for Environmental Management Support, Inc. (EMS)
March 31, 2017

Introduction

The following are observations from the verification study performed on a set of changes to the PRG Calculator. The section headings are named for the six itemized changes in the Verification Study Charge.

Summary

The set of changes were found to be implemented correctly with the following exceptions:

Some cases involving the secular equilibrium computation resulted in mismatches between the overall secular equilibrium PRG and the summation of the contributing parent and progeny radionuclides. In one case, the results were off by several magnitudes.

The building shielding factor did not appear to be working correctly. External exposure PRGs were evaluated in matched cases for residents with 24-hour indoor exposure and for internal workers. The external PRG ratios with and without 10 cm of building shielding did not match the referenced gamma shielding factors.

A couple of minor differences were found between the PRG Calculator and User Guide on individual produce consumption rates.

New inhalation Risk and Dose Coefficients

1. The Radon Dose and Risk Coefficient Report was reviewed. No errors were found. The report is well-written and well-referenced. A couple of minor items are noted below.

(https://epa-prgs.ornl.gov/radionuclides/RadonDoseandRiskCoefficientReport.pdf):

Location	Comment
Page 7 (sequential page of pdf)	typo on "is described". (No space)
Page 9	Figure 4 has formatting error.
Page 11	Table numbering restarts in the Results section so that there are two tables in the report numbered 1 and two numbered 2.

2. Checks on the PRG Calculator for Rn-222 in soil for a resident result in a total PRG of 9.15E-5 Bq/g when secular equilibrium is selected, but a summation of the individual PRGs of the parent and progeny, adjusted for branching factors, results in 2.11e-04 Bq/g. The SE value is more than 50% lower than the summation.

The Secular Equilibrium (SE) PRG Calculation Has Been Revised/The +D and +E isotopes Have Been Removed

The option to select these isotopes is no longer available. It may be appropriate to provide some discussion of incorporation of these isotopes in a FAQ.

To check the function of the PRG Calculator with this revision of the options, a number of comparison runs were made with a variety of radionuclide chains: U-238, Sr-90, C-137, Bi-212[1], Np-237.

The results provided expected matches except for the following:

- U-238 progeny and parent summed to 41% higher than the Secular Equilibrium result.
- The Bi-212 Total PRG for resident soil was 3.02e-2 Bq/g, but the individual contributors (only Bi-212 and Tl-208) were 1.05e3 and 7.58e2, respectively, summing to 7.00e2 Bq/g. A similar comparison for these isotopes and the composite worker option were also orders of magnitude different.

Gamma Shielding Provided by Clean Soil Cover Under a Building

A test was set up to isolate the GSF_b effect. A resident scenario was established in the PRG Calculator with 24 hours indoor exposure, 0 hours outdoor exposure. The soil covering was set to 0 cm. The GSF_i was set to 1[2]. A base case was then run with 0 cm for GSF_b, followed by 10 cm for GSF_b. The source was Co-60. Floor size was 500 m^2. The expectation was that the ratio of the two exposure PRGs should equal the shielding value for 10 cm Co-60 in the ORNL/TM-2013/00. Instead of the expected factor of 0.17, the result was 0.32.

A second trial was run with the same parameters except for an indoor worker. This had the same result.

A third trial was run for an indoor worker with exposure to Am-241 (no progeny). This result showed a shielding reduction factor of 0.0096 instead of the 0.0057 expected from the table.

The MCL document was modified to remove +D and +E isotopes

https://epa-prgs.ornl.gov/radionuclides/documents/MCLs_2016.pdf

Reviewed the document and found that there were no +D and +E isotopes identified.

The Produce Intake Rates Are Derived From 22 Individual Produce Items

A PRG case was run with options for Cs-137 farmer scenario, with the "Show Individual Produce PRG Output" option. The results matched expectations from the user guide with the exception of minor duplication in the report and parameter differences noted in Attachment 4.

---

[1] The objective in choosing various radionuclides with progeny was to check the robustness of the calculator in handling shorter and longer-lived progeny, especially when the progeny had significant dose contributions. It is recognized that a selection of Bi-212 by itself is not a realistic PRG need; it is used only to check general calculator functionality.

[2] Changing the GSF_i value was not necessary, and cases with the default value of 0.4 had the same result ratio. Equation references: $PRG_{far\text{-}soil\text{-}ext}$ and $PRG_{iw\text{-}soil\text{-}ext}$.

Attachment 1: Checks with R programming calculation checks, browser and spreadsheet outputs screenshots.

Checks on Rn-222 Secular Equilibrium vs. Individual Progeny Output options

Default

Resident PRGs for Soil

Isotope	Ingestion PRG (Bq/g)	Inhalation PRG (Bq/g)	External Exposure PRG (Bq/g)	Produce Consumption PRG (Bq/g)	Total PRG (Bq/g)
*Secular Equilibrium PRG for Rn-222	6.59E-03	1.01E+01	5.13E-04	1.13E-04	9.15E-05

Default
Resident PRGs for

Isotope	Default Soil Volume Gamma Shielding Factor	Ingestion PRG (Bq/g)	Inhalation PRG (Bq/g)	External Exposure PRG (Bq/g)	Produce Consumption PRG (Bq/g)	Total PRG (Bq/g)
At-218	1.00E+00	-	-	6.57E+10	-	6.57E+10
Bi-210	1.00E+00	1.80E+03	9.01E+05	2.03E+03	3.07E+00	3.06E+00
Bi-214	1.00E+00	3.90E+07	2.41E+09	2.77E+02	5.47E+04	2.76E+02
Hg-206	1.00E+00	-	-	1.03E+04	-	1.03E+04
Pb-210	1.00E+00	2.81E-02	2.87E+01	4.22E+00	2.15E-04	2.13E-04
Pb-214	1.00E+00	1.47E+07	1.42E+09	1.52E+03	1.26E+05	1.50E+03
Po-210	1.00E+00	4.79E-01	1.02E+03	4.52E+03	3.00E-02	2.82E-02
Po-214	1.00E+00	-	-	3.84E+13	-	3.84E+13
Po-218	1.00E+00	-	6.87E+10	2.12E+12	-	6.65E+10
Rn-218	1.00E+00	-	-	2.05E+10	-	2.05E+10
Rn-222	1.00E+00	-	2.36E+08	4.35E+03	-	4.35E+03
Tl-206	1.00E+00	-	-	1.58E+06	-	1.58E+06
Tl-210	1.00E+00	-	-	2.32E+03	-	2.32E+03

```
       rn      br  ind.prg
1  At-218 2.0e-04 6.57e+10
2  Bi-210 1.0e+00 3.06e+00
3  Bi-214 1.0e+00 2.76e+02
4  Hg-206 1.9e-08 1.03e+04
5  Pb-210 1.0e+00 2.13e-04
6  Pb-214 1.0e+00 1.50e+03
7  Po-210 1.0e+00 2.82e-02
8  Po-214 1.0e+00 3.84e+13
9  Po-218 1.0e+00 6.65e+10
10 Rn-218 1.0e-03 2.05e+10
11 Rn-222 1.0e+00 4.35e+03
12 Tl-206 1.3e-06 1.58e+06
13 Tl-210 2.1e-04 2.32e+03
> PRG.sum.se<-function(x,br.f) 1/(sum(1/(x/br.f)))
> format(PRG.sum.se(ind.prg,br),sci=T)
[1] "2.113884e-04"

9.15e-5/2.113884e-04
[1] 0.4328525 #The SE appears to miss the summation of the parent and progeny by over 50%.
```

Attachment 2: Checks on Summation of PRGs – a number of scenarios for checking totals

```
> # Checks on summation method used:
> PRG.sum<-function(x) 1/(sum(1/x))
> # check this function
> PRG.sum(c(2,3,4,5)); 1/(1/2+1/3+1/4+1/5)
[1] 0.7792208
[1] 0.7792208
#U-238 PRG's Resident Soil Bq/g all summed (without branching fractions)
> chain.prg<-scan()
1: 6.57E+10
2: 3.06E+00
3: 2.76E+02
4: 1.03E+04
5: 1.51E+01
6: 3.83E+05
7: 2.13E-04
8: 1.50E+03
9: 2.82E-02
10: 3.84E+13
11: 6.65E+10
12: 2.59E-04
13: 2.05E+10
14: 4.35E+03
15: 1.67E-02
16: 1.26E+01
17: 1.58E+06
18: 2.32E+03
19: 4.02E-03
20: 4.44E-03
21:
Read 20 items
> PRG.sum(chain.prg)
[1] 0.0001095814
> format(PRG.sum(chain.prg),sci=T)
[1] "1.095814e-04" # Compare to in SE 6.50E-05

# check on PRG combination of Ingestion, Inhalation, External Exposure and Produce Consumption for At-210:
> chain.prg<-scan()

> rm(chain.prg)
> ind.prg<-scan()
1: 1.05E+05          1.68E+08   5.81E+00   8.07E+01
5:
Read 4 items
> format(PRG.sum(ind.prg),sci=T)
[1] "5.419521e+00" #Match

# Check on short-lived U-238 decay progeny with correction or branching factor
> ind.prg<-scan()
1: 3.83E+05
2: 1.51E+01
3: 1.26E+01
4: 4.44E-03
5:
Read 4 items
```

```
> rn<-scan(what="character")
1: Pa-234m
2: Pa-234
3: Th-234
4: U-238
5:
> br<-c(1,1.6e-3,1,1)
> PRG.sum.se<-function(x,br.f) 1/(sum(1/(x/br.f)))
> data.frame(rn,ind.prg,br/ind.prg)
      rn  ind.prg   br.ind.prg
1 Pa-234m 3.83e+05 2.610966e-06
2  Pa-234 1.51e+01 1.059603e-04
3  Th-234 1.26e+01 7.936508e-02
4   U-238 4.44e-03 2.252252e+02

> PRG.sum.se(ind.prg,br)
[1] 0.004438434 #adding all short-lived makes essentially no difference. Sum is same as U-238.

# check on PRG combination of Ingestion, Inhalation, External Exposure and Produce Consumption for U-238:
> ind.prg<-scan()
1: 2.46E-01 1.32E+01   3.46E+01   4.52E-03
5:
Read 4 items
> format(PRG.sum(ind.prg),sci=T)
[1] "4.436387e-03" #match

# Check on combination of lowest PRG's in U-238 chain (all br=1)
> ind.prg<-scan()
1: 2.13E-04
2: 2.59E-04
3: 4.02E-03
4: 4.44E-03
5: 1.67E-02
6: 2.82E-02
7:
Read 6 items
> rn<-scan(what="character")
1: Pb-210
2: Ra-226
3: U-234
4: U-238
5: Th-230
6: Po-210
7:
Read 6 items
> format(PRG.sum(ind.prg),sci=T)
[1] "1.095871e-04"
> br<-rep(1,6)
> data.frame(rn,ind.prg,br/ind.prg)
      rn  ind.prg br.ind.prg
1 Pb-210 0.000213 4694.83568
2 Ra-226 0.000259 3861.00386
3  U-234 0.004020  248.75622
4  U-238 0.004440  225.22523
5 Th-230 0.016700   59.88024
6 Po-210 0.028200   35.46099
> format(PRG.sum.se(ind.prg,br),sci=T)
```

```
[1] "1.095871e-04" #Higher than U-238 SE value by:
1-6.50E-05/1.095871e-04
[1] 0.4068645 #41%.
#This is the same result essentially, as the gross combination above.

#Check of Sr-90
#SE components of total PRG resident soil
> ind.prg<-scan()
1: 2.44E-01 7.20E+02   2.20E-01     1.34E-04
5:
Read 4 items
> format(PRG.sum(ind.prg),sci=T)
[1] "1.338449e-04"  #Match
# Rerun of calculator by with progeny shows essentially all PRG due to Sr-90 when progeny are included.

#Check of Cs-137
> ind.prg<-scan()
1: 7.76E-01 2.78E+03   1.69E-03     3.35E-03
5:
Read 4 items
> format(PRG.sum(ind.prg),sci=T)
[1] "1.121689e-03" #Match

# Cs-137 by progeny
> ind.prg<-scan()
1: 5.92E+03
2: 4.42E-03
3:
Read 2 items
>
> rn<-scan(what="character")
1: Ba-137m
2: Cs-137
3:
Read 2 items
> br<-c(0.944,1)
> data.frame(rn,ind.prg,ind.prg)
       rn  ind.prg ind.prg.1
1 Ba-137m 5.92e+03  5.92e+03
2  Cs-137 4.42e-03  4.42e-03
> PRG.sum.se<-function(x,br.f) 1/(sum(1/(x/br.f)))
> format(PRG.sum.se(ind.prg,br),sci=T)
[1] "4.419997e-03"

#Check of Bi-212 for Tl-208 specifically

> rn<-scan(what="character")
1: Bi-212
2: Tl-208
3:
Read 2 items
> ind.prg<-scan()
1: 1.05E+03
2: 7.58E+02
3:
Read 2 items
> br<-c(1,0.36)
```

Default Resident PRGs for Isotope	Ingestion PRG (Bq/g)	Inhalation PRG (Bq/g)	External Exposure PRG (Bq/g)	Produce Consumption PRG (Bq/g)	Total PRG (Bq/g)
Bi-212	3.08E+06	4.32E+08	1.35E+03	4.72E+03	1.05E+03
Po-212	-	-	-	-	-
Tl-208	-	-	7.58E+02	-	7.58E+02

>

> format(PRG.sum.se(ind.prg,br),sci=T)
[1] "7.006162e+02" vs. Assume equilibrium option 6.18E-04

Resident PRGs for Soil

Isotope	Ingestion PRG (Bq/g)	Inhalation PRG (Bq/g)	External Exposure PRG (Bq/g)	Produce Consumption PRG (Bq/g)	Total PRG (Bq/g)
**Secular Equilibrium PRG for Bi-212*	*1.97E+01*	*2.76E+03*	*6.31E-04*	*3.02E-02*	*6.18E-04*

#Farmer Biota Direct

Default

Farmer PRGs for Contaminated Food Products

Isotope	Produce Consumption PRG (Bq/g)	Poultry Consumption PRG (Bq/g)	Egg Consumption PRG (Bq/g)	Beef Consumption PRG (Bq/g)	Dairy Consumption PRG (Bq/g)	Swine Consumption PRG (Bq/g)	Fish Consumption PRG (Bq/g)
**Secular Equilibrium PRG for Bi-212*	*1.87E-03*	*2.66E-02*	*4.72E-02*	*1.75E-02*	*3.61E-03*	*3.13E-02*	*3.66E-03*

This matches the output for individual progeny, but none of the progeny have any PRGs.

Composite Worker by individual progeny:

Default
Composite Worker

Isotope	Halflife (yr)	Default Soil Volume Area Correction Factor	Default Soil Volume Gamma Shielding Factor	Ingestion PRG (Bq/g)	Inhalation PRG (Bq/g)	External Exposure PRG (Bq/g)	Total PRG (Bq/g)
Bi-212	1.15E-04	1.00E+00	1.00E+00	2.01E+07	5.35E+08	1.96E+03	1.96E+03
Po-212	9.48E-15	9.00E-01	1.00E+00	-	-	-	-
Tl-208	5.81E-06	1.00E+00	1.00E+00	-	-	1.10E+03	1.10E+03

…and SE:

Composite Worker PRGs for Soil

Isotope	Ingestion PRG (Bq/g)	Inhalation PRG (Bq/g)	External Exposure PRG (Bq/g)	Total PRG (Bq/g)
**Secular Equilibrium PRG for Bi-212*	*1.33E+02*	*3.56E+03*	*9.55E-04*	*9.55E-04*

#Mismatch

#Check Np-237 and Pa-233 Farmer Biota Direct

Default

Farmer PRGs for Contaminated Food Products

Isotope	Produce Consumption PRG (pCi/g)	Poultry Consumption PRG (pCi/g)	Egg Consumption PRG (pCi/g)	Beef Consumption PRG (pCi/g)	Dairy Consumption PRG (pCi/g)	Swine Consumption PRG (pCi/g)	Fish Consumption PRG (pCi/g)
**Secular Equilibrium PRG for Np-237*	*5.63E-05*	*8.02E-04*	*1.42E-03*	*5.26E-04*	*1.09E-04*	*9.43E-04*	*1.10E-04*

Default
Farmer PRGs for C Products

Isotope	Produce Consumption PRG (pCi/g)	Poultry Consumption PRG (pCi/g)	Egg Consumption PRG (pCi/g)	Beef Consumption PRG (pCi/g)	Dairy Consumption PRG (pCi/g)	Swine Consumption PRG (pCi/g)	Fish Consumption PRG (pCi/g)
Ac-225	1.88E-04	2.67E-03	4.75E-03	1.75E-03	3.63E-04	3.14E-03	3.68E-04
At-217	-	-	-	-	-	-	-
Bi-213	7.10E-02	1.01E+00	1.80E+00	6.64E-01	1.37E-01	1.19E+00	1.39E-01
Fr-221	-	-	-	-	-	-	-
Np-237	6.15E-04	8.77E-03	1.56E-02	5.75E-03	1.19E-03	1.03E-02	1.20E-03
Pa-233	5.69E-03	8.11E-02	1.44E-01	5.32E-02	1.10E-02	9.53E-02	1.11E-02
Pb-209	1.46E-01	2.08E+00	3.70E+00	1.37E+00	2.83E-01	2.45E+00	2.86E-01
Po-213	-	-	-	-	-	-	-
Ra-225	3.32E-04	4.73E-03	8.39E-03	3.10E-03	6.42E-04	5.56E-03	6.50E-04
Th-229	1.75E-04	2.50E-03	4.44E-03	1.64E-03	3.40E-04	2.94E-03	3.44E-04
Tl-209	-	-	-	-	-	-	-
U-233	5.26E-04	7.49E-03	1.33E-02	4.91E-03	1.02E-03	8.81E-03	1.03E-03

Compare to output from: progeny throughout chain

```
> rn<-scan(what="character")

1: Th-229
2: Ac-225
```

```
3: Ra-225
4: U-233
5: Np-237
6: Pa-233
7: Bi-213
8: Pb-209
9:
Read 8 items #produce consumption items
> ind.prg<-scan()
1: 1.75E-04
2: 1.88E-04
3: 3.32E-04
4: 5.26E-04
5: 6.15E-04
6: 5.69E-03
7: 7.10E-02
8: 1.46E-01
9:
Read 8 items
> format(PRG.sum(ind.prg),sci=T)
[1] "5.627677e-05" #SE Np-237 matches sum of individual progeny.
```

Attachment 3Check on GSF$_b$

```
> #GSF 500 m^2 resident GSFo 0 cm GSFb 0 or 10 cm 24 hr/d indoors
> # Set GSFi=1
> PRGx.Co60.10cm<-9.95E-03 #external exposure PRG pCi/g
> PRGx.Co60.0cm<-3.22E-03
> GSF<-0.17 # https://epa-prgs.ornl.gov/radionuclides/GSF_FINAL.pdf table 3
> #Result as fraction of GSF in table:
> data.frame("table GSF"=GSF,"result.fraction"=(PRGx.Co60.0cm/PRGx.Co60.10cm)/GSF)
  table.GSF result.fraction
1      0.17        1.903636

> #GSF 500 m^2 INDOOR Worker GSFo 0 cm GSFb 0 or 10 cm 24 hr/d indoors
> # Set GSFi=1
> PRGx.Co60.10cm<-5.01E-02 #external exposure PRG pCi/g
> PRGx.Co60.0cm<-1.62E-02
> GSF<-0.17 # https://epa-prgs.ornl.gov/radionuclides/GSF_FINAL.pdf table 3
> #Result as fraction of GSF in table:
> data.frame("table GSF"=GSF,"result.fraction"=(PRGx.Co60.0cm/PRGx.Co60.10cm)/GSF)
  table.GSF result.fraction
1      0.17        1.902078

> #GSF 500 m^2 INDOOR Worker GSFo 0 cm GSFb 0 or 10 cm 24 hr/d indoors
> # Set GSFi=1 Am-241
> PRGx.Am241.10cm<-2.27E+03 #external exposure PRG pCi/g
> PRGx.Am241.0cm<-21.8
> GSF<-5.7E-03 # https://epa-prgs.ornl.gov/radionuclides/GSF_FINAL.pdf table 3
> PRGx.Am241.0cm/PRGx.Am241.10cm
[1] 0.009603524
> #Result as fraction of GSF in table:
> data.frame("table GSF"=GSF,"result.fraction"=(PRGx.Am241.0cm/PRGx.Am241.10cm)/GSF)
  table.GSF result.fraction
1    0.0057        1.684829
```

Attachment 4: Individual Produce Items

Selected options in the PRG calculator for Cs-137 farmer scenario, Show Individual Produce PRG Output. Notes on review:

- Parameters for apples appear duplicated in the output.
- IRSTfar-c (strawberry ingestion rate - farmer child) g/day = 25.3, but the PRG User's Guide has a value of 25.8.
- IRSNfar-a (snap bean ingestion rate - farmer adult) g/day = 54.2 but the PRG User's Guide has a value of 54.3.

```
• # Produce Items summing to produce PRG
• > ind.prg<-scan()
• 1: 0.000838      0.00201 0.00241 0.0021  0.0022  0.000948        0.00311
    0.000242        0.000948        0.00144 0.00218 0.00238 0.00267 0.00292
    0.00069 0.00113 0.00226 0.000548        0.00114 0.00141 0.00185 0.000829
• 23:
• Read 22 items
• > format(PRG.sum(ind.prg),sci=T)
• [1] "5.044121e-05" Match
```

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Profile:

Health Physicist with over twenty years of professional experience in the areas of operational health physics, radiological design, and engineering calculations. Strong technical ability, team building skills and communication skills with scientific and general audiences.

Education and Certification

- American Board of Health Physics Certified (CHP) since 1993
- Master of Science degree in Health Physics, University of Cincinnati, 1989
- Graduate Certificate in Epidemiology and Biostatistics, Drexel University, 2006
- Bachelor of Science degree in Nuclear Technology, University of the State of New York, 1988
- Naval Nuclear Power School, Mechanical Operator Training and Engineering Laboratory Technician (1982)
- Additional graduate level college courses and professional training courses (list available)

Experience Summary

- 1991 to present - Health Physicist/Radiological Engineer with Savannah River Nuclear Solutions and predecessor companies at the Savannah River Site.
- 1988 – 1991 - Health Physicist at the Fernald Site (transferred with Westinghouse to SRS)
- 1986 - 1988 - Co-op and part time experience. While a full-time student, worked as a university research assistant; plant layout specialist at a GE aircraft engine plant; and health physics technician at two commercial nuclear power plant refueling outages.
- 1980-1986 - US Navy - Engineering Laboratory Technician (water chemistry and radiation protection), machinist, supervisor.

Skills

- Radiological engineering calculations
- Calibration, Testing, Uncertainty Analysis for Radiation Instrumentation
- Operational health physics calculations
- Radiological protection technical support
- Schedule development in managed projects.
- Support of nuclear safety including risk assessments, safety analyses, facility safety documentation.
- Development of administrative controls (procedures, manuals).
- Incident investigations; root cause analyses.
- Team building, consensus development.
- Presentations; communication with scientific and general audiences.

Skills, continued

- Plant troubleshooting including assessment of data from data acquisition systems and distributed control systems.
- Industrial Hygiene – supported beryllium and Legionella programs and performed gas concentration calculations.
- Emergency Preparedness drill scenario development and drill control.
- Radiological Software Quality Assurance

Experience Details

- Savannah River Site support Aiken, SC: 1991 – present. Supported facilities include the following processes:
  - Plutonium dispositioning,
  - Instrument calibration and testing (Deputy Technical Director for Calibrations at the Health Physics Instrument Calibration Laboratory),
  - High and low level waste processing,
  - Nuclear materials production (including plutonium, neptunium, uranium and tritium),
  - Laboratories, and
  - Storage.

- Radiological Engineering group (Site support), 2005-present: Provided support for all aspects of radiological design of new and ongoing projects, including:
  - Radiation shielding and dose rate calculations,
  - Aerosol Transport and Measurement,
  - Radiological containment and contamination control,
  - Internal radiation dose potential,
  - Material compatibility,
  - Access control,
  - Compliance with dose limits and As Low As Reasonably Achievable (ALARA),
  - Radioactive waste minimization,
  - Facility layout,
  - Radiological Design Engineering Standard,
  - Confinement Ventilation Engineering Standard,
  - Radiological Software Quality Assurance.

- H-Canyon (chemical separations plant) and H-B-Line (special nuclear material processing operations), 2004 – 2005, Provided field radiological engineering support including:
  - Bioassay review,
  - Radiological protection program development,
  - Instrumentation support,
  - Engineering and project interface,
  - Radiological shielding calculations,

<u>Experience Details, continued</u>

- Defense Waste Processing Facility and other SRS site support, 1991 - 2004
  - Was instrumental in the start-up and operation of DWPF, a high level waste vitrification facility. Served as cognizant system engineer for all radiation monitoring.
  - Performed engineering reviews of design changes and other operations and maintenance activities and ensured compliance with the defined safety envelope.
  - Developed and supported radiation monitor calibration programs.
  - Invented and implemented a cost-saving algorithm to check continuous air monitor functionality using plant data tracking systems and natural radon variations.
  - Developed and supported water treatment for cooling tower and closed loop process cooling and heating systems.
  - Supported chemical stack effluent monitoring system for nitrous oxides, mercury and benzene.
  - Provided engineering interface with environmental compliance on air and water discharge permitting issues for chemicals and radioactivity.
  - Developed a NIST-traceable beta dose rate calibration program for portable instruments.

- Westinghouse Materials Company of Ohio (later called Westinghouse Environmental Management Company of Ohio), 1988 – 1991. Production and remediation activities at uranium and thorium processing facilities at Fernald, Ohio.
  - Developed radiological measurement programs for field health physics applications including:
  - Statistical process control program for low level alpha-beta counting systems,
  - Radon progeny methods for Radon (Rn-222) and Thoron (Rn-220).
  - Developed new Flow Gemini database for radiological sample results.
  - Led cost-saving project to automate air sample data collection via bar code readers.
  - Led Environmental Remediation Health and Safety Plan process improvement team.
  - Developed health and safety strategies for numerous environmental remediation projects.

<u>Software Familiarity:</u>

- Experienced in:
  - MCNP (Monte Carlo N-Particle code),
  - R programming language,
  - Origen Module of SCALE (Standardized Computer Analyses for Licensing Evaluation),
  - Radiological Toolbox,
  - Microshield,
  - Microsoft Excel,
  - Microsoft Word

- Familiar with:
  - HTML and CSS (web page development),
  - Varskin

<u>Instrumentation and Systems Supported</u>

- Gamma and Beta radiation monitors: ion chambers (portable and installed with picoammeters), plastic scintillators, Sodium Iodide and Geiger-Mueller tube based systems;
- Alpha and beta continuous air monitors,
- Personnel contamination monitors,
- BF_3 and ^3He neutron detection, ROSPEC (rotating spectrum) neutron field measurement.
- Health Physics Calibration Laboratory systems with neutron, gamma, X-ray and Beta Sources.
- Central vacuum systems,
- Radon monitors,
- Low level alpha beta counting systems,
- Alpha and gamma spectroscopy,
- Laundry monitor,
- Stack monitors,
- Mobile contamination monitors.
- Chemical monitors: gas chromatographs, tracer gas monitors, gas analyzers using UV, IR and chemiluminescence, oxygen analyzers, explosive gas analyzers.
- Other instrumentation: thermocouples, pressure, level, air flow, distributed control system, recorders.

<u>Languages</u>

- Speak and read French at a functional level.
- Limited familiarity with Russian (e.g. can frequently comprehend signs) and Spanish (up to about the level of ordering food in a restaurant).

<u>Publications and Presentations</u>

- Health Physics Monitoring at the Defense Waste Processing Facility. Proceedings of the International Topical Meeting on Nuclear and Hazardous Waste Management (SPECTRUM '94). American Nuclear Society; 1994. (Sole author)
- An Algorithm for Source Checking Continuous Air Monitors Using Radon Progeny. *Health Physics* 79(3): 299; Dec 2000. (Principal author)
- Field Comparison of the Sampling Efficacy of Two Smear Media: Cotton Fiber and Kraft Paper. *Health Physics*, 83, suppl 1 S45-47; 2002. (Sole author)
- Experience in Neutron Monitoring at the Savannah River Site H-Canyon, Presented at the DOE ALARA Conference, August 2005. (Sole Author)
- Parallels of Radiation- and Financial-Risk Management: Impacts on Public Acceptance. *Health Physics*, 100, 2011. (Sole author)
- Monte Carlo Modeling versus Ion Chamber Measurements of Low Energy Photon and Beta Radiation, Presented to the Health Physics Society Annual Meeting, Sacramento, CA, July 2012.
- Monte Carlo Model of HPGe Detectors Used in Routine Lung Counting, *Applied Radiation and Isotopes, Applied Radiation and Isotopes*, 79(2013) 94–102. (Contributing Author)
- Hand Calculations for Transport of Radioactive Aerosols Through Sampling Systems, *Health Physics* 106(Supplement 2):S78-S87; 2014 (Principal author)

Conflict of Interest Certification

Verfication Study: U.S. Environmental Protection Agency (EPA), "Preliminary Remediation Goals (PRG) for Radionuclides Electronic Calculator"

A conflict of interest or lack of impartiality exists when the proposed reviewer personally (or the reviewer's immediate family), or his or her employer, has financial interests that may be affected by the results of verification study; or may provide an verification study may be impaired due to other factors. When the Reviewer knows that a reasonable person with knowledge of the facts may question the reviewer's impartiality or financial involvement, an apparent lack of impartiality or conflict of interest exists.

The following questions, if answered affirmatively, represent potential or apparent lack of impartiality (*any affirmative answers should be explained on the back of this form or in an attachment*):

- Did you contribute to the development of the calculator under review, or were you consulted during its development, or did you offer comments or suggestions to any drafts or versions of the document during its development? ☒ No ☐ Yes
- Do you know of any reason that you might be unable to provide impartial advice on the matter under consideration in this verification study, or any reason that your impartiality in the matter might be questioned? ☒ No ☐ Yes
- Have you had any previous involvement with the calculator under consideration? ☒ No ☐ Yes
- Have you served on previous advisory panels, committees, or subcommittees that have addressed the topic under consideration? ☒ No ☐ Yes
- Have you made any public statements (written or oral) on the issue? ☒ No ☐ Yes
- Have you made any public statements that would indicate to an observer that you have taken a position on the issue under consideration? ☒ No ☐ Yes
- Do you, your family, or your employer have any financial interest(s) in the matter or topic under review, or could someone with access to relevant facts reasonably conclude that you (or your family or employer) stand to benefit from a particular outcome of this verification study? ☒ No ☐ Yes

With regard to real or apparent conflicts of interest or questions of impartiality, the following provisions shall apply for the duration of this verification study:

(a) Reviewer warrants, to the best of his/her knowledge and belief, that there are no relevant facts or circumstances that could give rise to an actual, apparent, or potential organizational or personal conflict of interest, or that Reviewer has disclosed all such relevant information to EMS or to EPA.
(b) Reviewer agrees that if an actual, apparent, or potential personal or organizational conflict of interest is identified during performance of this verification study, he/she immediately will make a full disclosure in writing to EMS. This disclosure shall include a description of actions that Reviewer (or his/her employer) has taken or proposes to take after consultation with EMS to avoid, mitigate, or neutralize the actual, apparent, or potential organizational conflict of interest. Reviewer shall continue performance until notified by EMS of any contrary action to be taken.

[signature] 3-6-2017

Signature Date

☐ Check here if any explanation is attached

Mark G. Hogue

Printed Name

Affiliation/Organization