Verification Study of the "Preliminary Remediation Goals for Radionuclides in Buildings (BPRG)" Electronic Calculator

External Verification Study Record
October 16, 2015 – December 22, 2015

CONTENTS:

Verification Study Charge for:

U.S. Environmental Protection Agency (EPA), "Preliminary Remediation Goals for Radionuclides in Buildings" (BPRG) electronic calculator.

Background:

EMS, under contract EP-W-13-016 with EPA's Office of Solid Waste and Emergency Response, has been requested to obtain an external, independent verification study of the online BPRG electronic calculator.

The purpose of this recommended BPRG calculation tool is to assist risk assessors, remedial project managers, and others involved with risk assessment and decision-making at sites with contaminated buildings. The BPRG electronic calculator presents standardized exposure parameters and equations that should generally be used for calculating radionuclide PRGs for resident and indoor worker exposure scenarios.

Charge:

According to EPA's Guidance on the Development, Evaluation, and Application of Environmental Models (2009), v*erification* 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 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. We are enlisting two subject matter experts for this verification study. Your comments and recommendations will be used to revise the calculator so that the final version will reflect sound technical information and guidance.

As an independent tester of the BPRG 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 January 15, 2015. Please submit your comments in Microsoft Word and reference each comment to a specific step in the calculator and equation (http://epa-bprg.ornl.gov/bprg_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.*

How to Use the Calculator:

The BPRG calculator is available at http://epa-bprg.ornl.gov/cgi-bin/bprg_search, and the User's Guide is available at http://epa-bprg.ornl.gov/bprg_users_guide.html. To summarize,

Step 1 Select an exposure scenario. The BPRG calculator has nine exposure scenarios:

1. Resident
2. Indoor Worker

Step 2 Select media. The BPRG calculator has three media

1. Settled Dust
2. Ambient Air
3. 3-D external exposure

Step 3 Choose to have your results in either picocuries, which are the units usually used in the United States, or in bequerels which most of the rest of the world uses.

Step 4 Select BPRG type ─ either "Defaults" (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).

Step 5 Select either "yes" or "no" if you want a risk output

Step 6 Select one or more isotopes (or select "All") 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.

The equations used in the calculator are listed at http://epa-bprg.ornl.gov/bprg_equations.html. There are approximately 32 equations used in the calculator.

Shiya Wang
CO Department of Public Health and Environment

Technical Memorandum

Author: Shiya Wang
Subject: Verification Study Results for the EPA BPRG electronic calculator
Date: December 13, 2015

This memo is to report the verification study results and to provide comments or suggestions that could be used to revise the U.S. Environmental Protection Agency (EPA), “Preliminary Remediation Goals for Radionuclides in Buildings” (BPRG) electronic calculator and the User's Guide.

<u>Purpose of the Verification Study:</u>

This verification study is to examine the numerical technique in the electronic calculator to:

1. Ensure that the equations are programmed correctly;

2. Verify that the electronic calculator is consistent with the conceptual model and governing equations; and

3. Provide comments or suggestions that could be used to revise the calculator and the User's Guide.

<u>Summary of the Verification Study:</u>

I conducted the verification study for the BPRG electronic calculator during November 20 to December 10, 2015, which included the following steps:

1. Creating an independent calculator: I programmed the equations listed in the BPRG User's Guide using the Wolfram *Mathematica* 10.3 as an independent calculator.

2. I calculated, using both my independent calculator and the BPRG electronic calculator, the BPRGs for each exposure scenario (resident and indoor worker) and each media (settled dust, ambient air, and 3-D external exposure) with the default values for all parameters in the equations. Then, I compared the outputs between the two calculators. This step was to verify that the equations are programmed consistently between the governing equations in the BPRG User's Guide, my independent calculator, and the BPRG electronic calculator.

3. Again using both calculators, I calculated the BPRGs for each exposure and each media by testing various values for each parameter in the equations. Then, I compared the outputs between the two calculators. I also examined the outputs from the BPRG electronic calculator by changing the input parameters to see if the outputs were changed correctly with different inputs. This step was to further verify that the equations are programmed correctly and that the sources of error, such as rounding, are minimal.

Results of the Verification Study:

After conducting the steps described above, I have the following findings:

1. Overall, the BPRG electronic calculator is programmed correctly and consistently with the conceptual model and the governing equations as described in the BPRG User's Guide.

2. The numerical conversion between the pCi and Bq in the BPRG electronic calculator is correct.

3. The numerical calculations for risk by selecting “Yes” on the “Select Risk Output” are done correctly. However, the units for the user-inputted concentrations in some cases are not consistent with the units of the associated BPRGs.

4. There are a few discrepancies between the equations in the BPRG User's Guide and the BPRG electronic calculator, which mostly are errors in the BPRG User's Guide.

5. There are a few other errors in the BPRG User's Guide.

6. There are a few glitches in the BPRG electronic calculator.

The table below summarizes my specific comments regarding the findings Item 3, 4, 5, and 6:

	Location	Comments
1	User's Guide, Section 5, Table 1	This table does not list all of the parameters/variables used in all of the equations. Here are the missing parameters I have identified: Equation for $IFD_{res\text{-}adj}$: $EF_{res\text{-}c}$, $EF_{res\text{-}a}$, FQ_c, FQ_a Equation for $BPRG_{iw\text{-}dust\text{-}ing}$: SF_s (or SF_{oa} – see Item 3 below) Equation for $IFA_{res\text{-}adj}$: $ET_{res\text{-}c}$, $ET_{res\text{-}a}$, $EF_{res\text{-}c}$, $EF_{res\text{-}a}$ Equation for $BPRG_{iw\text{-}air\text{-}decay\text{-}inh}$: IRA_{iw} The description and the default values of these missing parameters should be added into Table 1. I believe that they have all been listed in the electronic calculator.
2	User's Guide, Section 4.1.1, Equation for $BPRG_{res\text{-}dust\text{-}ing}$	SF_s should be SF_o In the equation page of the BPRG electronic calculator[1], this equation lists SF_o instead of SF_s. Also, in Table 1 of the User's Guide, there is a SF_o but no SF_s.
3	User's Guide, Section 4.2.1, Equation for $BPRG_{iw\text{-}dust\text{-}ing}$	SF_s should be SF_{oa} In the equation page of the BPRG electronic calculator[1], this equation lists SF_{oa} instead of SF_s.
4	User's Guide, Section 4.2.1, Equation for $BPRG_{iw\text{-}dust\text{-}ing}$ and the same equation in the equation page of the BPRG electronic	The unit of SF_{oa} (or SF_s in this equation – see Item 3 above) should be risk/pCi instead of mrem/pCi.

	calculator	
5	User's Guide, Section 4.2.1, Equation for $BPRG_{iw-dust-ext}$ and the same equation in the equation page of the BPRG electronic calculator	ET_w should be ET_{iw}.
6	User's Guide, Section 4.1.2, Equation for $BPRG_{res-air-decay-sub}$	The denominator in this equation is missing an ED_{res}. The same equation in the equation page of the BPRG electronic calculator does have an ED_{res} and the numerical computer code does apply an ED_{res} in the calculation. In addition, the same equation but without half-life decay does have an ED_{res} in the denominator. Therefore, this equation should add an ED_{res} in the denominator in the User's Guide.
7	User's Guide, Section 4.1.3, Equation for $BPRG_{res-air-nodecay-inh}$ and the same equation in the equation page of the BPRG electronic calculator	The default value of $IFA_{res-adj}$ should be 161000 m^3 instead of 166000 m^3.
8	F_{surf} in all 3D direct external exposure equations in both User's Guide and the electronic calculator	In the BPRG output page of the BPRG electronic calculator for the 3D scenario for both resident and indoor worker, the F_{surf} is called "Room Factor". However, in Table 1 of the User's Guide, it is called "Surface Factor". I would suggest making it consistent by calling the same term in both places.
9	User's Guide, Section 4.2.4, Equation for $BPRG_{iw-3D-ext-15cm}$ and the same equation in the equation page of the BPRG electronic calculator	There is an "S" in the beginning of the denominator. This is an error and the "S" should be removed from the equation.
10	User's Guide, Section 4.2.4, Equation for $BPRG_{iw-3D-ext-1cm}$ and the same equation in the equation page of the BPRG electronic calculator	The unit of $SF_{ext-1cm}$ should be (risk-g/pCi-yr) instead of (mrem-g/pCi-yr). So the "mrem" should be replaced with "risk".
11	The BPRG electronic calculator	After selecting resident, dust, and the BPRG type of Site-specific and Database Heirarchy defaults, and clicking "Retrieve", it displays a page where users can specify the input values of each parameter. In this page, there are two duplicate tables for the same input parameters.

		Only the first table works (i.e. creates correct output values) when changing the input values. I would suggest removing the second table. Same thing occurs when selecting resident, air, and the BPRG type of Site-specific and Database Heirarchy defaults. So same recommendation for this case too.
12	BPRG User's Guide	In the BPRG electronic calculator, $t_{iw} = ED_{iw}$ is used for all cases. Maybe this can be mentioned in the User's Guide. Or, if these two parameters are always equal to each other, maybe just simply use one single parameter instead of two. Same comment for $t_{res} = ED_{res}$ too.
13	BPRG User's Guide, risk calculation	The BPRG electronic calculator has an option to calculate and output the risks if users specify the concentrations of the specific radionuclide. Even though this is not a complicated calculation, I would suggest describing in the User's Guide how the risk is calculated in the BPRG electronic calculator.
14	BPRG electronic calculator, risk calculation	I think that the BPRG electronic calculator assumes that the input concentration has the same unit as the associated BPRG. In most cases, the units of the concentration and the associated BPRG are consistent, except for the following: For dust: the unit of the BPRG is pCi/cm^2. However, the unit of the concentration is listed as pCi/m^3. It should be changed to pCi/cm2. For 3D, ground surface case: the unit of the BPRG is pCi/cm^2. However, the unit of the concentration is listed as pCi/g. It should be changed to pCi/cm^2.
15	BPRG electronic calculator, resident exposure scenario, dust, the BPRG type of Site-specific and Database Heirarchy defaults	On the page where users can input their own values for each parameter, I found that the $IFD_{res\text{-}adj}$ was always unchanged no matter how I changed any of the parameters (such as $FTSS_h$, $SA_{res\text{-}a}$, etc.) in its equation. I believe that this is a glitch in the program since I was able to change the IRD_{iw} for the indoor worker scenario.
16	BPRG electronic calculator, resident exposure scenario, dust, the BPRG type of Site-specific and Database Heirarchy defaults	On the page where users can input their own values for each parameter, both t_{res} and ED_{res} are highlighted and cannot be changed. I think this page should allow the users to change one of them. Therefore, this needs to be corrected.
17	BPRG electronic calculator, resident exposure scenario, air, the BPRG type of	Same comment as Item 16 but for air.

	Site-specific and Database Heirarchy defaults	
18	BPRG electronic calculator, resident exposure scenario, air, the BPRG type of Site-specific and Database Heirarchy defaults	On the page where users can input their own values for each parameter, I found that the $IFA_{res\text{-}adj}$ was always unchanged no matter how I changed any of the parameters (such as $ET_{res\text{-}c}$, $IRA_{res\text{-}a}$, etc.) in its equation. I believe that this is a glitch and should be corrected.
19	BPRG electronic calculator, the BPRG type of Site-specific with the Isotope Info type of "User-provided"	Only when all three media (dust, air, and 3D) are selected, then I can get an output of BPRGs. If I only select one or two of the media options, there is no output (even though I was able to get to the page where I can change the values of SF and other input parameters). I believe that this is a glitch in the calculator.

Notes:

[1] "The equation page of the BPRG electronic calculator" means that:

Select any of the exposure scenario and any of the media
Select BPRG type = Site-specific
Select Isotope Info Type = Database Heirarchy defaults
Select any of the radionuclides
Click on "Retrieve".
Then click on any of the specific exposure scenario and media.
Then it will display the specific equation. This is referred as "the equation page" in my comments.

RESUME

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EDUCATION

- Ph.D. 2008 Astronomy, University of Illinois at Urbana-Champaign
- M.S. 2002 Physics, National Tsing Hua University, Taiwan
- B.S. 2000 Physics, National Tsing Hua University, Taiwan

PROFESSIONAL DEVELOPMENT

- U.S. Nuclear Regulatory Commission Training courses for Agreement State Staff, including Fundamental Health Physics, Intermediate Health Physics, Advanced Health Physics, Internal Dosimetry, Health Physics for Uranium Recovery, MARSSIM, Environmental Monitoring, Visual Sampling Plan, Transportation of Radioactive Materials, IMPEP, and Inspection Procedures, during 2012 − 2015
- Project Management Certificate course, Spring Semester of 2015, Colorado State University

PROFESSIONAL EXPERIENCE

Environmental Protection Specialist II
Colorado Department of Public Health and Environment, 2013-present

- Primarily responsible for licensing, inspection, and regulations for uranium recovery facilities
- Certified inspector for uranium recovery facilities, decommissioning and decontamination service providers, and portable nuclear gauges
- Responsible for licensing and inspection for a low-level radioactive waste disposal facility and other licensees conducting water treatment, decommissioning and decontamination, and uranium processing
- Experienced with remediation sites that are under EPA Superfund
- Experienced with radiation safety, occupational and environmental monitoring, and quality control/quality assurance program for uranium recovery facilities

Environmental Protection Specialist I
Colorado Department of Public Health and Environment, 2012-2013

- Responsible for licensing, inspection, and regulations for uranium recovery facilities

Post-Doctoral Scientist
Chemistry Department, Emory University, 2011-2012

- Responsible for the reduction and processing for the data taken from the Herschel Space Observatory operated by the European Space Agency
- Chemical spectral analysis and models
- Analytically and statistically interpreted data
- Taught softwares responsible for analyzing Herschel data

Post-Doctoral Researcher
Department of Astronomy, University of Michigan, 2008-2011

- Responsible for the reduction, processing, and performance evaluation for the data taken from Herschel Space Observatory operated by the European Space Agency
- Chemical spectral analysis and models
- Analytically and statistically interpreted data
- Interned in Herschel Instrument Control Center at Groningen, Netherlands, for two months in 2009, assisting the calibration and performance evaluation of Herschel Space Observatory
- Worked in a ~60 member team and participated in multiple projects simultaneously
- Established a training strategy for teaching the Herschel data reduction and analysis

Ph.D. Student in Astronomy
Department of Astronomy, University of Illinois at Urbana-Champaign, 2002-2008

- Researched the correlation of star clustering and assessed its connection with the underlying physical mechanisms
- Established the ability to research both independently and in collaboration with others
- Established the ability to extract most information out of data and search for relevant theories/methods efficiently for the interpretation
- Experienced in optical and radio telescope operations

Teaching Assistant
Physics Department, National Tsing Hua University, 2000-2002
Undergraduate courses: General Experimental Physics and General Astronomy

- lectured on the physics experiment processes and the operation of lab instruments

Master Student in Physcis
Physics Department, National Tsing Hua University, 2000-2002

- Numerical calculations (using the C programming language) to solve the quantum conditions of a molecular hydrogen in the extreme magnetic environment

Conflict of Interest Certification

Verfication Study: U.S. Environmental Protection Agency (EPA), "Building Preliminary Remediation Goals (BPRGs) 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 document 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
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- 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] 11/19/2015

Signature Date

☐ Check here if any explanation is attached

Shiya Wang

Printed Name

Colorado Department of Public Health and Environment

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Robert Litman
Radiochemistry Laboratory Basics

Verification of Calculations in EPA's "Preliminary Remediation Goals for Radionuclides in Buildings" (BPRG) electronic calculator

Robert Litman, PhD
Environmental Management Support, Inc.

December 2015

1 EXECUTIVE SUMMARY

Several different radionuclide combinations were used in verifying the calculations performed by the 30 plus equations in the Preliminary Radiation Goals for Radionuclides in Buildings (BPRG) Calculator. The equations from the BPRG User Guide were entered onto an Excel spreadsheet and the calculations performed for the same radionuclides as were entered into the calculator.

The on-line calculator provides a rapid means for getting estimates of activity concentrations for remediation goals. Both default and site specific variables can be input to the calculator providing excellent flexibility.

The values generated by Excel® spreadsheet and the on-line calculator were compared using a criterion of less than 1 % difference as an acceptable result. The equations used in the calculator are presented in the BPRG User Guide, however it is not possible to verify if the equations or constants presented in the user's guide are identical to those used in the calculator since the calculator equations are not available for inspection by the user. This became an issue with certain of the calculations as it was evident that some other factors were used in the on-line calculator that were not stipulated in the BPRG User Guide.

The presentation of the data output from the on-line calculator was sometimes confusing and should be arranged differently so that it is easier for the user to identify the specific output they desire. It is also not possible to obtain a single pdf output for the entire the scroll bar function at the bottom of the output page does not translate to Adobe.

Finally the presentation of the equations both on-line and in the BPRG User Guide is very poor. Attempting to show equations with embedded units and wrapping an equation over more than one line does not aid in understanding how the equation is to be employed. A more traditional approach to equation presentation should be used.

2 DISCUSSION OF VERIFICATION METHOD AND RESULTS

NOTE: Typed sentences in bolded ***italics*** denote areas of discrepancy or areas for need of improvement.

The equations presented in the BPRG User Guide have several constants that are calculated and then used in the calculator:

- $IFD_{res\text{-}adj}$ 3,200,400 cm^2
- $IFA_{res\text{-}adj}$ 161,000 m^3
- IRD_{iw} 176.4 cm^2

Each of these were verified as correct via hand calculation using the inputs provided in the BPRG User Guide. ***An error regarding these constants in the BPRG User Guide was noted in Section '4.1.3 Exposure to Ambient Air without Half-life Decay' under the "Inhalation" equation where the*** $IFA_{res\text{-}adj}$ ***had an incorrect value of 166,000*** m^3***. This needs to be corrected.***

The images of the equations in the on-line calculator are fuzzy. This is perhaps an issue with using an image copy versus a direct character copy effect. This could be improved.

The equation presentation should be in a more traditional format. Using more than a single line to present the equation and the addition of the units with the symbols within the equations make them difficult to read and interpret. ***Using only the symbols in the equation, and then following the description of each symbol with their units will help in the visualization and understanding of the equation.***

On the on-line page for the calculator when one expands the "Using the BPRG Calculator" and goes to Step 2 the following message appears,

> "2. Selec BPRG Type
>
> > Select the type of BPRG desired. If "Defaults" is selected go to Step 3. If "Site Specific" is selected go to step 4."

Note the typo for the word "Selec" and also that "Site Specific" is step 7 not Step 4. This confusing direction is repeated in some of the other steps as well.

In "Step 9 View Results" one of the options is to print results to a pdf format. When this is selected in Windows 10 (with Acrobat Reader DC) the information in the results section is truncated. The selection below is from the pdf:

Figure 1. Output from On-line Calculator

Default

Resident Building PRGs for Dust

Radionuclide	Soil Ingestion Slope Factor (risk/pCi)	External Exposure Slope Factor (Ground Plane) (risk/yr per pCi/cm²)	Lambda	Halflife (years)	Dissipation	Decay	Ingestion BPRG (pCi/cm²)	External Exposur BPRG (pCi/cm²)
Ag-110m+D	2.28E-11	2.45E-06	1.01E+00	6.84E-01	1.00E+00	1.00E+00	3.61E-01	4.31E-01
Ba-140	4.03E-11	1.63E-07	1.98E+01	3.49E-02	1.00E+00	1.00E+00	4.00E+00	1.27E+02
Pb-210	1.72E-09	1.72E-09	3.12E-02	2.22E+01	1.00E+00	5.56E-01	2.66E-04	3.41E+01
Pu-239+D	2.28E-10	2.06E-10	2.87E-05	2.41E+04	1.00E+00	7.47E-04	1.37E-03	1.95E+02

Note that the last two columns that appear on the BPRG Calculator on-line (Dust BPRG pCi/$m^3$and Dust BPRG mg/m^3) are missing from the pdf page since in order to view them the user needs to use the on-line scroll bar beneath the table. ***There is no way to get the complete results portion of the page onto one pdf file. This issue should be addressed (see recommendation below on reorganization of the output data table).***

The fourth and fifth columns shown in Figure 1 are redundant. Since the half-life is not used directly it adds nothing to the results, especially since the half-lives of radionuclides that are less than one year are always expressed in days or hours. ***It is recommended that the half-life column be deleted and the units for lambda in its column be inserted as "(yr^{-1})".***

The equation parameter, k (dissipation rate, yr^{-1}) is given as "zero" on the on-line printout page for the above radionuclides.

Figure 2. Partial Page of Input Parameters from On-line Calculator

Variable	Value
TR (target cancer risk) unitless	1.0E-6
t_{res} (time - resident) yr	26
ED_{res} (exposure duration - resident) yr	26
F_{in} (fraction time spent indoors) unitless	1
k (dissipation rate constant) yr^{-1}	0.0

However one must go into the user guide to find out that the equation components that use this variable must be omitted to verify the calculation (avoids division by zero). ***However there is no guidance in the guide on when k should not be zero and the variables' parameters used in the equations.***

In section 4.3.8 of the user guide it says to use a value for k of zero. If zero is used for k the equation is unsolvable because it leads to a "divide by zero" error. ***Correct the user guide to state that if the dissipation factor is not to be used, eliminate the terms containing it from the equation.***

Also with regard to the dissipation factor, the BPRG discussion says that the basis for dissipation may be based on studies of dioxin at the Binghamton State Office Building. This would be incorrect for radionuclide settling as the mass of radionuclidic matter is infinitesimally small compare to that of dioxin particles. Thus their settling rates would not be comparable just based on the large differences in their aerodynamic diameters. ***Until a study of settling rates of radionuclides is conducted in a real environment it is suggested that the dissipation constant be removed from these equations entirely.***

The output for this situation is also in conflict with what the user guide states:

Figure 3. BPRG User Guide Information

Radionuclide	**Soil Ingestion Slope Factor (risk/pCi)**	**External Exposure Slope Factor (Ground Plane) (risk/yr per pCi/cm^2)**	**Lambda**	**Halflife (years)**	***Dissipation***	Decay	Ingestion BPRG (pCi/cm^2)	External Exposure BPRG (pCi/cm^2)
Ag-110m	2.28E-11	2.45E-06	1.01E+00	6.84E-01	***1.00E+00***	1.00E+00	3.61E-01	4.31E-01

Per the User's Guide, "This equation is for values of k that are greater than zero; when k=0, the dissipation term is not quantified to avoid division by zero". The printout shows that the dissipation factor is 1.00E+00; what this really means is that the terms including "k" have been set to unity. ***This is incorrectly explained in the BPRG User Guide.***

One example of the Excel® spreadsheet method used to verify the on-line calculator results is shown here:

Figure 4. Example of Method used for Verification of On-Line Equation Output Values

Calculated Value by Hand Verification													BPRG			Agree to within 1 %	
Resident exposure to ambient air with half life										Ambient air			Calculator			(Y/N)	
	λ	TR	Tres	k	SFi	IFA	Fin	Fi		Inhalation with decay	Inhalation w/o decay		Inhalation	Inhalation			
		1.00E-06	26	0		1.61E+05	1	1		pCi/m3			with decay	w/o decay			
Co-60	1.31E-01				1.01E-10					2.166E-01	6.150E-02		2.18E-01	6.17E-02		y	y
H-3	5.63E-02				8.47E-13					1.397E+01	7.333E+00		1.40E+01	7.33		y	y
Pu-238	7.90E-03				5.22E-08					1.316E-04	1.190E-04		1.32E-04	1.19E-04		y	y
Ra-226+D	4.33E-04				2.82E-08					2.215E-04	2.203E-04		2.21E-04	2.20E-04		y	y

The formula used for agreement (last two columns) was

Agreement (Y/N) =IF(ABS((BPRG Calc-Hand Calc)/BPRG calc) < 0.01,"y","N") (1)

Thus if the values were within 1 % (0.01) then agreement would be verified. In several of the calculations, the values were not exact for the three significant figures generated, even though the results were within 1 %. ***Based on the observation for this, and several other calculations, that the values do not match exactly it is suspected that the on-line calculator truncates some of the input parameters at two significant figures prior to the final calculation. This should be checked and corrected or the reason for the calculational discrepancy resolved.***

In Section 4.1.4, "3-D Direct External Exposure" the equation in the BPRG User Guide does not include the "Default Room Factors" See Figure 6 for Calculation without Default Room Factors per the BPRG Equation). The only way to get the on-line and the hand calculated values to agree is to put these in the spreadsheet calculation (Figure 5). The Default Room Factors only appear in the on-line version once a calculation has been attempted, and are shown on the bottom portion with the results. The top portion of the output form that identifies the input parameters for the calculation only states that for the Default Room Factor the "default" is chosen. The descriptions for these "default" factors on the input portion (e.g., 'room size') of the form do not exactly match the descriptions on the output portion of the form (e.g., Default Room Factor 'infinite volume', 'ground plane', or different distances are used).

Figure 5. Using Default Room Factors as per On-line Calculator

Resident 3-D Direct External-Exposure															
		Risk	ED_{res}	SOIL VOLUME	$IFD_{res-adj}$	F_{in}	F_{I}	Fam	Foffset	EFres	EDres	SAres-a	Default	3-D External	BPRG Calculator
		1.000E-06	2.600E+01	EX SF	3.200E+06	1.E+00	1.E+00	1.E+00	1.E+00	9.589E-01	2.600E+01	4.900E+01	Room Factor	Dust-Resident	3-D External pCi/g
Ag-110m	1.010E+00			1.310E-05									8.580E+00	9.371E-03	9.410E-03
Ba-140	1.980E+01			7.590E-07									2.140E+00	1.271E+01	1.270E+01
Pb-210	3.120E-02			1.480E-09									2.060E+00	1.921E+01	1.920E+01
Pu-239+D	2.870E-05			2.090E-10									1.330E-01	1.443E+03	1.450E+03

Figure 6. Using BPRG User Guide where Default Room Factors are not shown.

Resident 3-D Direct External-Exposure															Values
		Risk	ED_{res}	SOIL VOLUME	$IFD_{res-adj}$	F_{in}	F_{I}	Fam	Foffset	EFres	EDres	SAres-a	3-D External	BPRG Calculator	within 1 %
		1.000E-06	2.600E+01	EX SF	3.200E+06	1.E+00	1.E+00	1.E+00	1.E+00	9.589E-01	2.600E+01	4.900E+01	Dust-Resident	3-D External pCi/g	(Y/N)
Ag-110m	1.010E+00			1.310E-05									8.040E-02	9.410E-03	N
Ba-140	1.980E+01			7.590E-07									2.720E+01	1.270E+01	N
Pb-210	3.120E-02			1.480E-09									3.956E+01	1.920E+01	N
Pu-239+D	2.870E-05			2.090E-10									1.920E+02	1.450E+03	N

The BPRG User Guide needs to have the entire equation for this model inserted instead of the current version that does not include the "Default Room Factors".

The BPRG User Guide should also describe how the output format is configured as in the current format the user needs to go back and forth across columns to determine which defaults were used to get each activity concentration.

It would be much improved if the default factors were located so that the individual results from different default parameters were aligned with External Slope factors as shown in Figure 7. This would also allow the conversion to a pdf format to show all the results and parameters on a single file.

Figure 7. Suggested Improvement in Table Display for Calculated Output Values

Radionuclide (Decay constant, yr^{-1}		Soil Volume External Exposure Slope Factor (risk/yr per pCi/g)	External Exposure Slope Factor (Ground Plane) (risk/yr per pCi/cm^2)	Soil Volume External Exposure Slope Factor (1 cm) (risk/yr per pCi/g)	Soil Volume External Exposure Slope Factor (5 cm) (risk/yr per pCi/g)	Soil Volume External Exposure Slope Factor (15 cm) (risk/yr per pCi/g)
Ag-110m (1.01)		1.31E-05	2.45E-06	2.52E-06	7.17E-06	1.13E-05
	Default Room Factor (Infinite Volume), 8.58	**9.41E-03**				
	Default Room Factor (Ground Plane), 5.08		**8.48E-02**			
	Default Room Factor (1 cm), 14.5			**2.89E-2**		
	Default Room Factor (5 cm), 22.2				**6.64E-03**	
	Default Room Factor (15 cm), 17.3					**5.39E-03**

Section 4.2 value for IRD_{iw} in the BPRG User Guide and in the equation section of the on-line calculator is listed as 176.4 cm^2/d. However, on the results page in the input section for the on-line calculation it lists the value of the constant as 176 cm^2/day.

The calculations performed for the indoor worker dust ingestion case in section 4.2 used the value of 176.4. While one of the cases used was within a 1 % acceptable error, the other three were not as shown in the top part of Figure 8. If the value of 176 is used the results would be even further away from a 1 % agreement. ***The cause of this discrepancy needs to be investigated and the value used for the IRD_{iw} factor used consistently throughout the documentation.***

Figure 8. Comparison of the Calculations for the Indoor Worker

Hand calculation												Value from Calculatoı		Agree				
Worker Ingestion-dust										Ingestion		Ingestion		(Y/N)				
	λ	TR	Tiw	k	SFo	IRD	Fin	Fi	Efiw	Dust-worker		Dust-worker						
		1.E-06	26	0		176.4	1	1	250	pCi/cm2		pCi/cm2						
Ag-110m	1.01E+00				6.03E-12					3.95E+00		3.820E+00		N	1.034E+00			
Ba-140	1.98E+01				6.85E-12					6.82E+01		6.590E+01		N	1.034E+00			
Pb-210	3.12E-02				5.99E-10					2.21E-03		2.180E-03		N	1.014E+00			
Pu-239+D	2.87E-05				1.21E-10					7.50E-03		7.520E-03		y	9.972E-01			
Worker External-Exposure			Tiw						Efiw	Foffset	EDiw	Etw	External		Value from Calculator	Agree to within 1 %		
		1.E-06	25	0		176.4	1	1	0.684932	1	25	0.333333	Dust-worker			(Y/N)		
Ag-110m	1.01E+00				2.45E-06								1.806E+00		1.810E+00	y		1.002419
Ba-140	1.98E+01				1.63E-07								5.320E+02		5.310E+02	y		0.998028
Pb-210	3.12E-02				1.72E-09								1.467E+02		1.470E+02	y		1.002054
Pu-239+D	2.87E-05				2.06E-10								8.508E+02		8.530E+02	y		1.002597

The equations listed in the on-line format for the Indoor Worker Exposure to Settled Dust Equation (External) includes a constant ED_{iw} (25 years) which is not included in the equation in the BPRG User Guide Equation. ***The BPRG User Guide needs to be edited to include this parameter in the equation.***

The 3-D Indoor Worker Direct External Exposure calculations were performed as for previous equations with the results shown in Figure 9. All values calculated are approximately 4% different than from the on-line calculator. The half-life used for ^{99m}Tc is 6.15 hours. While this is its true half-life, it could not possibly be present unless its progenitor, ^{99}Mo, were present ($t_{1/2}$ =66 hours). ***The cause of this calculational discrepancy needs to be investigated and the half-life for ^{99}Mo should be used in place of that of ^{99m}Tc (this is a generic issue with the calculator and should be addressed for other short lived progeny such as the progeny of ^{106}Ru which is ^{106}Rh, half-life 29 seconds).***

Figure 9. Indoor Worker 3-D External Exposure

Resident 3-D Direct External-Exposure																	
		Risk	t_{iw}	SFext-sv	GSF_b	F_{in}	F_l	Fam	Foffset	F_{surf}	ETiw	EFiw	EDiw	Default Rm Factor	3-D External	BPRG Calculator	
	λ, y^{-1}	1.00E-06	2.60E+01		1	1	1	1	1	1	3.33E-01	6.85E-01	2.50E+01	Inf volume	Exposure IW	3-D External pCi/g	Agree (Y/N)
Ir-192	3.43			3.39E-06										6.06	7.61E-01	0.732	N
Ru-106+D	0.677			9.71E-07										0.943	3.37E+00	3.24	N
Sb-125	2.51E-01			1.83E-06										4.16	1.50E-01	0.144	N
Tc-99m	1.01E+03			3.95E-07										1.56	7.47E+03	7.17E+03	N

The term for the 'Default Room Factor' also does not appear in the equations in the BPRG User Guide or in the equations section of the on-line calculator*.* The equation actually used by the on-line calculator does include this factor. ***Both the BPRG User Guide and the BPRG Equations presented on-line need to be corrected to include this parameter in the equations.***

An attempt was made to verify that the equations for the on-line calculator would also correctly calculate activity concentrations when other than default factors were used. The two radionuclides selected were ^{140}Ba and ^{109}Cd, and the "site specific" option was chosen. The parameters chosen are shown in Attachment 1. When the radio button on the page bottom "retrieve" is clicked, no calculation is performed regardless of which of the three equations for output is selected. ***The operation of the calculator for other than default values seems not to be working, this needs to be investigated.***

3 CONCLUSIONS

The on-line BPRG Calculator provides a rapid means for estimating the radionuclide activity concentrations for many different scenarios regarding potential exposure to residents or indoor workers. It also has the flexibility for inputting other than default parameters for certain equation variables. This provides a great deal of flexibility in the utility of the calculator.

However there are many areas where this tool and the BPRG User Guide can be improved so that a new user can put it to use rapidly and be confident that the output values are correct. The suggestions for improvement/editing are noted in bolded italics in the text above.

Attachment 1

Isotope	SF_s (risk/pCi)	SF_{sa} (risk/pCi)	SF_{ext-gp} (risk-yr/pCi-cm^2)	SF_i (risk/pCi)	$SF_{ext-sub}$ (risk-yr/pCi-m^3)	SF_{ext} (risk-yr/pCi-g)	$SF_{ext-1cm}$ (risk-yr/pCi-g)	$SF_{ext-5cm}$ (risk-yr/pCi-g)	$SF_{ext-15cm}$ (risk-yr/pCi-g)	K_d
Ba-140	4.03E-11	6.85E-12	1.63E-07	2.31E-11	7.40E-10	7.59E-07	1.63E-07	4.58E-07	6.94E-07	4.00E-01
Cd-109	1.07E-11	3.36E-12	1.14E-08	2.19E-11	1.84E-11	8.69E-09	4.05E-09	7.45E-09	8.69E-09	1.00E+0C

Dust

Resident
Exposure to Settled Dust on Surfaces

Combined Ingestion and Ground Plane External Exposure

Dust External Exposure

Dust Ingestion

Dust Total

26	ED_{res} (exposure duration - resident) yr	1	F_{in} (fraction time spent indoors) unitless
20	ED_{res-a} (exposure duration - resident adult) yr	1	$F_{OFF-SET}$ (off-set factor) unitless
6	ED_{res-c} (exposure duration - resident child) yr	3	FQ_a (frequency of hand to mouth - adult) event/hr
350	EF_{res} (exposure frequency - resident) day/yr	17	FQ_c (frequency of hand to mouth - child) event/hr
350	EF_{res-a} (exposure frequency - resident adult) day/yr	0.5	$FTSS_h$ (fraction transferred surface to skin - hard surface) unitless
350	EF_{res-c} (exposure frequency - resident child) day/yr	0.1	$FTSS_s$ (fraction transferred surface to skin - soft surface) unitless
24	ET_{res} (exposure time) hr/day	3200400	$IFD_{res-adj}$ (age-adjusted dust ingestion rate - resident) cm^2
6	$ET_{res-a,h}$ (exposure time - resident adult hard surface) hr/day	0.5	k (dissipation rate constant) yr^{-1}
6	$ET_{res-c,h}$ (exposure time - resident child hard surface) hr/day	49	SA_{res-a} (surface area of fingers - resident adult) cm^2

10	$ET_{res-a,s}$ (exposure time - resident adult soft surface) hr/day	16	SA_{res-c} (surface area of fingers - resident child) cm^2
10	$ET_{res-c,s}$ (exposure time - resident child soft surface) hr/day	0.5	SE (saliva extraction factor) unitless
.7	F_{AM} (area and material factor) unitless	26	t_{res} (time - resident) yr
.4	F_i (fraction of time spent in compartment) unitless	1.0E-6	TR (target cancer risk) unitless

			Tiw													
worker Exposure Ambient air with Half life						IRAiw		Etiw	Efiw	Foffset	EDiw	3-D Extern	SAres-a			
		0.000001	25	0		60	1	0.333	250	1	25	Dust-Resid	49			
Ag-110m	1.01				4.55E-11							4.44E+00		4.45	y	9.99E-01
Ba-140	19.8				2.31E-11							1.72E+02		172	y	9.98E-01
Pb-210	0.0312				1.59E-08							7.25E-04		7.26E-04	y	9.99E-01
Pu-239+D	2.87E-05				5.55E-08							1.44E-04		1.44E-04	y	1.00E+00

			Tiw												
worker Exposure submersion with Half life															
		0.000001	25				1	0.333	0.684932		25				
Ag-110m	1.01				1.20E-08							3.69E+02		369	y
Ba-140	19.8				7.40E-10							1.17E+05		117000	y
Pb-210	0.0312				3.93E-12							6.43E+04		64100	y
Pu-239+D	2.87E-05				3.22E-13							5.45E+05		544000	y

			Tiw												
worker Exposure submersion **without** Half life															
		0.000001	25			60	1	0.333	250		25				
Ag-110m	1.01				4.55E-11							1.76E-01		0.176	y
Ba-140	19.8				2.31E-11							3.47E-01		0.347	y
Pb-210	0.0312				1.59E-08							5.04E-04		5.04E-04	y
Pu-239+D	2.87E-05				5.55E-08							1.44E-04		1.44E-04	y

Hand calculation

Value from Calculator

Resident Ingestion-dust	λ	TR	Tres	k	Sfo	IFD	Fin	Fi	Ingestion Dust-Resident	Value from Calculator	Agree to within 1 % (Y/N)
		1.00E-06	26	0		3.20E+06	1	1	pCi/cm^2		
Am-241	1.60E-03				1.84E-10				1.73E-03	1.73E-03	y
Bi-214+D	1.83E+04				4.03E-13				3.69E+05	3.69E+05	y
Ce-134	8.00E+01				4.51E-11				1.44E+01	1.44E+01	y
Ce-144+D	8.88E-01				9.58E-11				7.53E-02	7.53E-02	y

Resident External-Exposure									Fam	Foffset	EFres	EDres	External Dust-Resident	Value from Calculator	Agree to within 1 % (Y/N)
		1.00E-06	26	0		3.20E+06	1	1	1	1	0.958904	2.60E+01			
Ag-110m	1.01E+00				2.45E-06								4.30E-01	4.31E-01	y
Ba-140	1.98E+01				1.63E-07								1.27E+02	1.27E+02	y
Pb-210	3.12E-02				1.72E-09								3.40E+01	3.41E+01	y
Pu-239+D	2.87E-05				2.06E-10								1.95E+02	1.95E+02	y

Resident 3-D Direct External-Exposure									Fam	Foffset	EFres	EDres	3-D External Dust-Resident	SAres-a		
		1.00E-06	26	0		3.20E+06	1	1	1	1	0.958904	2.60E+01		49		
Ag-110m	1.01E+00				1.31E-05								8.04E-02		9.41E-03	N
Ba-140	1.98E+01				7.59E-07								2.72E+01		1.27E+01	N
Pb-210	3.12E-02				1.48E-09								3.96E+01		1.92E+01	N
Pu-239+D	2.87E-05				2.09E-10								1.92E+02		1.45E+03	N

Resident 3-D Direct External-Exposure																Values
		Risk	ED_{res}	SOIL VOLUME	$IFD_{res-adj}$	F_{in}	F_{I}	Fam	Foffset	EFres	EDres	SAres-a	Default	3-D External	BPRG Calculator	within 1 %
		1.000E-06	2.600E+01	EX SF	3.200E+06	1.E+00	1.E+00	1.E+00	1.E+00	9.589E-01	2.600E+01	4.900E+01	Room Facto	Dust-Resident	3-D External pCi/g	(Y/N)
Ag-110m	1.010E+00			1.310E-05									8.580E+00	9.371E-03	9.410E-03	y
Ba-140	1.980E+01			7.590E-07									2.140E+00	1.271E+01	1.270E+01	y
Pb-210	3.120E-02			1.480E-09									2.060E+00	1.921E+01	1.920E+01	y
Pu-239+D	2.870E-05			2.090E-10									1.330E-01	1.443E+03	1.450E+03	y
Resident 3-D Direct External-Exposure 1 cm				SOIL VOLUME				Fam	Foffset	EFres	EDres	SAres-a	Default	3-D External		
		1.000E-06	2.600E+01	EX SF - 1 cm	3.200E+06	1.E+00	1.E+00	1.E+00	1.E+00	9.589E-01	2.600E+01	4.900E+01	Room Facto	Dust-Resident		
Ag-110m	1.010E+00			2.520E-06									1.450E+01	2.883E-02	2.890E-02	N
Ba-140	1.980E+01			1.630E-07									6.330E+00	2.001E+01	2.000E+01	N
Pb-210	3.120E-02			9.530E-10									8.550E+00	7.186E+00	7.190E+00	N
Pu-239+D	2.870E-05			6.880E-11									1.780E+00	3.276E+02	3.280E+02	N
Resident 3-D Direct Exte		risk		SOIL VOLUME				Fam	Foffset	EFres	EDres	SAres-a	Default	3-D External		
		1.000E-06	2.600E+01	EX SF - 5 cm	3.200E+06	1.E+00	1.E+00	1.E+00	1.E+00	9.589E-01	2.600E+01	4.900E+01	Room Facto	Dust-Resident		
Ag-110m	1.010E+00			7.170E-06									2.210E+01	6.647E-03	6.640E-03	N
Ba-140	1.980E+01			4.580E-07									7.420E+00	6.076E+00	6.090E+00	N
Pb-210	3.120E-02			1.470E-09									7.760E+00	5.133E+00	5.140E+00	N
Pu-239+D	2.870E-05			1.510E-10									5.390E+00	4.930E+01	4.930E+01	N
Resident 3-D Direct External-Exposure 15 cm				SOIL VOLUME				Fam	Foffset	EFres	EDres	SAres-a	Default	3-D External		
		1.000E-06	2.600E+01	EX SF - 15 cm	3.200E+06	1.E+00	1.E+00	1.E+00	1.E+00	9.589E-01	2.600E+01	4.900E+01	Room Facto	Dust-Resident		
Ag-110m	1.010E+00			1.130E-05									1.730E+01	5.388E-03	5.390E-03	N
Ba-140	1.980E+01			6.940E-07									2.420E+00	1.229E+01	1.230E+01	N
Pb-210	3.120E-02			1.480E-09									7.620E-01	5.192E+01	5.180E+01	N
Pu-239+D	2.870E-05			2.010E-10									1.670E-01	1.195E+03	1.200E+03	N

Calculated Value by Hand Verification

Resident exposure to ambient air with half life

	λ	TR	Tres	k	SFi	IFA	Fin	Fi	Ambient air Inhalation with decay	Inhalation w/o decay	BPRG Calculator Inhalation with decay	BPRG Calculator Inhalation w/o decay	Agree to within 1 % (Y/N)	
		1.00E-06	26	0		1.61E+05	1	1	pCi/m3					
Co-60	1.31E-01				1.01E-10				2.166E-01	6.150E-02	2.18E-01	6.17E-02	y	y
H-3	5.63E-02				8.47E-13				1.397E+01	7.333E+00	1.40E+01	7.33	y	y
Pu-238	7.90E-03				5.22E-08				1.316E-04	1.190E-04	1.32E-04	1.19E-04	y	y
Ra-226+D	4.33E-04				2.82E-08				2.215E-04	2.203E-04	2.21E-04	2.20E-04	y	y

	λ	TR	Tres	EF res	Sfsub	GSFa	Fin	Fi	EDres	submersion with decay	submersion w/o decay	BPRG Calculator submersion with decay	BPRG Calculator submersion w/o decay		
		1.000E-06	2.600E+01	9.589E-01		1.000E+00	1.000E+00	1.000E+00	2.600E+01	pCi/m3					
Co-60	1.310E-01				1.120E-08					1.262E+01	3.581E+00	12.6	3.57	y	y
H-3	5.630E-02				0.000E+00					---	---	---	---		
Pu-238	7.900E-03				2.560E-13					1.733E+05	1.567E+05	1.74E+05	1.57E+05	y	y
Ra-226+D	4.330E-04				7.740E-09					5.211E+00	5.182E+00	5.21	5.18	y	y

Hand calculation

Worker Ingestion-dust	λ	TR	Tiw	k	SFo	IRD	Fin	Fi	Efiw	Ingestion Dust-worker	Value from Calculator Ingestion Dust-worker pCi/cm2	Agree (Y/N)	
		1.E-06	26	0		176.4	1	1	250	pCi/cm2			
Ag-110m	1.01E+00				6.03E-12					3.95E+00	3.820E+00	N	1.034E+00
Ba-140	1.98E+01				6.85E-12					6.82E+01	6.590E+01	N	1.034E+00
Pb-210	3.12E-02				5.99E-10					2.21E-03	2.180E-03	N	1.014E+00
Pu-239+D	2.87E-05				1.21E-10					7.50E-03	7.520E-03	y	9.972E-01

Worker External-Exposure			Tiw						Efiw	Foffset	EDiw	Etw	External Dust-worker	Value from Calculator	Agree to within 1 % (Y/N)	
		1.E-06	25	0		176.4	1	1	0.684932	1	25	0.3333333				
Ag-110m	1.01E+00				2.45E-06								1.806E+00	1.810E+00	y	1.002419
Ba-140	1.98E+01				1.63E-07								5.320E+02	5.310E+02	y	0.998028
Pb-210	3.12E-02				1.72E-09								1.467E+02	1.470E+02	y	1.002054
Pu-239+D	2.87E-05				2.06E-10								8.508E+02	8.530E+02	y	1.002597

Resident 3-D Direct External-Exposure

	λ, y^{-1}	Risk	t_{iw}	SFext-sv	GSF_b	F_{in}	F_l	Fam	Foffset	F_{surf}	ETiw	EFiw	EDiw	Default Rm Factor Inf volume	3-D External Exposure IW	BPRG Calculator 3-D External pCi/g	Agree (Y/N)	
		1.00E-06	2.60E+01		1	1	1	1	1	1	3.33E-01	6.85E-01	2.50E+01					
Ir-192	3.43			3.39E-06										6.06	7.61E-01	0.732	N	0.962458
Ru-106+D	0.677			9.71E-07										0.943	3.37E+00	3.24	N	0.96201
Sb-125	2.51E-01			1.83E-06										4.16	1.50E-01	0.144	N	0.95739
Tc-99m	1.01E+03			3.95E-07										1.56	7.47E+03	7.17E+03	N	0.960311

CURRICULUM VITAE

Robert Litman
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352-633-8444

EDUCATION

1.Brooklyn College - B.S., Chemistry (1971)
2.City University of New York - PhD, Analytical Chemistry (1975)

PROFESSIONAL EXPERIENCE

2002 to now - Independent Consultant with
- Environmental Management Support
- Radiation Safety and Control Services
- ChemStaff
- Electric Power Research Institute
- Pacific Northwest National Laboratories
- US Nuclear Regulatory Commission (USNRC)

1998 to 2002 - Principal Chemist (Engineering), Seabrook Station
1996 to 1998 - Chemistry Manager, Seabrook Station
1985 to 1996 - Chemistry Supervisor, Seabrook Station
1981 to 1985 - Senior Chemistry Training Instructor, Seabrook Station
1975 to 1981 - Assistant Professor of Chemistry, University of Lowell
1971 to 1975 - Graduate Fellow 'A' City University of New York at Brooklyn College

additionally...

2006 to present- Senior Consultant ChemStaff, Inc. performing the following activities:

- Conducted PWR Primary Water Chemistry Training (5days) for several Nuclear Power Plants
- Conducted gamma spectrometry training (5 days) for several Nuclear Power Plants
- Wrote end of cycle reports for Braidwood and Byron (Exelon Plants)
- Performed radiochemistry laboratory assessments at six different facilities
- Reviewed the FSAR for the AREVA EPR Design plants in the US for US NRC

2002 to Present -

- Conducted Basic Radiochemistry training classes for the US EPA at the National Analytical and Radiation Laboratory (NAREL) in Montgomery, AL

- Developed and taught training modules for MARLAP Manual, EPA 402-B-04-001A-C, NUREG 1576 (2006-present)
- Peer Review Committee for NRC on NUREG-1861, “Peer Review of GSI-191 Chemical Effects Research Program”.
- Provided a review for the NRC of “Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191, WCAP-16530-NP”
- Co-authored Revision 2 to Regulatory Guide 4.15 for USNRC
- Developed “Evaluation Guidance for the Review of GSI-191 Plant-Specific Chemical Effect Evaluations (Sept 2007)” for USNRC (ADAMS Accession Number ML080380214)
- Co-Authored “Radiological Laboratory Sample Analysis Guide for Incidents of National Significance – Radionuclides in Air” (EPA-R-402-09-007) for US EPA (2009)
- Co-Authored, “Radiological Laboratory Sample Screening Analysis Guide for Incidents of National Significance”, (EPA-R-402-09-008) for US EPA (2008)
- Co-authored “Radiological Laboratory Sample Analysis Guide for Incidents of National Significance-Radionuclides in Water (EPA –R-402-07-007)” for USEPA (2008)
- Authored Chapters 12-14 of MARLAP and Co-Authored Chapter 15. EPA 402-B-04-001A-C, NUREG 1576 (2006)

1997 to 2005 Participated in the following EPRI committees for PWR:

a. Primary Water Chemistry Guidelines Committee (authored Appendix G on Reactor Coolant Radionuclides) EPRI 1002884
b. Secondary Water Chemistry Guidelines Committee (Revised Chapter 7, “Data: Collection, Evaluation ad Management”) EPRI 1008224
c. Materials Reliability Program Committee (Sampling and Analysis Guidance for Deposits Found on Reactor Pressure Vessels at Various Locations (September 2003)
d. Primary to Secondary Leak Rate Guidelines Committee EPRI TR-104788-R2 (developed section on action levels)
e. Closed Cooling Water Chemistry Guideline, EPRI 1007280, Revision 1 (wrote Chapter 7 Technical Basis of Monitoring Parameters).

1997 Peer Evaluator at Diablo Canyon Nuclear Power Plant for Institute of Nuclear Power Operations (INPO)

1996 to 2007 1. Contract Lecturer and Radiochemistry Consultant for RSCS as a Senior Chemist

2. Independent Contractor working on the Multi-Agency Radiochemistry Analytical Protocols Manual (MARLAP) for the EPA.

1994 - Appointed as a Peer Evaluator for Seabrook Station Training programs by INPO.

1992 to 1996 - 1. Contract Lecturer for Technical Management Services, Inc. Teaching "Practical Radiochemistry"

2. Independent Contractor for USEPA NAREL Montgomery, AL. Reviewed technical procedures for accuracy and modified them for technical enhancements. Performed independent review of laboratory techniques.

1992 - Received Excellence award from Seabrook Nuclear Power Station for maintaining and improving chemistry programs.

1986 to 2002- Participated in the Seabrook Station Emergency Response Organization in the following capacities:

- Chemistry Coordinator
- Emergency Offsite Facilities (EOF) Coordinator
- Emergency Drill controller
- Emergency Response Drill Scenario Development
- Emergency Response Training Instructor

PROFESSIONAL AFFILIATIONS

1. American Chemical Society (since 1971)
2. ASTM Committee D19.04 Radiochemistry Methods in Water (since 1996)
3. Standard Methods Special Committee on Development of ^{90}Sr Analysis in Water (Since 2004)

AWARDS

2002	Technology Transfer Award presented by EPRI for leadership in development of the PWR Primary Water Chemistry Guidelines
2012	Founders Award, Radiobioassay and Radiochemical Measurements Conference
2013	Standards Development Award, ASTM Committee D19 on Water

PROFESSIONAL REFERENCES

1. Radiation Safety and Control Services (RSCS), 91 Portsmouth Avenue, Stratham, NH 03885. Contact: Jay Tarzia.
2. Environmental Management Support (EMS), 8601 Georgia Avenue, Suite D, Silver Spring, MD 20910. Contact; Jay Bassin
3. Electric Power Research Institute, 3412 Hillview Avenue, Palo Alto, CA 94303. Contact: Keith Fruzetti
4. Altran Corporation, 451 D Street, Boston MA. Contact: William McBrine.
5. ChemStaff, 3180 Theodore Street, Joliet, IL 60435 Contact: Joe Bates 800.741.5211
6. John Griggs, PhD. Radiochemistry Laboratory Manager, USEPA National Analytical and Radiation Laboratory (NAREL), Montgomery Alabama.

CURRENT CONTRACTUAL ACTIVITIES

- Training on MARLAP Manual Part I, The Directed Planning Process
- Development of Laboratory Guides for Emergency Sample Analysis Support (See www.epa.gov/narel/ “incident Response Guides” for a list of co-authored guides)
- Support to US NRC on PWR Containment Sump Screen Blockage Following a Large Break LOCA (US NRC GSI-191)
- Training at Contract Laboratories and Power Plants for Radiological Instrumental Analysis

AREAS OF TECHNICAL EXPERTISE WHILE AT SEABROOK STATION

I was Seabrook Station's Principal Chemist during my last five years at the plant. My job responsibilities included corrosion control methods, analysis of corrosion mechanisms, environmental innovations for biocide effectiveness, long term trending of plant chemistry performance parameters, monitoring of trends in plant radiochemical parameters, and radiological effluent surveillance oversight.

During my tenure at Seabrook the chemistry programs received the highest ratings from both the Nuclear Regulatory Commission (NRC) and the Institute of Nuclear Power Operations (INPO). We also received the highest ratings from the NHDES for our NPDES program compliance. Part of the technical responsibility that I was responsible for was the NPDES Permit Renewal Process, evaluation of non-routine discharges and program implementation for new biocides and anti-scalants.

One of the programs I initiated at Seabrook was component inspection. This program helped to assess corrosion mechanisms, biological fouling, and effectiveness of general corrosion control. The inspections provided a chronology so that from one maintenance period to the next an accurate assessment cold be made of the components health. The plant engineering group relies on these inspections to help maintain system efficiencies.

Another important program was the integration of the station's primary to secondary leak response. I worked with computer engineering, operations, Instrument and Control, and chemistry personnel to provide control room operators with a continuous monitor, which provide a gallon per day read out, as well as a rate of change display. I also provided the training on the new system to these groups.

I participated in the site Environmental Review Board (ERB) and was a team member for the successful ISO 14001 Certification Program in 2001.
I served as the Chairperson of the Laboratory Quality Control and Audit Committee (LQCAC), which each year evaluates the laboratory that the station uses for 10CFR50/61 and Bioassay programs. This committee was comprised of laboratory clients interested in ensuring that the technical programs met regulatory requirements.

I represented Seabrook Station on five technical EPRI committees and have made significant contributions in those areas since 1998:

1. Primary Water Chemistry Guidelines
2. Secondary Water Chemistry Guidelines
3. Primary to Secondary Leak Guidelines
4. Stator Coolant System Guidelines
5. Robust Fuels Working Group 1.

AREAS OF EXPERTISE

While at the University of Lowell and at Seabrook Station my major focus was gamma ray spectroscopy and radiochemical separations as analytical tools. I have extensive experience in preparing Radiological Effluent Technical Specification Reports (Regulatory Guide 1.21), as well as revising sampling and analytical procedures to be used for radiochemical analyses.

I have been an auditor for several nuclear power plant chemistry programs and contract laboratory programs for their radiochemical processes and procedures over the past 15 years. In that time, I have aided in the development and improvement of these procedures.

I developed a 40-hour instructional course in radiochemistry that has been presented 23 times in the past fifteen years. Attendees at these courses included personnel from state and government as well as contract radiochemistry laboratories and nuclear power facilities. This has helped me to maintain a current status of the radiochemical practices in use, and where the radiochemistry community needs to progress in this area.

Since 2002, I have developed four new training classes: Pressurized Water Reactor Primary Chemistry, Quality Assurance/Quality Control Programs at Nuclear Power Plants, Practical Gamma Ray Spectrometry. Each course has been given several times.

I have been participating in the ASTM D19.04 committee on Radiochemistry since 1997, and in the Standard Methods Committee for development of a modified radiochemical strontium procedure since 2004.

RECREATIONAL INTERESTS

1. USSF Soccer Referee, Grade 8 (1999 NH State Referee of the Year)
2. Florida State High School Soccer Official
3. NFHS Softball Umpire
4. FL State High School Softball Umpire

Conflict of Interest Certification

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

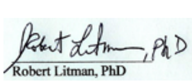
A conflict of interest or lack of impartiality exists when the proposed reviewer personally (or the reviewer's immediate family), or his or her employer, has financial interests that may be affected by the results of verification study; or may provide an verification study may be impaired due to other 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 document 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? X 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? X No ☐ Yes
- Have you had any previous involvement with the review document(s) under consideration? X No ☐ Yes
- Have you served on previous advisory panels, committees, or subcommittees that have addressed the topic under consideration? X No ☐ Yes
- Have you made any public statements (written or oral) on the issue? X 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? X 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? X 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.



____________________________ 12/22/2015 ______ ☐ Check here if any explanation is attached

Signature Date

Robert Litman, PhD

Printed Name

Sub-Contractor to Environmental Management Support, Inc

Affiliation/Organization