Verification Study of the "Dose Compliance Concentrations for Radionuclides in Buildings" Electronic Calculator

External Verification Study Record
March 17, 2016 – May 31, 2016

CONTENTS:

Verification Study Charge for:

U.S. Environmental Protection Agency (EPA), "Dose Compliance Concentrations for Radionuclides in Buildings" (BDCC) electronic calculator.

Background:

EMS, under contract EP-W-13-016 with EPA's Office of Superfund Remediation and Technology Innovation, has been requested to obtain an external, independent verification study of the online BDCC electronic calculator.

The purpose of this recommended BDCC 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 BDCC electronic calculator presents standardized exposure parameters and equations that should generally be used for calculating radionuclide Dose Compliance Concentrations for both 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 BDCC 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 (Abraham Parker, abraham.parker@emsus.com) on or before May 31, 2016. Please submit your comments in Microsoft Word and reference each comment to a specific step in the calculator and equation (https://epa-bdcc.ornl.gov/bdcc_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 BDCC calculator is available at https://epa-bdcc.ornl.gov/, and the User's Guide is available at https://epa-bdcc.ornl.gov/bdcc_users_guide.html. To summarize,

Step 1 Select an exposure scenario. The BDCC calculator has nine exposure scenarios each for:

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 Select BDCC 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 4 Select either "yes" or "no" for a dose output
Step 5 Choose to have your results in either picocuries, which are the units usually used in the United States, or in becquerels which most of the rest of the world uses.
Step 6 Select which ICRP Publication rule to follow. Users of this calculator tool should choose the dose conversion factors (DCFs) (International Commission on Radiological Protection (ICRP) 30, 60 or 107) required by the ARAR. If DCFs are not specified within the regulation (for example, the Code of Federal Regulations for a federal standard that is being complied with as an ARAR), then users should generally choose ICRP 107 DCFs. This recommendation is consistent with the guidance contained in "Use of IRIS Values in Superfund Risk Assessment" (OSWER 9285.7-16) for EPA to evaluate dose based upon its best scientific judgment.
Step 7 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 https://epa-bdcc.ornl.gov/bdcc_equations.html.
There are approximately 28 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 BDCC electronic calculator
Date: May 28, 2016

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), "Dose Compliance Concentrations for Radionuclides in Buildings" (BDCC) electronic calculator and the User's Guide.

Purpose of the Verification Study:

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.

Summary of the Verification Study:

I conducted the verification study for the BDCC electronic calculator during May 4 to May 25, 2016, which included the following steps:

1. Creating an independent calculator: I programmed the equations listed in the BDCC User's Guide using the Microsoft Excel for Mac, Version 14.1.4, as an independent calculator.

2. Using both my independent calculator and the BDCC electronic calculator, I computed the BDCCs for each exposure scenario (resident and indoor worker) and each media (settled dust, ambient air, and 3-D direct 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 BDCC User's Guide, my independent calculator, and the BDCC electronic calculator.

3. Again using both calculators, I computed the BDCCs for each exposure scenario, each media, and each ICRP rule 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 BDCC 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.

4. Finally, I examined the dose calculations and the conversions for pCi – Bq and mass basis BDCCs in the BDCC electronic calculator, for each exposure scenario, each media, and each ICRP rule.

Results of the Verification Study:

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

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

2. The numerical conversion between the pCi and Bq in the BDCC electronic calculator is incorrect. (Comment Item 1 below)

3. The DCF values were retrieved incorrectly from the reference document, ORNL 2014c (*Calculation of Slope Factors and Dose Coefficients and appendix*, *Center for Radiation Protection Knowledge*. *September 2014*). The DCF values in the BDCC electronic calculator seem to be directly taken from ORNL 2014c without taking into account the difference in the DCF units between the BDCC calculator and ORNL 2014c. Unit conversions should be conducted. (Comment Item 2 below)

4. The BDCC unit conversion to a mass basis in the BDCC electronic calculator is done incorrectly and not consistent with the equations listed in Item 11 of the "BDCC Frequently Asked Questions (FAQ)". (Comment Item 3 below)

5. The dose calculation in the BDCC electronic calculator by selecting "Yes" on the "Select Dose Output" is done correctly. However, there are a few glitches. (Comment Item 4 below)

6. There are a few other glitches in the BDCC electronic calculator. (Comment Item 5 – 12 below)

The table below summarizes my specific comments regarding the findings Item 2, 3, 4, 5, and 6:

	Location	Comments
1	BDCC electronic calculator, pCi – Bq conversion; This comment is true for all exposure scenario, media, BDCC Type, isotopes, and ICRP rules.	I found that the BDCC output values when "Select Units" = "pCi" on the input page is selected are always equal to the BDCC output values when "Select Units" = "Bq" on the input page is selected. This occurs no matter which exposure scenario, media, BDCC Type, isotope, or ICRP rule is selected. This does not make sense because 1 Bq = 27 pCi; therefore, there should be a conversion factor of 27 between the output BDCCs using different units, assuming the same input dose limit (DL). For example, on the input page, select "Select Scenario" = "Resident", "Select Media" = "Dust", "Select BDCC Type" = "Defaults", "Select Dose Output" = "No", "Select Units" = "pCi", "Select ICRP rule" = "107 – Center for Radiation Protection Knowledge", "Select Individual Isotopes" = "Am-241", then click "Retrieve". The output ingestion BDCC (pCi/cm^2) is 9.24E-03. Using a direct unit conversion of 1 Bq = 27 pCi, this means that the BDCC = 9.24E-03 pCi/cm^2 = 3.42 E-04 Bq/cm^2. However, if we go back to the input page, change "Select Units" to

		"Bq" and click "Retrieve" again. The output ingestion BDCC (Bq/cm^2) = 9.24E-03. I don't think this is correct; the output BDCC (Bq/cm^2) should be 3.42E-04 instead of 9.24E-03, to be consistent with the results obtained by selecting "pCi" unit with the same inputs. In order to verify the pCi – Bq conversion, I used my independent calculator and inputted DL = 1 mrem/yr or 1E-5 Sv/yr and ingestion DCF = 8.81E-4 mrem/pCi or 2.38E-7 Sv/Bq, I obtained ingestion BDCC = 9.24E-03 pCi/cm^2 or 3.42 E-04 Bq/cm^2. This verified that the BDCC result using Bq unit should be 1/27 times of the BDCC result using pCi unit. There is another evidence indicating that the BDCC (Bq basis) should not be equal to the BDCC (pCi basis). Using the BDCC electronic calculator, the BDCC outputs (e.g., mg/kg; Bq unit selected) are always 27 times of the BDCC outputs (e.g., mg/kg; pCi unit selected). This does not make sense either because with the same DL, the BDCC values (e.g., mg/kg) should be the same no matter whether pCi or Bq is selected, assuming the same inputs. **My suggestions:** (1) The numerical calculations when Bq unit is selected should be checked to see how BDCC (Bq basis) outputs are obtained. It seems to me that in the BDCC electronic calculator, the BDCC outputs (Bq basis) are simply programmed to be equal to the BDCC outputs (pCi basis) for all exposure scenarios, media, isotopes, and ICRP rules. As I explained above, if this is the case, the program should be changed to have BDCC outputs (Bq basis) = 1/27 of the BDCC outputs (pCi basis). (2) An alternate way to calculate the BDCC outputs (Bq basis) is to calculate the BDCCs using the BDCC equations by converting the DL and DCF to Sv and Bq basis. However, this will be a more complicated route as the conversion for DL and DCF need to be accurate too. In fact, the current BDCC electronic calculator has an error on DCF (both pCi and Bq basis) (see Item 2 below). Therefore, I would suggest using the method described in Item (1) above. (3) When selecting "Select Units" = "Bq", the DL in the user-provided input page and the output page should be listed as DL (dose limit) Sv/yr, instead of mrem/yr, to be consistent with all other SI units. And the default value of the DL in SI unit should be 1E-5 Sv/yr. Notes – I hope that I have explained this pCi-Bq conversion issue clearly. However, if not, please feel free to contact me so we can discuss this in more details.
2	BDCC electronic calculator, DCF values;	The reference document, ORNL 2014c (*Calculation of Slope Factors and Dose Coefficients and appendix, Center for Radiation Protection Knowledge*. *September 2014*) provides the DCF values in the BDCC electronic calculator. However, the DCF units used in the BDCC

This comment is true for all exposure scenario, media, BDCC Type, isotopes, and ICRP rules.

electronic calculator and the ORNL 2014c are different and this difference was not taken into account.

As an example, Table 2.1 and 2.2 below list the DCF values and units for Co-60 from these two sources (the values in red indicate wrong values that need to be corrected):

Table 2.1: Co-60 DCF comparison for pCi basis unit

Pathway	DCF in BDCC Calculator		DCF in ORNL 2014c	
	Values	Units	Values	Units
Ingestion	2.03E-5	mrem/pCi	2.03E-5	mrem/pCi
Inhalation	1.22E-4	mrem/pCi	1.22E-4	mrem/pCi
Air Submersion	2.22E4	mrem-m^3/pCi-yr	2.22E4	mrem-cm^3/pCi-yr
External – gp	2.69	mrem-cm^2/pCi-yr	2.69	mrem-cm^2/pCi-yr
External – 1cm	2.75	mrem-g/pCi-yr	2.75	mrem-g/pCi-yr
External – 5cm	7.98	mrem-g/pCi-yr	7.98	mrem-g/pCi-yr
External – 15cm	12.9	mrem-g/pCi-yr	12.9	mrem-g/pCi-yr
External - infinite	15.4	mrem-g/pCi-yr	15.4	mrem-g/pCi-yr

Table 2.1 shows that for air submersion, the units between the two sources are different; therefore, the DCF (mrem-m^3/pCi-yr) in the BDCC calculator should be = 2.22E4 mrem-cm^3/pCi-yr * (1 m/100 cm)^3 = 2.22E-2 mrem-m^3/pCi-yr, instead of 2.22E4 as listed in the table above and in the BDCC electronic calculator.

Table 2.2: Co-60 DCF comparison for Bq basis unit

Pathway	DCF in BDCC Calculator		DCF in ORNL 2014c	
	Values	Units	Values	Units
Ingestion	5.49E-9	Sv/Bq	5.49E-9	Sv/Bq
Inhalation	3.3E-8	Sv/Bq	3.3E-8	Sv/Bq
Air Submersion	1.19E-13	Sv-m^3/Bq-s	1.19E-13	Sv-m^3/Bq-s
External - gp	2.3E-15	Sv-cm^2/Bq-s	2.3E-15	Sv-m^2/Bq-s
External – 1cm	1.47E-17	Sv-g/Bq-s	1.47E-17	Sv-m^3/Bq-s
External – 5cm	4.27E-17	Sv-g/Bq-s	4.27E-17	Sv-m^3/Bq-s
External – 15cm	6.91E-17	Sv-g/Bq-s	6.91E-17	Sv-m^3/Bq-s
External - infinite	8.24E-17	Sv-g/Bq-s	8.24E-17	Sv-m^3/Bq-s

Table 2.2 shows that the DCF for external-gp, 1cm, 5cm, 15cm, and infinite in BDCC calculator should not be simply equal to the ones in ORNL 2014c because they have different units. For 3D External-gp (same as the external exposure for dust) case, the BDCC (Sv-cm^2/Bq-s) in the BDCC calculator should be = 2.3E-15 Sv-m^2/Bq-s * (100 cm/1 m)^2 = 2.3E-11 Sv-cm^2/Bq-s. As for 3D External-1cm, 5cm, 15cm, and infinite cases, the conversions are not as simple between Sv-g/Bq-s and Sv-m^3/Bq-s. However, one can simply convert the DCF (mrem-g/pCi-yr) to DCF (Sv-g/pCi-s) using the DCF values given in Table 2.1: 1 mrem-g/pCi-yr = 8.56E-12 Sv-g/pCi-s because 1 mrem = 1E-5 Sv and 1 year = 3.15E7 seconds. Therefore, the DCF for external-1cm, 5cm, 15cm, and infinite in the BDCC calculator should be corrected to 2.35E-11, 6.83E-11, 1.1E-10, and 1.32E-10 Sv-g/pCi-s

In conclusion, the DCF units in the BDCC electronic calculator and the ORNL 2014c are different; therefore, proper unit conversion

<table>
<tr><td></td><td></td><td>should be conducted before using the DCF values provided in the ORNL 2014c. In particular, as shown above in Table 2.1 and 2.2, the following DCF values for all exposure scenario, all isotopes, and all ICRP rules should be corrected: DCF of air submersion for pCi basis, DCF of dust external exposure for Bq basis, and all 3D DCF values for Bq basis.</td></tr>
<tr><td>3</td><td>BDCC electronic calculator, BDCC mass basis (e.g., mg/kg) conversion;

This comment is true for all exposure scenario, BDCC Type, isotopes, and ICRP rules.</td><td>Item 11 of the “BDCC Frequently Asked Questions (FAQ)” document provides the equations and conversion factors to convert BDCC in pCi/g, pCi/cm^2, and pCi/m^3 to mg/kg, mg/cm^2, or mg/m^3, respectively:

BDCC (mg/kg) = 2.8E-12 * A_w * $T_{1/2}$ * BDCC (pCi/g)
BDCC (mg/cm^2) = 2.8E-15 * A_w * $T_{1/2}$ * BDCC (pCi/cm^2)
BDCC (mg/m^3) = 2.8E-15 * A_w * $T_{1/2}$ * BDCC (pCi/m^3)

The above equations indicate that there are two conversion constants (2.8E-12 or 2.8E-15) depending on the units of the BDCCs. However, in the BDCC electronic calculator, no matter which BDCC units are used (i.e., pCi/g, pCi/cm^2, or pCi/m^3), they are all converted to the mass basis BDCCs using the conversion constant of 2.8E-12. This is not correct and not consistent with the above equations as provided in Item 11 of the FAQ document.

The table below lists the specific corrections needed for each media:
<table>
<tr><th>Exposure</th><th>Media</th><th>Corrections</th></tr>
<tr><td>Resident and Indoor worker</td><td>Dust</td><td>(1) The mass basis unit of the “Settled Dust BDCC” on the output page is listed as mg/kg. It should be corrected to mg/cm^2.
(2) The conversion constant programmed in the BDCC electronic calculator is 2.8E-12. It should be corrected to 2.8E-15.</td></tr>
<tr><td>Resident and Indoor worker</td><td>Air</td><td>On the output page, there is no mass basis BDCC output. Mass basis BDCCs for “Total BDCC” and “Total BDCC (no decay)” should be calculated and added to the output page. The proper equation to use is: BDCC (mg/m^3) = 2.8E-15 * A_w * $T_{1/2}$ * BDCC (pCi/m^3).</td></tr>
<tr><td>Resident and Indoor worker</td><td>3D</td><td>On the output page, the conversion constant programmed to compute the “3-D External BDCC (ground plane) (mg/cm^2)” is 2.8E-12. It should be 2.8E-15 instead.</td></tr>
</table>
The above corrections are needed no matter which option in the “BDCC Type”, “Select Dose Output”, “Select Units”, “Select ICRP rule”, and “Select Individual Isotopes” is selected.</td></tr>
<tr><td>4</td><td>BDCC electronic calculator, dose calculation;

This comment is true for all isotopes and ICRP rules</td><td>The numerical calculation for the dose output is done correctly when selecting “Yes” on the “Select Dose Output” from the input page. However, there are some glitches in the BDCC electronic calculator:

(1) For both resident and indoor worker scenario and for all isotopes and all ICRP rules, after selecting “Select Media” = “Dust”, “Select Dose Output” = “Yes”, and “Select Units” = “pCi” on the input page</td></tr>
</table>

		and clicking on “Retrieve”, there will be an area where user can input “Media Concentrations” for Dust. The unit is listed as “Dust (pCi/)”. It should be corrected to “Dust (pCi/cm^2)”. (2) For both resident and indoor worker scenario and for all isotopes and all ICRP rules, after selecting “Select Media” = “Air”, “Select Dose Output” = “Yes”, and “Select Units” = “pCi” on the input page and proceeding to the output page, there are no units listed for all dose outputs such as “Inhalation Dose”, “Total Dose” etc.. I would suggest adding the unit of “mrem” for each dose output. (3) Same comment as the Item (2) above but for “Select Media” = “3D”. In addition, there is no dose output at all for “Soil Volume Dose” even when an input concentration value is provided by the user. The above comments are also true for “Select Units” = “Bq” case.
5	BDCC electronic calculator, isotopes; This comment is true for all exposure scenario, media, units, and ICRP rules	There are a few glitches in the BDCC electronic calculator when the following isotopes are selected: C-11, C-14, Hg-193, Hg-193m, Hg-194, Hg-195, Hg-195m, Hg-197, Hg-197m, Hg-199m, Hg-203, I-120, I-120m, I-121, I-123, I-124, I-125, I-126, I-128, I-129, I-130, I-131, I-132, I-132m, I-133, I-134, I-135, Ni-56, Ni-57, Ni-59, Ni-63, Ni-65, Ni-66, Ru-103, Ru-105, Ru-106, Ru-106+D, Ru-94, Ru-97, S-35, S-38, Te-116, Te-121, Te-121m, Te-123, Te-123m, Te-125m, Te-127, Te-127m, Te-129, Te-129m, Te-131, Te-131m, Te-132, Te-133, Te-133m, Te-134. (1) There are no BDCC outputs if any of the above isotopes is selected and “Select BDCC Type” = “Defaults”. This is true for all exposure scenarios, media, units, and ICRP rules. (2) There are no BDCC outputs if any of the above isotopes is selected and “Select BDCC Type” = “Site-Specific” with “Select Isotope Info Type” = “Database defaults”. This is true for all exposure scenarios, media, units, and ICRP rules. (3) Unlike the previous two cases, there are BDCC outputs if any of the above isotopes is selected and “Select BDCC Type” = “Site-Specific” with “Select Isotope Info Type” = “User-provided”. However, after these selections and clicking on “Retrieve”, on the next page where users can provide their own DCF inputs, there are always two rows of DCF for the same isotope – one row with DCF values and one blank row. This is true for all exposure scenarios, media, units, and ICRP rules. If simply leave the blank row as it is and then click on “Retrieve”, the BDCC outputs look normal when “Select Media” = “Dust” or “3D” was selected on the input page, but there will be no BDCC outputs if “Select Media” = “Air” was selected on the input page. The above glitches indicate that there is something wrong in the program when any of the above isotopes is selected.
6	BDCC electronic	On the page where users can provide their own values for each

calculator, input parameters, t_{res}, t_{iw}, ED_{res}, ED_{iw}, when "Select BDCC Type" = "Site-specific"

This comment is true for all units, isotopes, and ICRP rules

parameter in the equation, there are a few glitches regarding t_{res}, t_{iw}, ED_{res}, ED_{iw}:

Exposure	Media	Comments
Resident	Dust and Air	t_{res} is not changeable and is not changed with any other parameters. Maybe it can be unlocked as a changeable parameter.
Indoor Worker	Dust	The BDCC equation does not have ED_{iw}; however, the output page (no matter which BDCC Type option is selected) still lists ED_{iw}. Maybe it can be removed. t_{iw} is not changeable and is not changed with any other parameters. Maybe it can be unlocked as a changeable parameter.
Indoor Worker	Air	ED_{iw} is listed as one of the inputs; maybe it can be removed, as the BDCC equation does not have ED_{iw}. t_{iw} is not changeable but is changed with ED_{iw}. However, if ED_{iw} is inputted as 0.0001 or less, then t_{iw} is always equal to 0 and there is no BDCC (decay) output. I would suggest removing ED_{iw} and simply unlock t_{iw} as a changeable parameter.
Resident	3D	The BDCC equation does not have ED_{res}; however, the output page (when "BDCC Type" = "Defaults") still lists ED_{res}. Maybe it can be removed. t_{res} is not changeable and is not changed with any other parameters. Maybe it can be unlocked as a changeable parameter.
Indoor Worker	3D	The BDCC equation does not have ED_{iw}; however, the output page (no matter which BDCC Type option is selected) still lists ED_{iw}. Maybe it can be removed. ED_{iw} is listed as one of the inputs; maybe it can be removed, as the BDCC equation does not have ED_{iw}. t_{iw} is not changeable but is changed with ED_{iw}. However, if ED_{iw} is inputted as 0.0001 or less, then t_{iw} is always equal to 0 and there are no BDCC outputs. I would suggest removing ED_{iw} and simply unlock t_{iw} as a changeable parameter.

7	BDCC electronic calculator, the page when users can input their own parameters, after selecting "Select BDCC Type" = "Site-specific") and "Select Media" = "Dust"	(1) The "Notes" right below the input parameters, Item 1 says "DCFs = ingestion dose conversion factor (mrem/pCi)". It should be DCF_0 instead of DCFs to be consistent with the symbol used in anywhere else in the electronic calculator and the User's Guide. (2) If "Select Isotope Info Type" = "User-provided" is further selected on the input page, then on the page where users can provide inputs of DCF: $DCF_{x\text{-}gp}$ should be changed to $DCF_{ext\text{-}gp}$ to be consistent with the symbol used in anywhere else in the electronic calculator and the User's Guide. The above two comments are true for both Resident and Indoor Worker exposure scenarios.
8	BDCC electronic calculator, the page when users can input their own DCF values, after selecting "Select BDCC Type" = "Site-specific") with "Select Isotope Info Type" = "User-provided" and "Select Media" = "Air"	$DCF_{x\text{-}sub}$ should be changed to DCF_{sub} to be consistent with the symbol used in anywhere else in the electronic calculator and the User's Guide. The above comment is true for both Resident and Indoor Worker exposure scenarios.
9	BDCC electronic calculator, the page when users can input their own DCF values, after selecting "Select BDCC Type" = "Site-specific") with "Select Isotope Info Type" = "User-provided" and "Select Media" = "3D"	$DCF_{x\text{-}sv1}$, $DCF_{x\text{-}sv5}$, $DCF_{x\text{-}sv15}$, and DCF_x should be changed to $DCF_{ext\text{-}1cm}$, $DCF_{ext\text{-}5cm}$, $DCF_{ext\text{-}15cm}$, and $DCF_{ext\text{-}sv}$ to be consistent with the symbols used in anywhere else in the electronic calculator and the User's Guide. The above comment is true for both Resident and Indoor Worker exposure scenarios.
10	BDCC electronic calculator, "Select Media" = "3D", BDCC output page	The output page lists "room factors" along with the BDCCs. However, they are called "Surface Factors" in the User's Guide. Maybe one of them can be changed to match the other to be consistent.
11	BDCC User's Guide webpage	The online User's Guide after clicking "Open All Sections" is different than the "PDF of User's Guide". The "PDF of User's Guide" appears to be an older version of the User's Guide and contains many errors such as discrepancies in equation symbols. I am not listing all these errors here since it can be simply replaced with the newer version (the one when "Open All Sections" is selected).
12	BDCC User's Guide	The inhalation equation of $BDCC_{res\_air\_decay\_inh}$ contains "$IFA_{res\text{-}adj}$".

	(the online version when “Open All Sections” is selected). Section 4.1.2	However, the equation right below the $BDCC_{res\_air\_decay\_inh}$ equation uses the symbol, $IFA_{r\text{-}adj}$”. It should be corrected to $IFA_{res\text{-}adj}$.

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

Peer Reviewer Conflict of Interest Certification

Peer Review: U.S. Environmental Protection Agency (EPA), "Dose Compliance Concentrations for Radionuclides in Buildings" (BDCC) electronic calculator

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

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- Do you know of any reason that you might be unable to provide impartial advice on the matter under consideration in this peer review, 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
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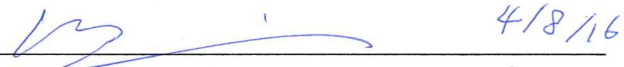
4/8/16

Signature Date

☐ Check here if any explanation is attached

Shiya Wang
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Colorado Department of Public Health and Environment
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Radiochemistry Laboratory Basics

Verification of Calculations in EPA's "Dose Compliance Concentrations for Radionuclides in Buildings (BDCC)" Electronic Calculator

Robert Litman, PhD
Environmental Management Support, Inc.

May 2016

1 CONTENTS

2 EXECUTIVE SUMMARY

Several different radionuclide combinations were used in verifying the calculations performed by the 30 plus equations in the Dose Compliance Concentrations for Radionuclides in Buildings (BDCC) Calculator. The equations from the BDCC 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 BDCC 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 calculations as it was evident that slightly different factors were used in the on-line calculator as opposed to those stated in the User's 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. The User's Guide cannot be viewed directly from the web page when one clicks on the hyperlink titled "PDF of User's Guide". The error message received is,

> "Cannot use Adobe Reader to view PDF in your web browser. Reader will now exit. Please exit your browser and try again"

However the PDF file can be downloaded.
This needs to be stated directly on the website so that the downloaded version can be used directly.

Finally the presentation of the equations both on-line and in the BDCC 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.

3 DISCUSSION OF VERIFICATION METHOD AND RESULTS

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

3.1 SPECIFIC COMMENTS RELATED TO THE USER'S GUIDE

In order to determine if the calculator is working correctly, it was necessary to review the user's guide to ensure that all the terms used were understood. Several problems were noted both with the description of radioactive decay chains and how to use the calculator. These are described in the sections below.

3.1.1 Section 1

Page 2 of the BDCC User's Guide states the following:

> "ICRP Publication 107 (ICRP2008) provides an electronic database of the physical data needed in calculation of radionuclide specific protection and operational quantities."

This publication is not the internationally accepted database for physical nuclear constants and should not be used.

The values for nuclear constants such as half-life, energies and decay particle abundance can be found either in the Brookhaven National Laboratory Interactive Chart of the Nuclides (http://www.nndc.bnl.gov/chart/) or in the Laboratoire National de Henri Becquerel Database (http://www.nucleide.org/DDEP_WG/DDEPdata.htm).

Inspection of these data bases shows that the half-lives used in several cases in the User's Guide are not correct. Some examples are ^{91m}Y, ^{76}As, ^{99m}Tc and ^{99}Mo. The differences in these half-lives generates a difference in the final dose calculated for different pathways.

The calculator may be used in several different ways. The description on the calculator page that states "Using the BDCC calculator" is confusing. In step 2 it tells you to skip down to step 4 if you select "Default" BDCCs. When you get to step 4 it tells you to go back to step 3 if you want results in "dose".
To avoid confusion and simplify the calculator use there should be two separate directions that does not skip between steps: one for "default" and one for "user-specified".

3.1.2 Section 2.2.5

This section discusses when to use the "+E" DCCs. The guidance provided states:

> "If the isotopes are found to be in secular equilibrium, the +E DCC values for the parent

should be used for the parent and the daughters included in the +E can be ignored".

This sentence should be rephrased as follows:

> *"If the isotopes are found to be in secular equilibrium, the +E DCC values for the parent should be used as it includes the DCC values for all of the progeny in secular equilibrium with the parent."*

The guide describes using the knowledge of whether or not secular equilibrium has been established. However it does not describe when: During sampling, transport, start of sample analysis, 100 year time frame, residence in the human body? The equations to make the proper estimate of "secular equilibrium" may be quite complex depending upon which time phase of the process is being discussed. The calculator does one calculation, which one is it? When this question was sent to the EPA representative the following answer was received:

> **"**The date of sampling is important. If the analysis was done years ago, many daughters could be gone. The risk assessor should be able to adjust for this. In general the BDCC is a static tool designed dose assessments in year zero. The +D provides PRGs with the peak dose for the isotope and selected daughters over the next 100 years and the +E provides the PRG for peak dose for the isotope and selected daughters over the next 1,000 years"

- *The second statement is incorrect. Progeny of parents from secular equilibrium grow-in with time. If the calculator only deals with secular equilibrium, the daughters will always be present if secular equilibrium was established at the time of sampling. Thus very specific guidance is needed here as the acquiring of secular equilibrium by radionuclides is very complicated and will vary significantly depending upon the specific radionuclides involved. Secular equilibrium in some cases may occur between the time of sampling and the time of analysis Additionally the equations required for either decay correction or in-growth are affected by many different physical and chemical parameters between the time of sampling, transport, and analysis. This is especially true when radon is part of the decay chain as shown in the example discussed in the next paragraph.*
- *If the BDCC is designed as "a static tool designed for dose assessment in year zero", this needs to be more clearly stated and examples of what "year zero" is should be provided as this may be different depending upon whether there is a current incident, or a long-standing remediation site.*
- *The concept of secular equilibrium is the only one used. Radionuclides such as ^{143}Ce and ^{143}Pr or ^{147}Nd and ^{147}Pm that are "no equilibrium" cases have ingrowth over days to years that are significant. Ba-140 ($t_{1/2}$= 12.75 d) is within transient equilibrium with ^{140}La ($t_{1/2}$= 1.68 d) within about 6 days. This is a specific example of the difficulty in using this calculator as the analysis can take place days after sampling and decay correction to time zero depends on many factors*.

- *Radionuclides with short lived daughters that generate a transient equilibrium do not have a mechanism for calculating dose based on the equilibrium concentrations*. Two examples of this are ^{99}Mo/^{99m}Tc and^{132}Te/^{132}I. In both cases the radionuclides will rapidly come into equilibrium with the parent between the time of sampling and analysis. *It does not appear that such a situation is effectively covered in the on-line software.*

Paragraph 3 in this section has information that does not make sense. It states the following:

> "Even though the decay chain of ^{228}Th is long there is no dose coefficient because the activity of any progeny after 100 years of chain ingrowth was less than 90 % of the parents activity"

The ^{228}Th half-life is 1.9 years and ^{224}Ra the first progeny has a half-life of 3.6 days. Thus they achieve secular equilibrium within about 28 days. The first progeny of ^{224}Ra is ^{220}Rn with a half-life of only 56 seconds; subsequent progeny are short lived as well. Thus the activity of all progeny are equal to that of the parent ^{228}Th within that same 28 days. Thus the sum of all progeny activity will be six times the activity of the parent, and thus much larger than 90 %. Additionally applying this example for the 100 year case is not a good idea since within 20 years the ^{228}Th and its progeny will have decayed away to an inconsequential amount.

The same paragraph refers to the decay of ^{137}Cs to ^{137m}Ba. It is unclear in the discussion which activity is being considered with regards to the decay of Cs-137: beta emission (two different energies), gamma (one single gamma ray), conversion electrons or x-rays? Isn't it the contribution from dose that we are concerned with?

While the derivation of these DCF values may be in the reference documents, a short paragraph in the user's guide needs to identify the general process.

Using the term "activity", instead of "dose", in this paragraph does not appear to be in accord with the purpose of the calculator.

If the term "activity" is to be used, it should be corrected to read "activity concentration".

The table that appears in Section 2.2.6 has incorrect half-lives for both ^{137}Cs and ^{228}Ra (they should be 30.08 years and 5.76 years, respectively). It is also unclear why there should be two designations for ^{137}Cs; +D and +E. The half-life of ^{137m}Ba is only 2.6 minutes thus secular equilibrium is within ten minutes. In the paragraph following the table, there is a description of how isomeric states are differentiated. The description is in disagreement with most frequently used method for differentiating these states. Higher energy isomeric states (no longer referred to as metastable states) are by convention denoted with numerical suffixes not successive letters.

3.1.3 Section 4.1

In the equations on-line there is a discrepancy in the terms used with those in the User's Guide.

- For ingestion DCFs is DCF_0.
- For contaminated building materials BDCC
- $DCF_{ext\text{-}sv}$ is DCF_{ext}

- F_{SURF} is F_{SURFsv}
- $F_{SURF1cm}$ is F_{SURF}

With the number of abbreviated constants these two formats must agree. Also since the equations in the calculator are not visible to the user, there is no way of knowing which term is actually being used if the discrepancy is not corrected.

This needs to be corrected so that the equations in both locations have the identical parameter designations, and they match what parameter is used in the calculator.

The equations presented in the BDCC User Guide (section 4.1) have two derived constants, $IFD_{res\text{-}adj}$ and IRD_{iw} which are calculated and then used in the calculator. These were verified as correct as shown in Figure 1.

Figure 1. Excerpt from Spreadsheet Used in Verification of Ingestion $IFD_{res\text{-}adj}$ and IRD_{iw}

IRD_{iw}	FTSSh	ETiw,h	FTSSs	SE	SAiw	FQiw
1.76E+02	5.00E-01	4.00E+00	1.00E-01	5.00E-01	4.90E+01	3.00E+00

	FTSSh	EFres-c	ETres-c,h	FTSSs	ETres-c,s	SE	AAFres-c
	0.5	350	6	0.1	10	0.5	0.23
IFDres-adj	123025						

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.*
- *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.*

This section (and Section 4.2.4 as well) contains 5 equations for calculations involving 3-D exposure (ground plane, 1 cm, 5 cm, 15 cm, and soil). There does not appear to be a method for computing dose values for soil even though constants are listed on the template and an input box is provided for soil values. This set up is very confusing (see figure below).

Figure 2. Screen Shot of the BDCC Calculator Media Concentration Page

BDCC Calculator

Media Concentrations

If a concentration is missing for a particular medium, put a "." (dot or period) in the input field.

Radionuclide	External Exposure 1 cm (pCi/g)	External Exposure 5 cm (pCi/g)	External Exposure 15 cm (pCi/g)	External Exposure Ground Plane (pCi/cm^2)	Soil? (pCi/g)
Ac-228					XXXXX?

Alternate External Exposure

This input page needs to be corrected.

Section 4.2.4 makes reference to 'resident dose' between the two picture sets, when in fact this section is for the indoor worker. *This reference needs to be corrected.*

4 VALIDATION OF CALCULATIONS

Attachment I has tables that compare the results of the on-line computation versus the results generated via excel spreadsheet, using the equations provided on-line. In the case of the Exposure to Dust on Settled Surfaces for the indoor worker, the on-line calculator's equation has the factor for the decay constant missing in the denominator of the equation. The table for this comparison in Attachment I shows this as a large discrepancy. However when the decay constant is input into the denominator of the on-line calculator result the recalculated value agrees with the spreadsheet result obtained.

The on-line equation for "Exposure to Dust on Settled Surfaces for indoor workers" must be corrected.

5 CONCLUSIONS

The on-line BDCC 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 BDCC 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 and also in the Attachment I.

6 ATTACHMENT I

Comparison of On-line Calculator to Spreadsheet results

7 RESIDENT DOSE FOR SETTLED DUST (INGESTION)

The percent difference between on-line results and those independently calculated on spreadsheet were well within the 1 % acceptance criterion.

Radionuclide	$BDCC_{res\_dust\_ing}$	DL (mrem/year)$_{Ind\ calc}$	DL (mrem/year)$_{on\text{-}line}$	% Difference
As-76	1.00E+02	4.09E-01	4.09E-01	-3.38E-02
Ba-140	5.00E+02	4.16E+01	4.17E+01	-1.69E-01
La-140	5.75E+02	4.63E+00	4.63E+00	-3.22E-02
Mo-99	2.40E+02	9.17E-01	9.17E-01	-1.34E-02

8 RESIDENT DOSE FOR AIR

The following tables for resident inhalation and external exposure show that the independent calculation and the on-line calculator agree to within 1 %.

Both the parents and progeny in the $^{140}Ba/^{140}La$ and the $^{99}Mo/^{99m}Tc$ transient relationships are independent. Thus the time of analysis with respect to "time zero" becomes very important since they reach equilibrium within a short time period. If transient equilibrium had not been established prior to sampling of the materials, the gamma spectrometry software that performs these analyses is not be able to accurately calculate the activity of each progeny at "time zero". *For such transient equilibrium pairs (there are many including naturally occurring radionuclides) some additional guidance in the User's Guide would allow practitioners to better assess how to handle this type of situation.*

Inhalation (with Half-life decay)				
	BDCCres_dust_inh	DL (mrem/year)$_{Ind\ calc}$	DL (mrem/year)$_{on\text{-}line}$	% Difference
As-76	100	8.88E-03	8.91E-03	-2.93E-01
Ba-140	500	3.77E+00	3.77E+00	5.02E-03
La-140	575	1.18E-01	1.18E-01	-4.14E-02
Mo-99	240	6.81E-02	6.81E-02	3.64E-02

Inhalation (without Half-life decay)				
	BDCCres_air_nodecay_inh	DL (mrem/year)$_{Ind\ calc}$	DL (mrem/year)$_{on\text{-}line}$	% Difference
As-76	1200	2.51E+01	2.51E+01	-1.89E-01
Ba-140	100	1.49E+01	1.49E+01	2.01E-01
La-140	115	3.56E+00	3.56E+00	5.97E-02
Mo-99	500	1.31E+01	1.31E+01	-2.18E-01

External Exposure Dose				
	BDCCres_air_decay_sub	DL (mrem/year)$_{Ind\ calc}$	DL (mrem/year)$_{on\text{-}line}$	% Difference
As-76	1.20E+03	1.83E+04	1.83E+04	7.08E-02
Ba-140	1.00E+02	7.31E+03	7.28E+03	4.51E-01
La-140	1.15E+02	1.51E+04	1.52E+04	-5.46E-01
Mo-99	5.00E+02	6.72E+03	6.73E+03	-2.17E-01
Tc-99m	4.80E+02	4.48E+02	4.49E+02	-1.28E-01

9 3-D DIRECT EXTERNAL EXPOSURE

The model selected for this analysis used the default parameters and was for a 10'x10'x10' room with drywall and dose determined for the room center. *The on-line calculator allowed values to be entered for soil volume and soil volume 15 cm, but a calculation was not performed for either of these cases.*

The following tables for resident inhalation and external exposure show that the independent calculation and the on-line calculator agree to within 1 %.

	Contaminated building materials in walls, floor and ceiling using soil volume toxicity values				
	$BDCC_{res\_3D\_ext\_SV}$	Drywall factor	DL $(mrem/year)_{Ind\ calc}$	DL $(mrem/year)_{on\text{-}line}$	% Difference
Ac-228	100	1.28	0.626753362	Calculation not performed by on-line calculator	
Ra-224	176	0.0495	0.005984369		
Ra-228	1.00E+02	6.58E-05	3.91035E-07		
Ra-228+D	100	1.22	555.3333751		
Th-228	1.76E+02	7.25E-03	0.007439083		
	Contaminated building materials in walls, floor and ceiling using 1 cm soil volume toxicity values				
	$BDCC_{res\_3D\_ext\_1\ cm}$	Drywall Room Factor	DL $(mrem/year)_{Ind\ calc}$	DL $(mrem/year)_{on\text{-}line}$	% Difference
Ac-228	100	1.56E+00	1.46E-01	1.46E-01	-1.37E-01
Ra-224	176	5.66E-02	1.58E-03	1.59E-03	-9.20E-01
Ra-228	1.00E+02	1.01E+00	6.01E-03	5.99E-03	3.56E-01
Ra-228+D	100	2.56E+00	2.22E+02	2.23E+02	-2.59E-01
Th-228	1.76E+02	1.14E-01	3.44E-02	3.43E-02	2.00E-01
	Contaminated building materials in walls, floor and ceiling using 5 cm soil volume toxicity values				

	$BDCC_{res\_3D\_ext\_5\ cm}$	Drywall Factor	DL $(mrem/year)_{Ind\ calc}$	DL $(mrem/year)_{on\text{-}line}$	% Difference
Ac-228	1.00E+02	1.89E+00	5.07E-01	5.09E-01	-4.34E-01
Ra-224	1.76E+02	6.65E-02	5.23E-03	5.28E-03	-9.30E-01
Ra-228	1.00E+02	1.11E+00	6.60E-03	6.60E-03	-5.33E-02
Ra-228+D	1.00E+02	3.01E+00	7.50E+02	7.51E+02	-9.23E-02
Th-228	1.76E+02	1.07E-01	8.21E-02	8.20E-02	1.03E-01
	Contaminated building materials in walls, floor and ceiling using 15 cm soil volume toxicity values				
	$BDCC_{res\_3D\_ext\_15\ cm}$		DL $(mrem/year)_{Ind\ calc}$	DL $(mrem/year)_{on\text{-}line}$	% Difference
Ac-228	100	1.56E+00	0.093461175	Calculation not performed by on-line calculator	
Ra-224	176	5.66E-02	0.027833465		
Ra-228	1.00E+02	1.01E+00	0.005951807		
Ra-228+D	100	2.56E+00	86.88373452		
Th-228	1.76E+02	1.14E-01	0.358095727		
	Contaminated dust on walls, floor and ceiling using ground plane toxicity values				
	$BDCC_{res\_3D\_ext\_gp}$	Drywall Room Factor	DL $(mrem/year)_{Ind\ calc}$	DL $(mrem/year)_{on\text{-}line}$	% Difference
Ac-228	1.00E+02	1.48E+00	1.41E-01	1.41E-01	3.86E-02
Ra-224	1.76E+02	4.32E-02	1.17E-03	1.18E-03	-7.59E-01
Ra-228	1.00E+02	7.50E-01	5.81E-02	5.81E-02	3.13E-02
Ra-228+D	1.00E+02	2.23E+00	1.98E+02	1.98E+02	-1.12E-01
Th-228	1.76E+02	1.86E-01	6.66E-02	6.65E-02	1.59E-01

10 INDOOR WORKER

Exposure to Settled Dust on Surfaces

The following tables for inhalation and external exposure show that the independent calculation and the on-line calculator agree to within 1 % *(except for those values calculated for Dust on Settled Surfaces – Exposure: see below).*

A different set of radionuclides was used for the next set of calculations to ensure that a significant number of radionuclides were covered for the calculations.

Exposure to Dust on Settled Surfaces - Ingestion				
Radionuclide	$BDCC_{iw\_dust\_ing}$	DL $(mrem/year)_{Ind\ calc}$	DL $(mrem/year)_{on\text{-}line}$	% Difference
Bi-214	1.50E+02	1.50E-04	1.50E-04	-2.33E-01
Bi-214+D	1.50E+02	1.50E-04	1.50E-04	-2.33E-01
Pb-210	1.00E+01	1.12E+03	1.12E+03	1.91E-02
Pb-214	1.30E+02	2.17E-04	2.17E-04	-1.50E-01

For the ingestion pathway the independent calculation results agree well with those of the on-line calculator.

However, it does not seem possible that the values for dose calculated for (^{214}Bi) and ($^{214}Bi+D$) could be the same since the latter should contain the dose contribution for 100 years for ^{214}Po, ^{210}Pb and ^{210}Po. It is suggested that the DCF values for these radionuclides be reviewed.

Exposure to Dust on Settled Surfaces - Exposure				
Radionuclide	$BDCC_{iw\_dust\_ext}$	DL $(mrem/year)_{Ind\ calc}$	DL $(mrem/year)_{on\text{-}line}$	% Difference
	1.50E+02	5.69E+01	3.11E-03	1.83E+06
	1.50E+02	5.69E+01	3.11E-03	1.83E+06
	1.00E+01	1.92E-01	5.70E-03	3.26E+03
	1.30E+02	8.43E+00	6.20E-04	1.36E+06

The on-line calculation shows a significant difference from the spreadsheet calculation. When the ratio of the spreadsheet value over the on-line value is calculated it equals the value of the decay constant for the radionuclide (for example for ^{214}Bi this is 1.83E+04).

It appears that the on-line calculator has omitted the value of the decay constant (λ) from the denominator of the equation for calculating the dose.

Exposure to Ambient Air with half-life decay

The following tables for inhalation and external exposure with half-life decay for the indoor worker show that the independent calculation and the on-line calculator agree to within 1 %

Exposure to air - Inhalation Exposure				
Radionuclide	$BDCC_{iw\_air\_decay\_inh}$	DL $(mrem/year)_{Ind\ calc}$	DL $(mrem/year)_{on\text{-}line}$	% Difference
Be-7	6.00E+01	1.48E-02	1.48E-02	2.63E-01
Cs-137+D	2.00E+01	1.52E+01	1.52E+01	1.60E-01
Sr-90+D	1.00E+02	3.03E+02	3.03E+02	1.09E-01
U-235	2.00E+02	3.38E+04	3.38E+04	-7.52E-07

Exposure to air - Submersion Exposure				
Radionuclide	$BDCC_{iw\_airdecay\_sub}$	DL $(mrem/year)_{Ind\ calc}$	DL $(mrem/year)_{on\text{-}line}$	% Difference
Be-7	6.00E+01	1.18E+03	1.18E+03	6.40E-02
Cs-137+D	2.00E+01	2.15E+04	2.15E+04	-5.99E-02
Sr-90+D	1.00E+02	3.74E+03	3.75E+03	-1.43E-01
U-235	2.00E+02	5.84E+04	5.86E+04	-2.60E-01

Exposure to Ambient Air without half-life decay

The following tables for ambient air exposure without half-life decay for the indoor worker show that the independent calculation and the on-line calculator agree to within 1 %

Exposure to air - Inhalation Exposure				
Radionuclide		$BDCC_{iw\_air\_nodecay\_inh}$		
Be-7	6.00E+01	DL $(mrem/year)_{Ind\ calc}$	DL $(mrem/year)_{on\text{-}line}$	% Difference
Cs-137+D	2.00E+01	7.11E-02	7.10E-02	1.41E-01
Sr-90+D	1.00E+02	1.54E+01	1.54E+01	0.00E+00
U-235	2.00E+02	3.07E+02	3.07E+02	-1.85E-14
			3.38E+04	0.00E+00

Exposure to air - Submersion Exposure				
Radionuclide	BDCCiw_airdecay_sub	DL (mrem/year)Ind calc	DL (mrem/year)on-line	% Difference
Be-7	6.00E+01	5.66E+03	5.66E+03	-4.36E-02
Cs-137+D	2.00E+01	2.17E+04	2.18E+04	-2.97E-01
Sr-90+D	1.00E+02	3.79E+03	3.79E+03	-1.20E-03
U-235	2.00E+02	5.84E+04	5.86E+04	-2.60E-01

3-D Direct External Exposure

The following tables for 3-D exposure for the indoor worker show that the independent calculation and the on-line calculator agree to within 1 %

	Contaminated building materials in walls, floor and ceiling using ground plane toxicity values				
Radionuclides	$BDCCiw_{3D\_ext\_sv}$	Concrete factor	$DL\ (mrem/year)_{Ind\ calc}$	$DL\ (mrem/year)_{on\text{-}line}$	% Difference
Ag-110m	1.00E+02	3.26E+00	1.42E+02	1.42E+02	-2.67E-02
Am-241	5.00E+00	1.23E+00	3.58E-02	3.56E-02	4.95E-01
Cf-252	1.00E+00	6.33E-01	6.42E-02	6.43E-02	-1.48E-01
Np-239	2.30E+01	2.51E+00	2.33E-02	2.33E-02	-8.07E-02

	Contaminated building materials in walls, floor and ceiling using 1 cm soil volume toxicity values				
Radionuclides	$BDCCiw_{3D\_ext\_1\ cm}$	Concrete factor	$DL\ (mrem/year)_{Ind\ calc}$	$DL\ (mrem/year)_{on\text{-}line}$	% Difference
Ag-110m	1.00E+02	4.22E+00	1.87E+02	1.87E+02	-1.07E-01
Am-241	5.00E+00	1.32E+00	2.76E-02	2.76E-02	-1.69E-01
Cf-252	1.00E+00	7.05E-01	7.07E-02	7.06E-02	8.29E-02
Np-239	2.30E+01	2.32E+00	2.13E-02	2.12E-02	4.30E-01

	Contaminated building materials in walls, floor and ceiling using 5 cm soil volume toxicity values				
Radionuclides	$BDCCiw_{3D\_ext\_5\ cm}$	Concrete factor	$DL\ (mrem/year)_{Ind\ calc}$	$DL\ (mrem/year)_{on\text{-}line}$	% Difference
Ag-110m	1.00E+02	5.01E+00	6.39E+02	6.39E+02	-5.24E-02
Am-241	5.00E+00	1.31E+00	5.17E-02	5.14E-02	5.85E-01
Cf-252	1.00E+00	7.81E-01	2.26E-01	2.25E-01	3.94E-01
Np-239	2.30E+01	2.16E+00	5.36E-02	5.34E-02	4.46E-01

	Contaminated building materials in walls, floor and ceiling using 15 cm soil volume toxicity values				
Radionuclides	$BDCCiw_{3D\_ext\_15\ cm}$	Concrete factor	$DL\ (mrem/year)_{Ind\ calc}$	$DL\ (mrem/year)_{on\text{-}line}$	% Difference
Ag-110m	1.00E+02	4.09E+00	8.29E+02	8.25E+02	4.62E-01
Am-241	5.00E+00	9.42E-01	4.00E-02	3.99E-02	1.77E-01
Cf-252	1.00E+00	7.14E-01	3.36E-01	3.35E-01	1.71E-01
Np-239	2.30E+01	1.99E+00	6.86E-02	6.83E-02	3.78E-01

CURRICULUM VITAE

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

- 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.

Peer Reviewer Conflict of Interest Certification

Peer Review: BDCC Calculator

A conflict of interest or lack of impartiality exists when the proposed peer reviewer personally (or the peer reviewer's immediate family), or his or her employer, has financial interests that may be affected by the results of the peer review; or may provide an unfair competitive advantage to the peer reviewer (or employer); or if the peer reviewer's objectivity in performing the peer review may be impaired due to other factors. When the Peer Reviewer knows that a reasonable person with knowledge of the facts may question the peer 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 peer 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
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- Have you served on previous advisory panels, committees, or subcommittees that have addressed the topic under consideration? XNo □ 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 peer 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 peer review? 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 peer review:

(a) Peer 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 Peer Reviewer has disclosed all such relevant information to EMS or to EPA.
(b) Peer Reviewer agrees that if an actual, apparent, or potential personal or organizational conflict of interest is identified during performance of this peer review, he/she immediately will make a full disclosure in writing to EMS. This disclosure shall include a description of actions that Peer 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. Peer Reviewer shall continue performance until notified by EMS of any contrary action to be taken.

□ Check here if any explanation is attached

Signature Date

Robert Litman
Printed Name

Radiochemistry Laboratory Basics
Affiliation/Organization