Dose Compliance Concentrations for Radionuclides at Superfund Sites (DCC) Calculator

External Verification Study Record

February 27 – March 27, 2023

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Verification Study Charge for:

U.S. Environmental Protection Agency (EPA), "Dose Compliance Concentrations for Radionuclides at Superfund Sites" (DCC) electronic calculator https://epa-dccs.ornl.gov/

Background:

EMS, Inc., under contract EP-W-13-016 with EPA's Office of Superfund Remediation and Technology Innovation, has been asked to conduct an external, independent verification study of the DCC electronic calculator. EPA developed the electronic calculator to help risk assessors, remedial project managers, and others involved with risk assessment and decision-making at sites with radioactively contaminated soil, water, air and biota. The DCC calculator provides guidance for calculating dose-based DCCs for radionuclides that comply with Applicable or Relevant and Appropriate Requirements (ARARs).

The homepage for the DCC calculator is at https://epa-dccs.ornl.gov/ where you can find links to the calculator (https://epa-dccs.ornl.gov/cgi-bin/dose_search) and User's Guide (https://epa-dccs.ornl.gov/users_guide.html).

Verification Study Charge:

According to EPA's Guidance on the Development, Evaluation, and Application of Environmental Models (2009), *verification* refers to activities designed to confirm that the mathematical framework embodied in the module is correct and that the calculations the calculator yields compare favorably with those obtained using known analytical solutions or numerical solutions from simulators based on similar or identical mathematical frameworks. In addition, the verification study will ensure that sources of error, such as rounding, are minimal. The equations used in the calculator are listed at https://epa-dccs.ornl.gov/equations.html.

We are enlisting two or three subject matter experts for this verification study. Your comments and recommendations will be used to verify existing equations and calculations so that the final version will reflect sound technical information and guidance.

You are encouraged to choose:

- Radionuclides from the "Common Isotopes" list and some other isotopes from the "Complete List" of radionuclides (Note that 2 or 3 isotopes at a time will be faster than picking more.)
  - Using the peak dose option (the first source and decay output in the list), with various "Peak Time Periods".
  - Using site-specific option, both "Database hierarchy defaults" and "User Provided".
  - Using the "Risk Output Option".

- Using different "Scenarios" and "Media", but at least including the more common scenarios/media (e.g., Resident (Soil, Tap Water, Fish), Outdoor Worker (Soil), Farmer (Combined Soil and Biota, Combined Water and Biota).

An explanation of how to use the calculator is provided below.

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

When your verification study is complete, e-mail your comments to EMS's Project Manager (Cindy Eyer, cindy.eyer@emsus.com) on or before **March 27, 2023**. Please submit your comments in Microsoft Word and reference each comment to a specific step in the calculator and equation (https://epa-dccs.ornl.gov/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 handwrite your comments.*

How to Use the Calculator (hover over any form section for additional instructions):

Step 1: Select a dose limit of 1 or select "Other" to manually enter an alternate risk value.

Step 2: Choose one of eight exposure scenarios (resident, indoor worker, outdoor worker, composite worker, construction worker (site-specific only), recreator (site-specific only), farmer, or soil to groundwater) and choose the media (soil, air, tap water, 2-D external exposure, or fish). Some of these exposure scenarios have multiple media choices; other scenarios will only involve one media so a choice will not appear.

Step 3: Under the Select Site Info Type choose either "Defaults" to get DCCs based on default exposure parameters or "Site-Specific" to change some of the exposure parameters.

Step 4: Choose whether or not dose output is desired.

Step 5: Select the International Commission on Radiological Protection (ICRP) Rule (107, 60/68/72, or 30).

Step 6: Select the units for the results – picocuries per gram, which are the units usually used in the United States, or becquerels per gram, which most of the rest of the world uses.

Step 7: Select one or more radionuclides for which to develop DCCs. Do not use the Select All option.

Step 8: Choose from one of the four Source and Decay Output Options.

Step 9: Choose from one of the five Peak Time Period Options.

Gehan Flanders

NRC

U.S. Environmental Protection Agency (EPA), "Dose Compliance Concentrations for Radionuclides at Superfund Sites" (DCC) Electronic Calculator

Introduction

The U.S. Environmental Protection Agency (EPA)'s Office of Superfund Remediation and Technology Innovation requested an external, independent verification study of their updated DCC electronic calculator. The EPA developed the electronic calculator to assist risk assessors, remedial project managers, and others involved with risk assessment and decision-making at sites with radioactively contaminated soil, water, air, and biota. The DCC calculator provides guidance for calculating dose based DCCs for radionuclides to comply with Applicable or Relevant and Appropriate Requirements (ARARs). To verify the calculator's accuracy, equations for residents, indoor workers, outdoor workers, composite workers, construction workers, recreators, and farmer receptor types were calculated by hand using default parameters. A standardized set of radionuclides including Am-241, Co-60, H-3, Tc-99, and Pu-238 were used for each calculation, and to ensure consistency in the calculations a dose limit of 25 millirem per year was selected.

Results

1) When running the calculator, the following message appears, "Peak DCCs require extra processing and may take up to several minutes to run." This message does not disappear once the program completes running.
2) If you attempt to use the camera tool to download graphs as .png files, the following message appears, "Your file could not be accessed, and the individual will lose the data."
3) For farmer receptor types, the media selected included combined soil and biota; however, the output table displayed soil only, and did not identify combined soil and biota as was selected. The output table was entitled, "Farmer Peak Dose DCCs for soil (complete chain decay)."

Conclusions

After performing the calculations for Am-241, Co-60, H-3, Tc-99, and Pu-238, EPA's DCC electronic calculator appears to be mathematically correct for all scenarios and pathways.

GEHAN FLANDERS

Professional Summary

Detailed health physicist, excellent at juggling multiple tasks and working and meeting deadlines under pressure. Broad international regulatory experience and a technical expert in radiological and environmental modeling.

Skills and Experience

- Expertise in radiological and environmental modeling utilizing RESRAD, Monte Carlo, kinetic air quality modeling, groundwater modeling, MILDOS and GoldSim modeling programs
- Experience with NRC, EPA and IAEA requirements and guidance
- Experience as a qualified uranium recovery inspector and license reviewer
- Experience as a qualified low-level radioactive materials waste inspector and license reviewer
- Experience as a qualified byproduct radioactive materials inspector

Work History

Manager, Radioactive Materials Section, January 2021 to March 2022
Radioactive Materials Division
Texas Commission on Environmental Quality (TCEQ)– Austin, TX

Serves as the manager of the Radioactive Materials Section and is responsible for the implementation of the agency's radioactive materials licensing programs including site decommissioning, source and special nuclear materials, uranium recovery and low-level waste activities. Manages the daily activities of 13 technical and administrative staff ensuring that agency work products reflect current scientific knowledge and correctly interpret agency and NRC regulations, policies and procedures. Works directly with staff health physicists on the review and development of complete and accurate correspondence, reports, permits, modifications, and amendments; and, by providing complete and accurate answers to inquiries, both orally and in writing, to agency Commissioners, senior managers, licensees and the general public. Also provides answers both orally and in writing to Texas Representatives and Senators primarily during legislative sessions. Ensures that statutes, regulations, rules, policies and procedures are developed in accordance with NRC requirements; and are accurately and consistently applied during reviews, development, and processing of plans, reports, correspondence, and permit applications. Represents the agency professionally during interactions with applicants, state and federal government officials, the general public and other agency staff at meetings, during hearings and telephone conversations. Manages and interacts with section staff and other team members to assure an accurate and consistent technical approach is practiced, and that work products are of high quality and consistent with internal procedures and all statutory and regulatory requirements. Ensures that staff are interviewed, hired and developed using performance management techniques. Plans, schedules, budgets and administers agency programs in accordance with established agency directives. Interprets state and federal laws, statutes, and regulations; develops policies and procedures; and assists in the development of state regulations; and reviews and directs program operations. Manages staff, workload and resources to meet agency goals and objectives. Leads the Section in a professional manner ensuring that high standards for quality and risk significant safety is consistently met. Ensures that section members communicate with other agency staff, government officials, and the regulated community in a professional manner. Assures that within set time frames, the Section produces peer-reviewed, accurate, and complete correspondence, reports, permits, modifications, and amendments. Participates as a member of the accident assessment team for radiological emergencies for the Comanche Peak Nuclear Power Plant and the South Texas Nuclear Generating Station.

Health Physicist, (Qualified Inspector) December 2018 to December 2020
Texas Commission on Environmental Quality – Austin, TX

Served as a radioactive materials inspector for the Critical Infrastructure Division conducting advanced compliance inspections of licensees using byproduct materials involving the handling, processing, storage and disposal of those materials in accordance with agency and NRC requirements. Performed inspections of Texas based waste processing facilities. Experience with other byproduct materials uses including medical, industrial and academic applications while working for the Egyptian Atomic Energy Authority. Managed and prepared for assigned TCEQ inspections by thoroughly reviewing facility compliance plans, licenses and amendments prior to initiation of the inspection. Conducted assigned inspections as directed by management at the Waste Control Specialists facility in Andrews County, Texas; and, at various uranium recovery sites across Texas, evaluating licensee performance, compliance with state and federal rules and regulations, and with respect to health, safety and security in accordance with agency goals and objectives. Responsible during inspections for the analysis and evaluation of radiological hazards, design specifications, operating procedures and security. Developed and submitted timely reports of inspections by thoroughly documenting licensee performance utilizing TCEQ data systems after verifying compliance with all applicable federal and state rules and regulations, and conditions of the license. Performed technical reviews of decommissioning funding plans as assigned. Assisted in the training and development of new staff by mentoring new inspectors with a focus on enhancing their inspection skills and techniques, as well as the correct performance of required surveys and safety reviews. Identified opportunities for professional growth and development through training, both internally and externally. Worked well with counterparts in the National Materials Program by participating in special projects such as NRC working groups developing policies and procedures and reviewing and providing technical comments on guidance documents used nationwide by state and federal regulatory bodies. Participated actively in the revision of NRC Procedure SA-110, “Reviewing the Non-Common Performance Indicator, Uranium Recovery Program”. Represented the TCEQ by actively participating in the Nuclear Regulatory Commission's Integrated Materials Performance Evaluation Program (IMPEP) by participating in the reviews of the Utah and Colorado Radiation Control Programs. Due to outstanding performance on those reviews, was specifically requested by NRC management to participate as one of a select group of individuals sharing in the inaugural review of NRC’s program during a “One NRC” IMPEP review to be performed in June 2021. Participated as a member of the accident assessment team for radiological emergencies for the Comanche Peak Nuclear Power Plant and the South Texas Nuclear Generating Station.

Health Physicist, (Qualified License Reviewer) June 2014 to November 2018
Texas Commission on Environmental Quality – Austin, TX

Served as a license reviewer for the Radioactive Materials Section with responsibility for reviewing complex licensing actions involving the Waste Control Specialists (WCS) radioactive waste storage facility, various Texas based radioactive waste processing facilities;

decommissioning facilities; and, multiple uranium recovery licensees. Evaluated WCS requests for the proposed Independent Spent Fuel Storage Installation (ISFSIs) to include independent environmental modeling assessments to confirm that the movement of radionuclides through the environment to groundwater proposed by the licensee were valid. Participated in special projects involving uranium recovery facilities to verify compliance with all federal and state requirements for specialized activities at each of the sites; and to assist in meeting the agency's desired regulatory outcomes. Performed independent environmental modeling assessments of uranium recovery facilities to confirm that the movement of radionuclides through the environment to groundwater proposed by the licensee were valid. Performed regulatory and technical reviews of license amendments and applications, interacting with other divisions and other regulatory agencies as necessary. Assisted in the training and development of new staff as requested. Independently would seek out professional development training opportunities both internally and externally. Participated on special projects and supported the work team in meeting agency goals and objectives regarding the agency's health, safety and security mission in a dynamic and ever-changing regulatory environment. Developed and maintained a database for licensee procedures and performed additional technical and regulatory reviews related to radioactive waste and radioactive material exemptions as directed. Worked with counterparts in the National Materials Program by participating in special projects such as NRC working groups developing policies and procedures and reviewing and providing technical comments on various guidance documents. Participated as a member of the accident assessment team for radiological emergencies for the Comanche Peak Nuclear Power Plant and the South Texas Nuclear Generating Station. Mentored students through a TCEQ internship program.

Graduate Research Assistant, January 2009 to May 2013
Texas A&M University - Kingsville – Kingsville, TX

Developed a new technique that will decrease the amount of mercury expelled into the environment from coal fired power plants. Studied homo-heterogeneous oxidation of mercury, in coal-fired facilities. Modeled air-quality utilizing (CHEMKIN-PRO). Prepared and measured surface water samples to determine BOD, OP, COD, and TP. Employed CROP-man model. Prepared samples into a spectrophotometer to determine wavelength of a uranium element. Utilized Gas Chromatographs and Inductively Coupled Plasma Mass Spectrometer to analyze samples.

Quality Staff Intern, June 2012 to August 2012
U.S. Environmental Protection Agency Headquarters – Washington, DC

Planned and conducted internal control reviews of quality and management integrity activities. Reviewed EPA and Chief Information Officer Directives (i.e., policies, guidelines, standards, and procedures) applicable to administrative operations in the Agency's Quality Staff office. Reviewed EPA and Federal guidance governing inspections, assessments, and review processes. Developed review plans, schedules, checklists, conduct interviews, and validated processes and reviews. Joined the Quality Staff assessment team conducting quality assessment interviews and developed the audit report and recommendations based on the interviews.

Health Physicist, (Qualified Radioactive Materials Inspector and Qualified Licensing Reviewer)
September 2002 to October 2008
Egyptian Atomic Energy Authority
National Center for Nuclear Safety and Radiation Control – Cairo, Egypt

Served as a fully qualified radioactive materials inspector, license reviewer and supervisor for the Egyptian Atomic Energy Authority. Issued licenses and conducted compliance inspections of licensees using byproduct materials for all types of medical, industrial and academic applications. Reviewed license applications and issued radioactive materials licensing actions using International Atomic Energy Agency (IAEA) guidance. Performed inspections of import and export shipments to ensure compliance with IAEA performance standards. Performed environmental sampling and sample analysis in conjunction with the nation's nuclear power reactor. Responded to incidents involving radioactive materials, and investigated allegations received by the agency or referred through the IAEA. Conducted radiological measurements during flyover operations and generated radiological maps for Egypt as a member of the team.

Issued licenses and inspected machines using open radiation sources as a member of the inspection team. Taught training courses covering radiation protection and radiological measurements. Planned and collected environmental samples (i.e., water, soil, and vegetation). Prepared samples for destructive and non-destructive analyses. Operated analytical equipment including Inductively Coupled Plasma Mass Spectrometers, Spectrophotometers, and Gas Chromatographs. Performed radiochemical separation of uranium and measured uranium by Laser Fluorimeter, determined natural and man-made radionuclides radiation levels using gamma spectrometry. Applied Instrumental Neutron Activation Analysis to assess major, minor, and trace elements in environmental samples. Performed radiochemical separation of 90Y (90Sr) and measurements using a Liquid Scintillation Counter. Separated alpha and beta emitters

Education

Ph.D.: Nuclear and Environmental Interdisciplinary Engineering, Completion in 2021
Texas A&M Health Science Center - College Station, TX

Master of Science: Environmental Engineering, 2013
Texas A&M University - Kingsville - Kingsville, TX
Modeling the effect of Hydrogen Peroxide on Homogeneous and Heterogeneous Oxidation of Elemental Mercury in Flue Gas.

Master of Science: Environmental Science, 2005
Ain Shams University - Cairo, Egypt
Determination of Naturally Occurring Radioactive Materials (NORM) in Petroleum Industry and their Control.

Bachelor of Science: Ecology, 1998
South Valley University - Sohag, Egypt

Publications

Martinez, Alvaro; Flanders, Gehan; Gor, Prajay, Effect of Hydrogen Peroxide on Homogeneous and Heterogeneous Oxidation of Elemental Mercury in Flue Gas, Department of Environmental Engineering, Texas A&M University-Kingsville, Kingsville, Texas, USA

Presentations

Flanders, Gehan; Martinez, Alvaro, Modeling the effect of Hydrogen peroxide on Homogeneous and Heterogeneous Oxidation of Elemental Mercury in Flue Gas. 2011, Pathway Student Research Symposium TAMUK, Kingsville, TX

Certifications and Associations

- Health Physics Society
- South Texas Chapter of the Health Physics Society
- Air & Waste Management Association (AWMA)

References

Available upon request

Verification Study Conflict of Interest Certification

Verification Study: **Dose Compliance Concentrations (DCC) for Radionuclides at Superfund Sites Electronic Calculator**

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

- Did you contribute to the development of the calculator (and associated webpages) being verified, or were you consulted during its development, or did you offer comments or suggestions to any drafts or versions of the calculator during its development? ☒ No ☐ Yes
- Do you know of any reason that you might be unable to provide impartial advice on the matter under consideration in this verification study, or any reason that your impartiality in the matter might be questioned? ☒ No ☐ Yes
- Have you had any previous involvement with the DCC calculator under consideration? ☒ No ☐ Yes
- Have you served on previous advisory panels, committees, or subcommittees that have addressed the topic under consideration? ☒ No ☐ Yes
- Have you made any public statements (written or oral) on the issue? ☒ No ☐ Yes
- Have you made any public statements that would indicate to an observer that you have taken a position on the issue under consideration? ☒ No ☐ Yes
- Do you, your family, or your employer have any financial interest(s) in the matter or topic under this verification study, 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) Participant 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 Participant has disclosed all such relevant information to EMS or to EPA.
(b) Participant 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 Participant (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. Participant shall continue performance until notified by EMS of any contrary action to be taken.

Gehan Flanders 2/6/23 ☐ Check here if any explanation is attached

Signature Date

Gehan Flanders

Printed Name

NRC

Affiliation/Organization

Arthur S. Rood

K-Spar Inc.

Verification Study for the U.S. Environmental Protection Agency Dose Compliance Concentrations (DCC) for Radionuclides at Superfund Sites

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March 24, 2023

Introduction

Environmental Management Support, Inc. (EMS) is tasked by the U.S. Environmental Protection Agency (EPA) with providing verification and review of the EPA's online Dose Compliance Concentration (DCC) calculator for radionuclides at superfund sites. Cindy Eyer of EMS enlisted the help of several subject matter experts to provide a verification study of the DCC calculator. Verification refers to the activities designed to confirm that the mathematical framework embodied in the module is correct and that the calculations the calculator yields compare favorably with those obtained using known analytical solutions or numerical solutions from simulators based on similar or identical mathematical frameworks. This report contains the results of this verification study performed by Arthur Rood of K-Spar Inc.

Verification Procedure

The verification study was performed by selecting a radionuclide with progeny that does not peak in the first year. Using default and site-specific values, DCCs were calculated using the online DCC calculator (https://epa-dccs.ornl.gov) for different exposure scenarios. The output was exported to a spreadsheet, and hand calculations performed in the spreadsheet were used to compute the DCC components (without decay) using the list of input parameters provided in the exported spreadsheet. Hand calculations refer to a calculation within the Excel spreadsheet using the equations for the different quantities that are presented in the DCC user's manual and the input parameters that were exported to the spreadsheet. The undecayed results can be compared to the hand calculations to assure that part of the DCC calculator is working properly. Next, a decay-ingrowth factor calculated using either the EPA decay chain calculator available on the DCC webpage or another external calculation is applied to the undecayed results, and these can be compared to the DCCs at the time of peak dose. In general, Ra-226 was selected as the radionuclide, but for some calculations, Co-60 and Cs-137 were used to help understand the overall process because their decay chains are simpler. For all scenarios evaluated the output spreadsheet with the hand calculations are provided.

Some General Comments on DCC Calculator

1. The second paragraph of the DCC calculator welcome page states "*This tool presents recommended DCCs calculated using suggested default input parameters and the latest dose conversion factors.*" The dose conversion factors (more accurately termed dose coefficients) are NOT the latest for inhalation, ingestion, and external exposure and represent values over 20-years old. ORNL/TM-2013/00 (2014) is cited as the source for all dose coefficients. The latest dose coefficients are in DOE (2022) for internal dosimetry and EPA (2019) for external exposure.
2. The equations and parameter values listed in the output, and variable definitions need to be consistent. That is the only way a validation exercise can be conducted. For the external pathway for residential soil, I had to infer what the correct value was to use in the hand calculation.

3. There is no rationale provided for setting the default dose limit at 1 mrem/yr. According to the documentation, the EPA dose limit is 12 mrem, which is 12% of the federal and international dose limit of 100 mrem/yr. This value (i.e., 12 mrem/yr) should be the default value in the DCC.
4. The option to run all radionuclides at once should be disabled because the calculator bogs down and does not run to completion, especially when the Peak option is used.

Verification Study Results

Scenario: Residential Soil, Default Parameters, Infinite Peak Time Period
Spreadsheets:
Ra-226-DCC_Resident_soil_27Feb2023_1632036.xlsx
Co-60-DCC_Resident_soil_28DEB2023_2533910.xlsx]

1. The variables, $ACF_{ext\text{-}sv}$, $GSF_{i\text{-}total}$, and $GSF_{o\text{-}ext\text{-}sv}$ are not listed in the Soil Inputs sheet. Those variables (except $GSF_{i\text{-}total}$) are defined in the detailed user manual, but a value is needed for verification. A value is provided for ACF, but not $ACF_{ext\text{-}sv}$. $ACF_{ext\text{-}sv}$ is defined as the Area Correction Factor - soil volume in the user's manual. The value for ACF is assigned a value of 100,000 m^2. $GSF_{i\text{-}total}$,is more than likely the indoor gamma shielding factor, which is listed as GSF_i on the Soil Inputs sheet and the user's manual, and has a default value of 0.4. $GSF_{o\text{-}ext\text{-}sv}$ is likely the outdoor gamma shielding factor which value is probably 1.0. Assuming the ACF is the ratio of the default site area of 100,000 m^2 to the actual site area, then for the default values, $ACF_{ext\text{-}sv}$ would be 1.0. $ACF_{ext\text{-}sv}$ should be unitless based on the equation for the DCC for external exposure. When these assumptions are made (i.e., $ACF_{ext\text{-}sv}$ =1.0, $GSF_{i\text{-}total}$ = 0.4, and $GSF_{o\text{-}ext\text{-}sv}$ = 1.0, the hand calculation matches the value reported in the output.
2. The ED_{res} value listed in the Soil Inputs sheet is listed as 26 years. It should be 1 year.
3. It is not clear the decay and ingrowth calculations are being done correctly. Take a simple example like Co-60 (half-life 5.27 years). The resident DCC is driven by external exposure. Produce ingestion makes a minor contribution. The Soil DCC sheet provides the undecayed DCC. The exposure duration is 1 year. The average activity (assuming unit concentration and 1-year exposure time) in the soil after 1 year assuming one decay member is:

$$\frac{\int_0^1 e^{-\lambda t}dt}{1\,year} = \frac{1}{1\,year}\frac{1}{\lambda}\left(1 - e^{-\lambda}\right)$$

For Co-60, the average activity is 0.937. A form of this equation is shown at the bottom of the Supporting Equations page for DCC Equations on the web page. The decay corrected DCC is:

$$DCC_{decay-corr} = \frac{DCC}{DF}$$

where DCC = the undecayed DCC and DF is the decay factor given by the previous equation. Note that the total DCC is the inverse of the sum of the inverse of the individual pathway DCCs.

$$DCC_{total} = \frac{1}{\frac{1}{DCC_{inh}} + \frac{1}{DCC_{ing}} + \frac{1}{DCC_{ext}} + \frac{1}{DCC_{prod}}}$$

The output from the DCC calculator assuming all default parameters and the hand calculation is shown in Table 1.

Table 1. Output of decayed and undecayed pathway DCCs for Ra-226 in Residential Soil using default exposure parameters and 0 to1-year average decay factor (0.937).

	Ingestion DCC DL=1.0E+00 (pCi/g)	Inhalation DCC DL=1.0E+00 (pCi/g)	External Exposure DCC DL=1.0E+00 (pCi/g)	Produce Consumption DCC DL=1.0E+00 (pCi/g)	Total DCC DL=1.0E+00 (pCi/g)
Undecayed DCC	1.14E+03	1.80E+06	1.95E-01	1.68E+00	**1.75E-01**
Hand-calculated decayed DCC	1.22E+03	1.92E+06	2.08E-01	1.79E+00	1.86E-01
Value reported in Peak DCC sheet	1.22E+03	1.92E+06	2.09E-01	4.65E+01	2.08E-01

All exposure pathways match (within rounding error) except produce ingestion shown on the "Peak DCC Soil Co60" worksheet. This accounts for the difference in the Total DCC. The undecayed DCC for produce is 1.68 pCi/g, which matches the worksheet labeled Produce Soil Co60. But in the "Peak DCC Soil Co60" worksheet, the produce DCC is 45 pCi/g (see Table 2). It is unclear why difference because decay is not provided in any of the produce equations in the documentation. The documentation needs to clearly state how decay is addressed for produce consumption because the values do not match up.

Table 2. The DCC at the time of peak for Co-60 in Residential Soil.

Exposure Route	Peak DCC for Co-60 DL=1 (pCi/g)	Maximum dose during peak interval (mrem/year)	Maximum Dose rate during peak interval (mrem/year)	Maximum Dose Year ED=1 (year)
Ingestion	***1.22E+03***	***8.19E-04***	***8.74E-04***	***1.00E-08 - 1.00E+00***
Inhalation	***1.92E+06***	***5.21E-07***	***5.56E-07***	***1.00E-08 - 1.00E+00***
External Exposure	***2.09E-01***	***4.79E+00***	***5.12E+00***	***1.00E-08 - 1.00E+00***
Produce Consumption	***4.65E+01***	***2.15E-02***	***2.30E-02***	***1.00E-08 - 1.00E+00***
Total	***2.08E-01***	***4.82E+00***	***5.14E+00***	***1.00E-08 - 1.00E+00***

4. Hand calculations were used to verify non-decayed produce PRGs from all 26 fruits and vegetables. Hand calculated values were within rounding error of values reported in the Ra-226 output spreadsheet. However, this took some trial and error because there is no crosswalk between each fruit and vegetable and the soil-to-plant transfer factors for the various types of fruit and vegetable categories (i.e., woody tree, leaf, root, tubers etc.). This crosswalk should be added to the documentation.
5. The decay corrected produce PRGs for Ra-226 had the same problem identified for Co-60. That is, they did not agree with the hand calculations.
6. There is a fundamental conceptual problem with the entire produce ingestion pathway. The root uptake factor is radionuclide-specific and applied to all radionuclides in the decay chain regardless of half-life. For short-lived progeny, any uptake into the edible portion of the produce from the soil will have long since decayed away before consumption. The progeny activity in the edible portion of the plant is controlled by the presence of the parent in the edible portion of the plant, which in turn is controlled by the parent soil-to-plant transfer factor and not that of the progeny. A simple way to fix this problem is to employ a half-life cutoff (suggest 180 days) such

that uptake of progeny from the soil from root uptake is based on the parent uptake and not that of the progeny.

7. All the age-adjusted intake amounts (e.g, IFCUres-adj (age-adjusted cucumber ingestion fraction) g) are stated to be fractions. They are not fractions but total intake amounts. This should be corrected in the output spreadsheet.

Scenario: Farmer Scenario – Combined Soil and Biota, Default Parameters, Infinite Peak Time Period
Spreadsheet:
Ra-226-DCC_Farmer_soil10MAR2023_3608865.xlsx

1. There were far too many values to check for the allotted time. Therefore, exposure pathways that were checked were those that were not included in the residential soil. Calculation checks were performed on shellfish ingestion and beef ingestion. There was a slight difference in the hand calculated value for the Ra-226 DCCfar-soil-shellfish-ing. The hand calculation was 9.41E-5 pCi/g whereas the value reported was 9.43E-5 pCi/g. Otherwise the shellfish ingestion DCC agree with the hand calculations. The beef ingestion pathway also agreed in addition to the decayed peak DCC using decay-ingrowth factors for 135 years. That is, the undecayed DCCfar-sol-beef-ing when decay corrected (by dividing by the decay-ingrowth factor), matched the value reported on the Peak DCC Soil Ra226 sheet. Fish, milk, poultry, and eggs are similar in structure to the beef and shellfish, and thus it is expected that those pathways will also agree with hand calculations.

Scenario: Composite Worker, Default and Site-Specific Parameters, Infinite Peak Time Period
Spreadsheets
Ra-226-DCC_Composite_Worker_soil_10MAR2023_3664808.xlsx,
Ra-226-DCC_Composite_Worker_soil_14MAR2023_623373.xlsx,
Co-60-DCC_Composite_Worker_soil_14MAR2023_627581.xlsx

1. All undecayed values checked out using defaults and a site-specific run using an area of 500 m^2 instead of the default value (10,000 m^2).
2. The decay-corrected values also compared well for each pathway to the DCC at the time of peak dose.
3. An additional run was performed using Co-60 with default parameters. The decay corrected DCC at peak dose matched the hand calculations when the average decay-ingrowth factor (0.937) over the 0-1-year time period was used.
4. It would help if the area correction factor listed on the "Soil DCC Ra226" worksheet had the variable name in its title (ACF_{ext-sv})

Scenario: Soil to Groundwater
Spreadsheet
Ra-226-DCC_Soil_to_Groundwater_s2gw_14MAR2023_632378.xlsx

1. The user manual equation for inhalation appears to be missing the A_{eq} term in the denominator. When this term is included in the denominator, the hand calculation for inhalation DCC for volatiles matches the values in the output spreadsheet.

- **inhalation** (The inhalation exposure route is only calculated for C-14 and H-3 as well as Rn-
volatilization in the equation comes from household uses of water (e.g., showering, laundering, d

$$DCC_{res-wat-inh}\left(\frac{pCi}{L}\right) = \frac{DL\left(\frac{mrem}{yr}\right)}{DCF_i\left(\frac{mrem}{pCi}\right) \times IFA_{res-adj}\left(6,195\ m^3\right) \times K\left(\frac{0.5\ L}{m^3}\right)}$$

The equation should read:

$$DCC_{res-wat-in}\ \left(\frac{pCi}{L}\right) = \frac{DL\ \frac{mrem}{yr}}{DCF_i\left(\frac{mrem}{pCi}\right) \times IFA_{res-adj} \times K \times A_{eq}}$$

2. The purpose of the soil to Groundwater DCC is to arrive at the soil concentration (in pCi/g) of a given radionuclide that will result in the dose constraint (1 mrem/yr default value) being met. This value is missing on the Peak DCC sheet in the output spreadsheet (see Table 3). The Soil to Groundwater PRG calculator (based on carcinogenic risk) however does provide this value, listed as the soil screening level (SSL). Suggest adding the SSL to the Peak Dose DCC for the complete decay chain.

Table 3. Soil-to-Groundwater DCCs for Ra-226

Peak Dose DCCs for Soil to Groundwater (complete chain decay)

Exposure Route	Peak DCC for Ra-226 DL=1 (pCi/L)	Maximum dose during peak interval (mrem/year)	Maximum Dose rate during peak interval (mrem/year)	Maximum Dose Year ED=1 (year)	Hand Calculated Values (pCi/L)
Ingestion	*1.21E-01*	*8.28E+00*	*8.28E+00*	*1.34E+02 - 1.35E+02*	*1.21E-01*
Inhalation	*2.89E+00*	*3.47E-01*	*3.47E-01*	*1.17E-01 - 1.12E+00*	*3.8E+00*
Immersion	*1.79E+03*	*5.60E-04*	*5.60E-04*	*1.20E-01 - 1.12E+00*	*1.79E+03*
Produce Consumption	*4.77E-02*	*2.10E+01*	*2.10E+01*	*1.34E+02 - 1.35E+02*	*4.77E-02*
Total	*3.38E-02*	*2.96E+01*	*2.96E+01*	*1.34E+02 - 1.35E+02*	*8.60E-02*

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3. The decay corrected peak DCC in water for water ingestion, produce ingestion, and immersion matched the values reported on the Peak DCC page. The inhalation and total did not. The inhalation value was calculated to be 3.8 pCi/L and total was 8.6E-2 pCi/L.

Scenario: Resident Soil with Site-Specific Values
Spreadsheet
Ra226-Cs137-Co60-DCC_Resident_soil_23MAR2023_1439220.xlsx

1. For this verification, three radionuclides were selected (Co-60, Cs-137, and Ra-226) and site-specific produce types and contaminated fractions were used. Comparisons assumed that the undecayed dose from each pathway was correct (based on earlier results). The main purpose of this exercise was to check the decay-corrected dose and Peak DCC.
2. For each radionuclide the produce pathway had problems. Namely, the undecayed DCC for produce was always significantly less than peak DCC which is decay corrected. The undecayed produce DCC for Co-60, Cs-137, and Ra-226 was 266 pCi/g, 251 pCi/g, and 4.78 pCi/g respectively. The peak DCCs for each radionuclide are shown in the Tables 4, 5, and 6 below. All the peak DCCs are substantially greater than the undecayed DCCs. The decay-corrected DCCs are expected to be higher but the difference is not accounted for by the decay-ingrowth factors for each radionuclide in the decay chain. The Ra-226 peak DCCs by pathway was based on the decay factor at 70 years (the time of peak dose) and these values are not expected match the hand calculation because each pathway peaks at different times compared to the total.

Table 4. Resident soil DCCs for Co-60 at the time of peak dose using non-default parameters.

Exposure Route	Peak DCC for Co-60 DL=12 (pCi/g)	Maximum dose during peak interval (mrem/year)	Maximum Dose rate during peak interval (mrem/year)	Maximum Dose Year ED=1 (year)	Hand Calculation DCC (pCi/g)
Ingestion	***1.46E+04***	***8.19E-04***	***8.74E-04***	***1.00E-08 - 1.00E+00***	***1.46E+04***
Inhalation	***2.30E+07***	***5.21E-07***	***5.56E-07***	***1.00E-08 - 1.00E+00***	***2.31E+07***
External Exposure	***2.50E+00***	***4.79E+00***	***5.12E+00***	***1.00E-08 - 1.00E+00***	***2.51E+00***
Produce Consumption	***7.38E+03***	***1.63E-03***	***1.74E-03***	***1.00E-08 - 1.00E+00***	***2.84E+02***
Total	***2.50E+00***	***4.80E+00***	***5.12E+00***	***1.00E-08 - 1.00E+00***	***2.49E+00***

Table 5. Resident soil DCCs for Cs-137 at the time of peak dose using non-default parameters.

Exposure Route	Peak DCC for Cs-137 DL=12 (pCi/g)	Maximum dose during peak interval (mrem/year)	Maximum Dose rate during peak interval (mrem/year)	Maximum Dose Year ED=1 (year)	Hand Calculation DCC (pCi/g)
Ingestion	***5.73E+03***	***2.09E-03***	***2.12E-03***	***1.00E-08 - 1.00E+00***	***5.73E+03***
Inhalation	***1.73E+07***	***6.95E-07***	***7.03E-07***	***1.00E-08 - 1.00E+00***	***1.73E+07***
External Exposure	***1.14E+01***	***1.05E+00***	***1.06E+00***	***1.00E-08 - 1.00E+00***	***1.15E+01***
Produce Consumption	***6.60E+03***	***1.82E-03***	***1.84E-03***	***1.00E-08 - 1.00E+00***	***2.54E+02***

Total	***1.14E+01***	***1.05E+00***	***1.07E+00***	***1.00E-08 - 1.00E+00***	***1.09E+01***

Table 6. Resident soil DCCs for Ra-226 at the time of peak dose using non-default parameters. The hand calculated DCCs are based on a decay factor of 70-years.

Exposure Route	Peak DCC for Ra-226 DL=12 (pCi/g)	Maximum dose during peak interval (mrem/year)	Maximum Dose rate during peak interval (mrem/year)	Maximum Dose Year ED=1 (year)	Hand Calculation DCC (pCi/g)
Ingestion	***2.48E+01***	***4.84E-01***	***4.84E-01***	***1.34E+02 - 1.35E+02***	***2.64E+01***
Inhalation	***3.56E+04***	***3.37E-04***	***3.37E-04***	***1.17E+02 - 1.18E+02***	***3.66E+04***
External Exposure	***3.46E+00***	***3.47E+00***	***3.47E+00***	***1.18E-01 - 1.12E+00***	***3.56E+00***
Produce Consumption	***1.32E+02***	***9.11E-02***	***9.11E-02***	***1.27E+02 - 1.28E+02***	***5.30E+00***
Total	***3.07E+00***	***3.91E+00***	***3.90E+00***	***7.09E+01 - 7.19E+01***	***1.97E+00***

Summary and Conclusions

In general, all the undecayed values reported in the spreadsheet appear to be calculated correctly. Some improvement in the documentation as stated in the comments would help with traceability of the calculations. Problems were encountered when decay corrections were applied, especially for the produce pathway. If other processes are taking place, such as hold-up times between harvest and consumption that would result in a decrease in activity in the food product, they are not explained in the documentation. Additionally, there is a fundamental flaw in the conceptual model for short-lived radioactive progeny in food products. That is, the activity level of short-lived progeny with long-lived parents in food products is controlled by the parent concentration which in turn is controlled by the parent soil-to-plant concentration ratio and not that of the progeny.

References

DOE (U.S. Department of Energy), 2022. *DOE Derived Concentration Technical Standard*. DOE STD-1196-2022. U.S. Department of Energy, Washington DC, December.

EPA (U.S. Environmental Protection Agency), 2019. *Federal Guidance Report 15: External Exposure to Radionuclides in Air, Water, and Soil*. EPA 402-R-19-002. U.S. Environmental Protection Agency, Washington DC, August

Ra226-DCC_Resident_soil

Default
Resident Soil Inputs

Variable	Value
DL (dose limit) mrem/yr	1
AAF_{res-c} (soil age adjustment factor - resident child) unitless	0.23
AAF_{res-a} (soil age adjustment factor - resident adult) unitless	0.77
t_{res} (time - resident) yr	1
ED_{res} (soil exposure duration - resident) yr	26
ET_{res} (soil exposure time - resident) hr/day	24
ET_{res-c} (soil exposure time - resident child) hr/day	24
ET_{res-a} (soil exposure time - resident adult) hr/day	24
ET_{res-i} (soil exposure time - indoor resident) hr/day	16.416
ET_{res-o} (soil exposure time - outdoor resident) hr/day	1.752
ED_{res-c} (soil exposure duration - resident child) yr	6
ED_{res-a} (soil exposure duration - resident adult) yr	20
EF_{res} (soil exposure frequency - resident) day/yr	350
EF_{res-c} (soil exposure frequency - resident child) day/yr	350
EF_{res-a} (soil exposure frequency - resident adult) day/yr	350
IRS_{res-a} (soil intake rate - resident adult) mg/day	100
IRS_{res-c} (soil intake rate - resident child) mg/day	200
IRA_{res-a} (soil inhalation rate - resident adult) m^3/day	20
IRA_{res-c} (soil inhalation rate - resident child) m^3/day	10
$IFS_{res-adj}$ (age-adjusted soil ingestion factor - resident) mg	43050
$IFA_{res-adj}$ (age-adjusted soil inhalation factor - resident) m^3	6195
GSF_i (gamma shielding factor - indoor) unitless	0.4
$MLF_{produce}$ (produce mass loading factor) unitless	0.0135
Site area for ACF (area correction factor) m^2	1000000
Cover thickness for GSF_o (gamma shielding factor) cm	0 cm
Cover thickness for GSF_b (gamma shielding factor) cm	0 cm
Climate zone	Temperate
Soil type	Default
AAF_{res-c} (biota age adjustment factor - resident child) unitless	0.23
AAF_{res-a} (biota age adjustment factor - resident adult) unitless	0.77
$IRAP_{res-a}$ (apple ingestion rate - resident adult) g/day	73.9
$IRAP_{res-c}$ (apple ingestion rate - resident child) g/day	72
$IFAP_{res-adj}$ (age-adjusted apple ingestion fraction) g	25712
$IRCI_{res-a}$ (citrus ingestion rate - resident adult) g/day	306.5
$IRCI_{res-c}$ (citrus ingestion rate - resident child) g/day	206
$IFCI_{res-adj}$ (age-adjusted citrus ingestion fraction) g	99184
$IRBE_{res-a}$ (berry ingestion rate - resident adult) g/day	35.2
$IRBE_{res-c}$ (berry ingestion rate - resident child) g/day	24.2
$IFBE_{res-adj}$ (age-adjusted berry ingestion fraction) g	11434
$IRPC_{res-a}$ (peach ingestion rate - resident adult) g/day	115.7
$IRPC_{res-c}$ (peach ingestion rate - resident child) g/day	110.2
$IFPC_{res-adj}$ (age-adjusted peach ingestion fraction) g	40052
$IRPR_{res-a}$ (pear ingestion rate - resident adult) g/day	52.1
$IRPR_{res-c}$ (pear ingestion rate - resident child) g/day	69.4
$IFPR_{res-adj}$ (age-adjusted pear ingestion fraction) g	19627
$IRST_{res-a}$ (strawberry ingestion rate - resident adult) g/day	40.6
$IRST_{res-c}$ (strawberry ingestion rate - resident child) g/day	27.5
$IFST_{res-adj}$ (age-adjusted strawberry ingestion fraction) g	13155
$IRAS_{res-a}$ (asparagus ingestion rate - resident adult) g/day	40.1
$IRAS_{res-c}$ (asparagus ingestion rate - resident child) g/day	11.9
$IFAS_{res-adj}$ (age-adjusted asparagus ingestion fraction) g	11764
$IRBT_{res-a}$ (beet ingestion rate - resident adult) g/day	34.4
$IRBT_{res-c}$ (beet ingestion rate - resident child) g/day	6
$IFBT_{res-adj}$ (age-adjusted beet ingestion fraction) g	9753
$IRBR_{res-a}$ (broccoli ingestion rate - resident adult) g/day	30.5
$IRBR_{res-c}$ (broccoli ingestion rate - resident child) g/day	13.2
$IFBR_{res-adj}$ (age-adjusted broccoli ingestion fraction) g	9282
$IRCB_{res-a}$ (cabbage ingestion rate - resident adult) g/day	85.1
$IRCB_{res-c}$ (cabbage ingestion rate - resident child) g/day	11.8
$IFCB_{res-adj}$ (age-adjusted cabbage ingestion fraction) g	23884
$IRCR_{res-a}$ (carrot ingestion rate - resident adult) g/day	27.1
$IRCR_{res-c}$ (carrot ingestion rate - resident child) g/day	14.5
$IFCR_{res-adj}$ (age-adjusted carrot ingestion fraction) g	8470
$IRCO_{res-a}$ (corn ingestion rate - resident adult) g/day	60.2
$IRCO_{res-c}$ (corn ingestion rate - resident child) g/day	23.2
$IFCO_{res-adj}$ (age-adjusted corn ingestion fraction) g	18091
$IRCU_{res-a}$ (cucumber ingestion rate - resident adult) g/day	82.3
$IRCU_{res-c}$ (cucumber ingestion rate - resident child) g/day	24.5
$IFCU_{res-adj}$ (age-adjusted cucumber ingestion fraction) g	24152
$IRLE_{res-a}$ (lettuce ingestion rate - resident adult) g/day	36.7
$IRLE_{res-c}$ (lettuce ingestion rate - resident child) g/day	3.4
$IFLE_{res-adj}$ (age-adjusted lettuce ingestion fraction) g	10164
$IRLI_{res-a}$ (lima bean ingestion rate - resident adult) g/day	33.9
$IRLI_{res-c}$ (lima bean ingestion rate - resident child) g/day	22
$IFLI_{res-adj}$ (age-adjusted lima bean ingestion fraction) g	10907
$IROK_{res-a}$ (okra ingestion rate - resident adult) g/day	30.4
$IROK_{res-c}$ (okra ingestion rate - resident child) g/day	9.4
$IFOK_{res-adj}$ (age-adjusted okra ingestion fraction) g	8949
$IRON_{res-a}$ (onion ingestion rate - resident adult) g/day	21.5
$IRON_{res-c}$ (onion ingestion rate - resident child) g/day	5.9
$IFON_{res-adj}$ (age-adjusted onion ingestion fraction) g	6269
$IRPE_{res-a}$ (pea ingestion rate - resident adult) g/day	35
$IRPE_{res-c}$ (pea ingestion rate - resident child) g/day	22.6
$IFPE_{res-adj}$ (age-adjusted pea ingestion fraction) g	11251
$IRPP_{res-a}$ (pepper ingestion rate - resident adult) g/day	19.1
$IRPP_{res-c}$ (pepper ingestion rate - resident child) g/day	5.9
$IFPP_{res-adj}$ (age-adjusted pepper ingestion fraction) g	5622
$IRPU_{res-a}$ (pumpkin ingestion rate - resident adult) g/day	63.5
$IRPU_{res-c}$ (pumpkin ingestion rate - resident child) g/day	21.2
$IFPU_{res-adj}$ (age-adjusted pumpkin ingestion fraction) g	18819
$IRSN_{res-a}$ (snap bean ingestion rate - resident adult) g/day	53.8
$IRSN_{res-c}$ (snap bean ingestion rate - resident child) g/day	28.3
$IFSN_{res-adj}$ (age-adjusted snap bean ingestion fraction) g	16777
$IRTO_{res-a}$ (tomato ingestion rate - resident adult) g/day	80.1
$IRTO_{res-c}$ (tomato ingestion rate - resident child) g/day	36
$IFTO_{res-adj}$ (age-adjusted tomato ingestion fraction) g	24484
$IRPT_{res-a}$ (potato ingestion rate - resident adult) g/day	127.8
$IRPT_{res-c}$ (potato ingestion rate - resident child) g/day	47.3
$IFPT_{res-adj}$ (age-adjusted potato ingestion fraction) g	38249
$CF_{res-produce}$ (contaminated plant fraction) unitless	1
$CF_{res-apple}$ (contaminated apple fraction) unitless	1
$CF_{res-citrus}$ (contaminated citrus fraction) unitless	1
$CF_{res-berry}$ (contaminated berry fraction) unitless	1
$CF_{res-peach}$ (contaminated peach fraction) unitless	1
$CF_{res-pear}$ (contaminated pear fraction) unitless	1
$CF_{res-strawberry}$ (contaminated strawberry fraction) unitless	1
$CF_{res-asparagus}$ (contaminated asparagus fraction) unitless	1

$CF_{res-beet}$ (contaminated beet fraction) unitless	1
$CF_{res-broccoli}$ (contaminated broccoli fraction) unitless	1
$CF_{res-cabbage}$ (contaminated cabbage fraction) unitless	1
$CF_{res-carrot}$ (contaminated carrot fraction) unitless	1
$CF_{res-corn}$ (contaminated corn fraction) unitless	1
$CF_{res-cucumber}$ (contaminated cucumber fraction) unitless	1
$CF_{res-lettuce}$ (contaminated lettuce fraction) unitless	1
$CF_{res-lima\ bean}$ (contaminated lima bean fraction) unitless	1
$CF_{res-okra}$ (contaminated okra fraction) unitless	1
$CF_{res-onion}$ (contaminated onion fraction) unitless	1
$CF_{res-pea}$ (contaminated pea fraction) unitless	1
$CF_{res-pepper}$ (contaminated pepper fraction) unitless	1
$CF_{res-pumpkin}$ (contaminated pumpkin fraction) unitless	1
$CF_{res-snap\ bean}$ (contaminated snap bean fraction) unitless	1
$CF_{res-tomato}$ (contaminated tomato fraction) unitless	1
$CF_{res-potato}$ (contaminated potato fraction) unitless	1
MLF_{apple} (apple mass loading factor) unitless	0.00016
MLF_{citrus} (citrus mass loading factor) unitless	0.000157
MLF_{berry} (berry mass loading factor) unitless	0.000166
MLF_{peach} (peach mass loading factor) unitless	0.00015
MLF_{pear} (pear mass loading factor) unitless	0.00016
$MLF_{strawberry}$ (strawberry mass loading factor) unitless	0.00008
$MLF_{asparagus}$ (asparagus mass loading factor) unitless	0.000079
MLF_{beet} (beet mass loading factor) unitless	0.000138
$MLF_{broccoli}$ (broccoli mass loading factor) unitless	0.00101
$MLF_{cabbage}$ (cabbage mass loading factor) unitless	0.000105
MLF_{carrot} (carrot mass loading factor) unitless	0.000097
MLF_{corn} (corn mass loading factor) unitless	0.000145
$MLF_{cucumber}$ (cucumber mass loading factor) unitless	0.00004
$MLF_{lettuce}$ (lettuce mass loading factor) unitless	0.0135
$MLF_{lima\ bean}$ (lima bean mass loading factor) unitless	0.00383
MLF_{okra} (okra mass loading factor) unitless	0.00008
MLF_{onion} (onion mass loading factor) unitless	0.000097
MLF_{pea} (pea mass loading factor) unitless	0.000178
MLF_{pepper} (pepper mass loading factor) unitless	0.00222
$MLF_{pumpkin}$ (pumpkin mass loading factor) unitless	0.000058
$MLF_{snap\ bean}$ (snap bean mass loading factor) unitless	0.005
MLF_{tomato} (tomato mass loading factor) unitless	0.00177
MLF_{potato} (potato mass loading factor) unitless	0.00021
EF_{res} (produce exposure frequency - resident) day/yr	350
ED_{res} (produce exposure duration - resident) yr	26
ED_{res-c} (produce exposure duration - resident child) yr	6
ED_{res-a} (produce exposure duration - resident adult) yr	20
EF_{res-c} (produce exposure frequency - resident child) day/yr	350
EF_{res-a} (produce exposure frequency - resident adult) day/yr	350
City (Climate Zone)	Default
A_s (acres)	0.5
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77
PEF (particulate emission factor) m^3/kg	1359344438
A (PEF Dispersion Constant)	16.2302
B (PEF Dispersion Constant)	18.7762
C (PEF Dispersion Constant)	216.108
V (fraction of vegetative cover) unitless	0.5
U_m (mean annual wind speed) m/s	4.69
U_t (equivalent threshold value)	11.32
F(x) (function dependent on U_m/U_t) unitless	0.194

Output generated 27FEB2023:16:41:00

Resident DCCs for Soil (complete chain, no decay)

Isotope	Parent	ICRP Lung Absorption Type	Ingestion DCF (mrem/pCi)	Inhalation DCF (mrem/pCi)	External Exposure DCF (mrem/yr per pCi/g)	Half-life (years)	Default Soil Volume Area Correction Factor	Wet Soil-to-plant transfer factor Woody tree (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Leaf (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Root (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Shrub (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Non-leafy fruit (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Maize grain (pCi/g-fresh plant per pCi/g-wet soil)
Ra-226	Ra-226	S	1.68E-03	3.81E-02	3.18E-02	1.60E+03	1.00E+00	1.00E-02	9.10E-02	7.00E-02	1.00E-02	1.70E-02	2.40E-03
Rn-222	Ra-226	-	0.00E+00	6.55E-06	2.13E-03	1.05E-02	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Po-218	Ra-226	-	0.00E+00	7.62E-06	9.23E-09	5.90E-06	9.00E-01	2.00E-04	7.40E-03	5.80E-03	2.00E-04	2.00E-04	2.40E-04
At-218	Ra-226	-	0.00E+00	0.00E+00	5.57E-05	4.76E-08	9.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01
Rn-218	Ra-226	-	0.00E+00	0.00E+00	4.26E-03	1.11E-09	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb-214	Ra-226	S	7.36E-07	4.66E-05	1.26E+00	5.10E-05	1.00E+00	1.00E-02	8.00E-02	1.50E-02	1.00E-02	1.50E-02	1.20E-03
Bi-214	Ra-226	S	5.51E-07	3.66E-05	9.13E+00	3.79E-05	1.00E+00	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
Po-214	Ra-226	-	0.00E+00	0.00E+00	4.80E-04	5.21E-12	1.00E+00	2.00E-04	7.40E-03	5.80E-03	2.00E-04	2.00E-04	2.40E-04
Tl-210	Ra-226	-	0.00E+00	0.00E+00	1.68E+01	2.47E-06	1.00E+00	8.00E-05	8.00E-04	8.00E-05	8.00E-05	8.00E-04	8.00E-04
Pb-210	Ra-226	S	3.77E-03	2.23E-02	2.09E-03	2.22E+01	1.00E+00	1.00E-02	8.00E-02	1.50E-02	1.00E-02	1.50E-02	1.20E-03
Bi-210	Ra-226	S	6.66E-06	5.40E-04	5.47E-03	1.37E-02	1.00E+00	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
Po-210	Ra-226	S	6.48E-03	1.73E-02	5.64E-05	3.79E-01	1.00E+00	2.00E-04	7.40E-03	5.80E-03	2.00E-04	2.00E-04	2.40E-04
Hg-206	Ra-226	-	0.00E+00	0.00E+00	6.13E-01	1.55E-05	1.00E+00	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01
Tl-206	Ra-226	-	0.00E+00	0.00E+00	1.28E-02	7.99E-06	1.00E+00	8.00E-05	8.00E-04	8.00E-05	8.00E-05	8.00E-04	8.00E-04

Isotope	Wet Soil-to-plant transfer factor Legume seed (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Tuber (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Herbaceous (pCi/g-fresh plant per pCi/g-wet soil)	Default Soil Volume Gamma Shielding Factor	Total Indoor GSF Soil Volume	Particulate Emission Factor (m^3/kg)	Ingestion DCC DL=1.0E+00 (pCi/g)	Inhalation DCC DL=1.0E+00 (pCi/g)	External Exposure DCC DL=1.0E+00 (pCi/g)	Produce Consumption DCC DL=1.0E+00 (pCi/g)	Total DCC DL=1.0E+00 (pCi/g)	Total DCC DL=1.0E+00 (mg/kg)	Total (hand calc)
Ra-226	1.40E-02	1.10E-02	1.00E-02	1.00E+00	4.00E-01	1.36E+09	1.39E+01	5.76E+03	9.47E+01	5.46E-02	**5.44E-02**	5.51E-08	5.44E-02
Rn-222	0.00E+00	0.00E+00	0.00E+00	1.00E+00	4.00E-01	1.36E+09	-	3.35E+07	1.41E+03	-	**1.41E+03**	9.20E-09	1.41E+03
Po-218	2.70E-04	2.70E-03	2.00E-04	1.00E+00	4.00E-01	1.36E+09	-	2.88E+07	3.62E+08	-	**2.67E+07**	9.60E-08	2.67E+07
At-218	2.00E-01	2.00E-01	2.00E-01	1.00E+00	4.00E-01	1.36E+09	-	-	6.01E+04	-	**6.01E+04**	1.74E-12	6.01E+04
Rn-218	0.00E+00	0.00E+00	0.00E+00	1.00E+00	4.00E-01	1.36E+09	-	-	7.06E+02	-	**7.06E+02**	4.79E-16	7.06E+02
Pb-214	5.30E-03	1.50E-03	1.00E-02	1.00E+00	4.00E-01	1.36E+09	3.15E+04	4.71E+06	2.39E+00	1.66E+02	**2.36E+00**	7.21E-14	2.36E+00
Bi-214	1.00E-01	1.00E-01	1.00E-01	1.00E+00	4.00E-01	1.36E+09	4.21E+04	6.00E+06	3.29E-01	3.86E+01	**3.27E-01**	7.41E-15	3.26E-01
Po-214	2.70E-04	2.70E-03	2.00E-04	1.00E+00	4.00E-01	1.36E+09	-	-	6.27E+03	-	**6.27E+03**	1.96E-17	6.27E+03
Tl-210	8.00E-04	8.00E-05	8.00E-05	1.00E+00	4.00E-01	1.36E+09	-	-	1.79E-01	-	**1.79E-01**	2.61E-16	1.79E-01
Pb-210	5.30E-03	1.50E-03	1.00E-02	1.00E+00	4.00E-01	1.36E+09	6.15E+00	9.83E+03	1.44E+03	3.25E-02	**3.23E-02**	4.22E-10	3.23E-02
Bi-210	1.00E-01	1.00E-01	1.00E-01	1.00E+00	4.00E-01	1.36E+09	3.49E+03	4.06E+05	5.50E+02	3.20E+00	**3.17E+00**	2.56E-11	3.18E+00
Po-210	2.70E-04	2.70E-03	2.00E-04	1.00E+00	4.00E-01	1.36E+09	3.59E+00	1.27E+04	5.33E+04	1.48E-01	**1.42E-01**	3.18E-11	1.42E-01
Hg-206	3.00E-01	3.00E-01	3.00E-01	1.00E+00	4.00E-01	1.36E+09	-	-	4.91E+00	-	**4.91E+00**	4.39E-14	4.91E+00
Tl-206	8.00E-04	8.00E-05	8.00E-05	1.00E+00	4.00E-01	1.36E+09	-	-	2.35E+02	-	**2.35E+02**	1.09E-12	2.35E+02

Output generated 27FEB2023:16:41:00

Hand Calcuations

						Decay Fractions					Decay Corrected				
	Soil Ing	Inh	Ext	Total							Ext	Produce	Inh	Soil	Total
Isotope						1yr	127yr	117yr	134yr	102yr	1yr	127yr	117yr	134yr	102yr
Ra-226	1.38E+01	5.76E+03	9.46E+01	5.44E-02	Ra-226	1.00E+00	9.46E-01	9.51E-01	9.44E-01	9.57E-01	9.47E+01	5.77E-02	6.06E+03	1.47E+01	5.68E-02
Rn-222		3.35E+07	1.41E+03	1.41E+03	Rn-222	1.00E+00	9.46E-01	9.51E-01	9.44E-01	9.57E-01	1.41E+03		3.52E+07		1.47E+03
Po-218		2.88E+07	3.26E+08	2.67E+07	Po-218	1.00E+00	9.46E-01	9.51E-01	9.44E-01	9.57E-01	3.26E+08		3.03E+07		2.79E+07
At-218			5.40E+04	6.01E+04	At-218	2.00E-04	1.89E-04	1.90E-04	1.89E-04	1.91E-04	2.70E+08				3.15E+08
Rn-218			7.06E+02	7.06E+02			1.89E-07			1.91E-07					
Pb-214	3.16E+04	4.71E+06	2.39E+00	2.36E+00	Po-214	9.98E-01	9.46E-01	9.49E-01	9.43E-01	9.57E-01	2.39E+00	1.75E+02	4.96E+06	3.35E+04	2.46E+00
Bi-214	4.22E+04	6.00E+06	3.30E-01	3.26E-01	Bi-214	9.99E-01	9.46E-01	9.50E-01	9.43E-01	9.57E-01	3.30E-01	4.08E+01	6.31E+06	4.47E+04	3.41E-01
Po-214			6.27E+03	6.27E+03	Pb-214	9.98E-01	9.46E-01	9.49E-01	9.43E-01	9.57E-01	6.28E+03				6.55E+03
Tl-210			1.79E-01	1.79E-01	Tl-210	2.10E-04	1.99E-04	1.99E-04	1.98E-04	2.01E-04	8.54E+02				8.91E+02
Pb-210	6.16E+00	9.84E+03	1.44E+03	3.23E-02	Pb-210	3.02E-02	9.41E-01	9.37E-01	9.41E-01	9.28E-01	4.76E+04	3.45E-02	1.05E+04	6.55E+00	3.48E-02
Bi-210	3.49E+03	4.06E+05	5.50E+02	3.18E+00	Bi-210	2.96E-02	9.41E-01	9.37E-01	9.41E-01	9.28E-01	1.86E+04	3.40E+00	4.34E+05	3.71E+03	3.43E+00
Po-210	3.58E+00	1.27E+04	5.33E+04	1.42E-01	Po-210	1.58E-02	9.40E-01	9.36E-01	9.40E-01	9.28E-01	3.38E+06	1.57E-01	1.35E+04	3.81E+00	1.53E-01
Hg-206			4.91E+00	4.91E+00		5.75E-10	1.79E-08			1.76E-08	8.54E+09				2.79E+08
Tl-206			2.35E+02	2.35E+02		3.97E-08	1.26E-06			1.24E-06	5.92E+09				1.90E+08
										Total	2.89E-01	1.89E-02	2.97E+03	2.07E+00	1.77E-02
										Reported Pe	2.89E-01	4.91E-01	2.97E+03	2.07E+00	1.72E-01

Decay Fractions

Time (y)	1.00E+00	1.02E+02	1.17E+02	1.34E+02
Ra-226	1.00E+00	9.57E-01	9.51E-01	9.44E-01
Rn-222	1.00E+00	9.57E-01	9.51E-01	9.44E-01
Po-218	1.00E+00	9.57E-01	9.51E-01	9.44E-01
Pb-214	9.99E-01	9.57E-01	9.50E-01	9.43E-01
Bi-214	9.99E-01	9.57E-01	9.50E-01	9.43E-01
Po-214	9.99E-01	9.56E-01	9.50E-01	9.43E-01
Pb-210	3.02E-02	9.28E-01	9.37E-01	9.41E-01
Bi-210	2.96E-02	9.28E-01	9.37E-01	9.41E-01
Po-210	1.58E-02	9.27E-01	9.37E-01	9.41E-01

Resident Produce DCCs for Soil

Isotope	Apple Consumption DCC DL=1.0E+00 (pCi/g)	Asparagus Consumption DCC DL=1.0E+00 (pCi/g)	Beet Consumption DCC DL=1.0E+00 (pCi/g)	Berry Consumption DCC DL=1.0E+00 (pCi/g)	Broccoli Consumption DCC DL=1.0E+00 (pCi/g)	Cabbage Consumption DCC DL=1.0E+00 (pCi/g)	Carrot Consumption DCC DL=1.0E+00 (pCi/g)	Citrus fruit Consumption DCC DL=1.0E+00 (pCi/g)	Corn Consumption DCC DL=1.0E+00 (pCi/g)	Cucumber Consumption DCC DL=1.0E+00 (pCi/g)	Lettuce Consumption DCC DL=1.0E+00 (pCi/g)
Ra-226	2.28E+00	5.57E-01	8.72E-01	5.13E+00	3.57E+00	2.74E-01	1.00E+00	5.92E-01	1.30E+01	1.45E+00	5.62E-01
Rn-222	-	-	-	-	-	-	-	-	-	-	-
Po-218	-	-	-	-	-	-	-	-	-	-	-
At-218	-	-	-	-	-	-	-	-	-	-	-
Rn-218	-	-	-	-	-	-	-	-	-	-	-
Pb-214	5.20E+03	1.44E+03	9.20E+03	1.17E+04	9.14E+03	7.10E+02	1.06E+04	1.35E+03	5.58E+04	3.74E+03	1.43E+03
Bi-214	7.04E+02	1.54E+03	1.86E+03	1.58E+03	1.93E+03	7.59E+02	2.14E+03	1.83E+02	1.00E+03	7.51E+02	1.57E+03
Po-214	-	-	-	-	-	-	-	-	-	-	-
Tl-210	-	-	-	-	-	-	-	-	-	-	-
Pb-210	1.01E+00	2.81E-01	1.79E+00	2.28E+00	1.78E+00	1.38E-01	2.07E+00	2.63E-01	1.09E+01	7.29E-01	2.79E-01
Bi-210	5.83E+01	1.28E+02	1.54E+02	1.31E+02	1.60E+02	6.28E+01	1.77E+02	1.51E+01	8.29E+01	6.21E+01	1.30E+02
Po-210	1.67E+01	1.76E+00	2.67E+00	3.69E+01	1.38E+01	8.62E-01	3.09E+00	4.36E+00	2.22E+01	2.66E+01	7.27E-01
Hg-206	-	-	-	-	-	-	-	-	-	-	-
Tl-206	-	-	-	-	-	-	-	-	-	-	-

Isotope	Lima beans Consumption DCC DL=1.0E+00 (pCi/g)	Okra Consumption DCC DL=1.0E+00 (pCi/g)	Onion Consumption DCC DL=1.0E+00 (pCi/g)	Peaches Consumption DCC DL=1.0E+00 (pCi/g)	Pears Consumption DCC DL=1.0E+00 (pCi/g)	Peas Consumption DCC DL=1.0E+00 (pCi/g)	Peppers Consumption DCC DL=1.0E+00 (pCi/g)	Potatoes Consumption DCC DL=1.0E+00 (pCi/g)	Pumpkin Consumption DCC DL=1.0E+00 (pCi/g)	Snap beans Consumption DCC DL=1.0E+00 (pCi/g)	Strawberries Consumption DCC DL=1.0E+00 (pCi/g)
Ra-226	3.07E+00	3.90E+00	1.36E+00	1.47E+00	2.99E+00	3.74E+00	5.52E+00	1.39E+00	1.86E+00	1.87E+00	4.50E+00
Rn-222	-	-	-	-	-	-	-	-	-	-	-
Po-218	-	-	-	-	-	-	-	-	-	-	-
At-218	-	-	-	-	-	-	-	-	-	-	-
Rn-218	-	-	-	-	-	-	-	-	-	-	-
Pb-214	1.36E+04	1.01E+04	1.44E+04	3.34E+03	6.81E+03	2.20E+04	1.40E+04	2.08E+04	4.79E+03	7.86E+03	1.02E+04
Bi-214	1.60E+03	2.03E+03	2.89E+03	4.52E+02	9.23E+02	1.61E+03	3.16E+03	4.73E+02	9.63E+02	1.03E+03	1.38E+03
Po-214	-	-	-	-	-	-	-	-	-	-	-
Tl-210	-	-	-	-	-	-	-	-	-	-	-
Pb-210	2.66E+00	1.96E+00	2.80E+00	6.52E-01	1.33E+00	4.30E+00	2.74E+00	4.05E+00	9.35E-01	1.53E+00	2.00E+00
Bi-210	1.33E+02	1.68E+02	2.39E+02	3.74E+01	7.64E+01	1.33E+02	2.61E+02	3.92E+01	7.97E+01	8.52E+01	1.14E+02
Po-210	3.45E+00	6.16E+01	4.18E+00	1.10E+01	2.19E+01	3.06E+01	1.14E+01	1.39E+00	3.18E+01	1.75E+00	4.19E+01
Hg-206	-	-	-	-	-	-	-	-	-	-	-
Tl-206	-	-	-	-	-	-	-	-	-	-	-

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Hand Calculation PRGres-produce-ing (pCi/g)

Isotope																						
Ra-226	2.32E-02	5.06E-02	6.10E-02	5.21E-02	6.41E-02	2.49E-02	7.03E-02	6.00E-03	3.29E-02	2.46E-02	5.86E-02	5.46E-02	6.65E-02	9.49E-02	1.49E-02	3.03E-02	5.29E-02	1.06E-01	1.56E-02	3.16E-02	3.55E-02	4.52E-02
Rn-222																						
Po-218																						
At-218																						
Rn-218																						
Pb-214	5.28E+01	1.15E+02	1.39E+02	1.19E+02	1.46E+02	5.69E+01	1.60E+02	1.37E+01	7.51E+01	5.63E+01	1.34E+02	1.25E+02	1.52E+02	2.17E+02	3.39E+01	6.92E+01	1.21E+02	2.42E+02	3.55E+01	7.22E+01	8.10E+01	1.03E+02
Bi-214	7.06E+01	1.54E+02	1.86E+02	1.59E+02	1.96E+02	7.60E+01	2.14E+02	1.83E+01	1.00E+02	7.51E+01	1.79E+02	1.66E+02	2.03E+02	2.90E+02	4.53E+01	9.25E+01	1.61E+02	3.23E+02	4.74E+01	9.64E+01	1.08E+02	1.38E+02
Po-214																						
Tl-210																						
Pb-210	1.03E-02	2.25E-02	2.72E-02	2.32E-02	2.86E-02	1.11E-02	3.13E-02	2.67E-03	1.47E-02	1.10E-02	2.61E-02	2.43E-02	2.96E-02	4.23E-02	6.62E-03	1.35E-02	2.36E-02	4.72E-02	6.93E-03	1.41E-02	1.58E-02	2.02E-02
Bi-210	5.84E+00	1.28E+01	1.54E+01	1.31E+01	1.62E+01	6.29E+00	1.77E+01	1.51E+00	8.30E+00	6.22E+00	1.48E+01	1.38E+01	1.68E+01	2.40E+01	3.75E+00	7.65E+00	1.33E+01	2.67E+01	3.93E+00	7.98E+00	8.95E+00	1.14E+01
Po-210	6.00E-03	1.31E-02	1.58E-02	1.35E-02	1.66E-02	6.46E-03	1.82E-02	1.56E-03	8.53E-03	6.39E-03	1.52E-02	1.41E-02	1.72E-02	2.46E-02	3.85E-03	7.86E-03	1.37E-02	2.74E-02	4.03E-03	8.20E-03	9.20E-03	1.17E-02
Hg-206																						
Tl-206																						

Hand Calculation PRGres-soil-produce-ing (pCi/g)

Isotope																						
Ra-226	2.28E+00	5.56E-01	8.70E-01	5.12E+00	3.56E+00	2.74E-01	1.00E+00	5.91E-01	1.29E+01	1.45E+00	5.60E-01	3.06E+00	3.89E+00	1.35E+00	1.46E+00	2.98E+00	3.73E+00	5.51E+00	1.39E+00	1.85E+00	1.87E+00	4.49E+00
Rn-222																						
Po-218																						
At-218																						
Rn-218																						
Pb-214	5.20E+03	1.44E+03	9.20E+03	1.17E+04	9.14E+03	7.10E+02	1.06E+04	1.35E+03	5.58E+04	3.74E+03	1.43E+03	1.36E+04	1.01E+04	1.44E+04	3.34E+03	6.81E+03	2.20E+04	1.40E+04	2.08E+04	4.79E+03	7.86E+03	1.02E+04
Bi-214	7.05E+02	1.54E+03	1.86E+03	1.58E+03	1.94E+03	7.59E+02	2.14E+03	1.83E+02	1.00E+03	7.51E+02	1.57E+03	1.60E+03	2.03E+03	2.89E+03	4.52E+02	9.23E+02	1.61E+03	3.16E+03	4.73E+02	9.64E+02	1.03E+03	1.38E+03
Po-214																						
Tl-210																						
Pb-210	1.02E+00	2.82E-01	1.80E+00	2.28E+00	1.78E+00	1.39E-01	2.07E+00	2.63E-01	1.09E+01	7.30E-01	2.79E-01	2.66E+00	1.97E+00	2.80E+00	6.52E-01	1.33E+00	4.30E+00	2.74E+00	4.06E+00	9.36E-01	1.53E+00	2.00E+00
Bi-210	5.83E+01	1.28E+02	1.54E+02	1.31E+02	1.60E+02	6.28E+01	1.77E+02	1.51E+01	8.29E+01	6.21E+01	1.30E+02	1.33E+02	1.68E+02	2.39E+02	3.74E+01	7.64E+01	1.33E+02	2.61E+02	3.92E+01	7.97E+01	8.52E+01	1.14E+02
Po-210	1.67E+01	1.75E+00	2.66E+00	3.69E+01	1.37E+01	8.61E-01	3.09E+00	4.36E+00	2.22E+01	2.66E+01	7.26E-01	3.45E+00	6.16E+01	4.17E+00	1.10E+01	2.18E+01	3.06E+01	1.13E+01	1.39E+00	3.18E+01	1.75E+00	4.19E+01
Hg-206																						
Tl-206																						

$IFAP_{res-adj}$ (age-adjusted apple ingestion fraction) g	$IFAS_{res-adj}$ (age-adjusted asparagus ingestion fraction) g	$IFBT_{res-adj}$ (age-adjusted beet ingestion fraction) g	$IFBE_{res-adj}$ (age-adjusted berry ingestion fraction) g	$IFBR_{res-adj}$ (age-adjusted broccoli ingestion fraction) g	$IFCB_{res-adj}$ (age-adjusted cabbage ingestion fraction) g	$IFCR_{res-adj}$ (age-adjusted carrot ingestion fraction) g	$IFCI_{res-adj}$ (age-adjusted citrus ingestion fraction) g	$IFCO_{res-adj}$ (age-adjusted corn ingestion fraction) g	$IFCU_{res-adj}$ (age-adjusted cucumber ingestion fraction) g	$IFLE_{res-adj}$ (age-adjusted lettuce ingestion fraction) g	$IFLI_{res-adj}$ (age-adjusted lima bean ingestion fraction) g	$IFOK_{res-adj}$ (age-adjusted okra ingestion fraction) g	$IFON_{res-adj}$ (age-adjusted onion ingestion fraction) g	$IFPC_{res-adj}$ (age-adjusted peach ingestion fraction) g	$IFPR_{res-adj}$ (age-adjusted pear ingestion fraction) g	$IFPE_{res-adj}$ (age-adjusted pea ingestion fraction) g	$IFPP_{res-adj}$ (age-adjusted pepper ingestion fraction) g	$IFPT_{res-adj}$ (age-adjusted potato ingestion fraction) g	$IFPU_{res-adj}$ (age-adjusted pumpkin ingestion fraction) g	$IFSN_{res-adj}$ (age-adjusted snap bean ingestion fraction) g	$IFST_{res-adj}$ (age-adjusted strawberry ingestion fraction) g	$IFTO_{res-adj}$ (age-adjusted tomato ingestion fraction) g
25712	11764	9753	11434	9282	23884	8470	99184	18091	24152	10164	10907	8949	6269	40052	19627	11251	5622	38249	18819	16777	13155	24484

MLF_{apple} (apple mass loading factor) unitless	$MLF_{asparagus}$ (asparagus mass loading factor) unitless	MLF_{beet} (beet mass loading factor) unitless	MLF_{berry} (berry mass loading factor) unitless	$MLF_{broccoli}$ (broccoli mass loading factor) unitless	$MLF_{cabbage}$ (cabbage mass loading factor) unitless	MLF_{carrot} (carrot mass loading factor) unitless	MLF_{citrus} (citrus mass loading factor) unitless	MLF_{corn} (corn mass loading factor) unitless	$MLF_{cucumber}$ (cucumber mass loading factor) unitless	$MLF_{lettuce}$ (lettuce mass loading factor) unitless	$MLF_{lima\ bean}$ (lima bean mass loading factor) unitless	MLF_{okra} (okra mass loading factor) unitless	MLF_{onion} (onion mass loading factor) unitless	MLF_{peach} (peach mass loading factor) unitless	MLF_{pear} (pear mass loading factor) unitless	MLF_{pea} (pea mass loading factor) unitless	MLF_{pepper} (pepper mass loading factor) unitless	MLF_{potato} (potato mass loading factor) unitless	$MLF_{pumpkin}$ (pumpkin mass loading factor) unitless	$MLF_{snap\ bean}$ (snap bean mass loading factor) unitless	$MLF_{strawberry}$ (strawberry mass loading factor) unitless	MLF_{tomato} (tomato mass loading factor) unitless
0.00016	0.000079	0.000138	0.000166	0.00101	0.000105	0.000097	0.000157	0.000145	0.00004	0.0135	0.00383	0.00008	0.000097	0.00015	0.00016	0.000178	0.00222	0.00021	0.000058	0.005	0.00008	0.00177

CF=1 for all food types

Isotope	Wet Soil-to-plant transfer factor Woody tree (pCi/g-fresh plant	Wet Soil-to-plant transfer factor Leaf (pCi/g-fresh plant	Wet Soil-to-plant transfer factor Root (pCi/g-fresh plant	Wet Soil-to-plant transfer factor Shrub (pCi/g-fresh plant	Wet Soil-to-plant transfer factor Non-leafy fruit (pCi/g-fresh plant	Wet Soil-to-plant transfer factor Leaf (pCi/g-fresh plant	Wet Soil-to-plant transfer factor Root (pCi/g-fresh plant	Wet Soil-to-plant transfer factor Woody tree (pCi/g-fresh plant	Wet Soil-to-plant transfer factor Maize grain (pCi/g-fresh plant	Wet Soil-to-plant transfer factor Non-leafy fruit (pCi/g-fresh plant	Wet Soil-to-plant transfer factor Leaf (pCi/g-fresh plant	Wet Soil-to-plant transfer factor Legume seed (pCi/g-fresh plant
Ra-226	1.00E-02	9.10E-02	7.00E-02	1.00E-02	1.70E-02	9.10E-02	7.00E-02	1.00E-02	2.40E-03	1.70E-02	9.10E-02	1.40E-02
Rn-222	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Po-218	2.00E-04	7.40E-03	5.80E-03	2.00E-04	2.00E-04	7.40E-03	5.80E-03	2.00E-04	2.40E-04	2.00E-04	7.40E-03	2.70E-04
At-218	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01
Rn-218	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb-214	1.00E-02	8.00E-02	1.50E-02	1.00E-02	1.50E-02	8.00E-02	1.50E-02	1.00E-02	1.20E-03	1.50E-02	8.00E-02	5.30E-03
Bi-214	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
Po-214	2.00E-04	7.40E-03	5.80E-03	2.00E-04	2.00E-04	7.40E-03	5.80E-03	2.00E-04	2.40E-04	2.00E-04	7.40E-03	2.70E-04
Tl-210	8.00E-05	8.00E-04	8.00E-05	8.00E-05	8.00E-04	8.00E-04	8.00E-05	8.00E-05	8.00E-04	8.00E-04	8.00E-04	8.00E-04
Pb-210	1.00E-02	8.00E-02	1.50E-02	1.00E-02	1.50E-02	8.00E-02	1.50E-02	1.00E-02	1.20E-03	1.50E-02	8.00E-02	5.30E-03
Bi-210	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
Po-210	2.00E-04	7.40E-03	5.80E-03	2.00E-04	2.00E-04	7.40E-03	5.80E-03	2.00E-04	2.40E-04	2.00E-04	7.40E-03	2.70E-04
Hg-206	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01
Tl-206	8.00E-05	8.00E-04	8.00E-05	8.00E-05	8.00E-04	8.00E-04	8.00E-05	8.00E-05	8.00E-04	8.00E-04	8.00E-04	8.00E-04

Isotope	Wet Soil-to-plant transfer factor Non-leafy fruit (pCi/g-fresh plant	Wet Soil-to-plant transfer factor Root (pCi/g-fresh plant	Wet Soil-to-plant transfer factor Woody tree (pCi/g-fresh plant	Wet Soil-to-plant transfer factor Woody tree (pCi/g-fresh plant	Wet Soil-to-plant transfer factor Legume seed (pCi/g-fresh plant	Wet Soil-to-plant transfer factor Non-leafy fruit (pCi/g-fresh plant	Wet Soil-to-plant transfer factor Tuber (pCi/g-fresh plant	Wet Soil-to-plant transfer factor Non-leafy fruit (pCi/g-fresh plant	Wet Soil-to-plant transfer factor Legume seed (pCi/g-fresh plant	Wet Soil-to-plant transfer factor Herbaceous (pCi/g-fresh plant	Wet Soil-to-plant transfer factor Legume seed (pCi/g-fresh	Wet Soil-to-plant transfer factor
Ra-226	1.70E-02	7.00E-02	1.00E-02	1.00E-02	1.40E-02	1.70E-02	1.10E-02	1.70E-02	1.40E-02	1.00E-02	1.40E-02	1.00E-02
Rn-222	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Po-218	2.00E-04	5.80E-03	2.00E-04	2.00E-04	2.70E-04	2.00E-04	2.70E-03	2.00E-04	2.70E-04	2.00E-04	2.70E-04	2.00E-04
At-218	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01
Rn-218	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb-214	1.50E-02	1.50E-02	1.00E-02	1.00E-02	5.30E-03	1.50E-02	1.50E-03	1.50E-02	5.30E-03	1.00E-02	5.30E-03	1.00E-02
Bi-214	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
Po-214	2.00E-04	5.80E-03	2.00E-04	2.00E-04	2.70E-04	2.00E-04	2.70E-03	2.00E-04	2.70E-04	2.00E-04	2.70E-04	2.00E-04
Tl-210	8.00E-04	8.00E-05	8.00E-05	8.00E-05	8.00E-04	8.00E-04	8.00E-05	8.00E-04	8.00E-04	8.00E-05	8.00E-04	8.00E-05
Pb-210	1.50E-02	1.50E-02	1.00E-02	1.00E-02	5.30E-03	1.50E-02	1.50E-03	1.50E-02	5.30E-03	1.00E-02	5.30E-03	1.00E-02
Bi-210	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
Po-210	2.00E-04	5.80E-03	2.00E-04	2.00E-04	2.70E-04	2.00E-04	2.70E-03	2.00E-04	2.70E-04	2.00E-04	2.70E-04	2.00E-04
Hg-206	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01
Tl-206	8.00E-04	8.00E-05	8.00E-05	8.00E-05	8.00E-04	8.00E-04	8.00E-05	8.00E-04	8.00E-04	8.00E-05	8.00E-04	8.00E-05

Resident Peak Dose DCCs for Soil (complete chain decay)

Exposure Route	Peak DCC for Ra-226 DL=1 (pCi/g)	Maximum dose during peak interval (mrem/year)	Maximum Dose rate during peak interval (mrem/year)	Maximum Dose Year ED=1 (year)
Ingestion	***2.07E+00***	***4.84E-01***	***4.84E-01***	***1.34E+02 - 1.35E+02***
Inhalation	***2.97E+03***	***3.37E-04***	***3.37E-04***	***1.17E+02 - 1.18E+02***
External Exposure	***2.89E-01***	***3.47E+00***	***3.47E+00***	***1.18E-01 - 1.12E+00***
Produce Consumption	***4.91E-01***	***2.04E+00***	***2.04E+00***	***1.27E+02 - 1.28E+02***
Total	***1.72E-01***	***5.82E+00***	***5.82E+00***	***1.02E+02 - 1.03E+02***

Output generated 27FEB2023:16:41:00

Co-60-DCC_Resident_soil

Variable	Value
DL (dose limit) mrem/yr	1
AAF_{res-c} (soil age adjustment factor - resident child) unitless	0.23
AAF_{res-a} (soil age adjustment factor - resident adult) unitless	0.77
t_{res} (time - resident) yr	1
ED_{res} (soil exposure duration - resident) yr	26
ET_{res} (soil exposure time - resident) hr/day	24
ET_{res-c} (soil exposure time - resident child) hr/day	24
ET_{res-a} (soil exposure time - resident adult) hr/day	24
ET_{res-i} (soil exposure time - indoor resident) hr/day	16.416
ET_{res-o} (soil exposure time - outdoor resident) hr/day	1.752
ED_{res-c} (soil exposure duration - resident child) yr	6
ED_{res-a} (soil exposure duration - resident adult) yr	20
EF_{res} (soil exposure frequency - resident) day/yr	350
EF_{res-c} (soil exposure frequency - resident child) day/yr	350
EF_{res-a} (soil exposure frequency - resident adult) day/yr	350
IRS_{res-a} (soil intake rate - resident adult) mg/day	100
IRS_{res-c} (soil intake rate - resident child) mg/day	200
IRA_{res-a} (soil inhalation rate - resident adult) m^3/day	20
IRA_{res-c} (soil inhalation rate - resident child) m^3/day	10
$IFS_{res-adj}$ (age-adjusted soil ingestion factor - resident) mg	43050
$IFA_{res-adj}$ (age-adjusted soil inhalation factor - resident) m^3	6195
GSF_i (gamma shielding factor - indoor) unitless	0.4
$MLF_{produce}$ (produce mass loading factor) unitless	0.0135
Site area for ACF (area correction factor) m^2	1000000 m^2
Cover thickness for GSF_o (gamma shielding factor) cm	0 cm
Cover thickness for GSF_b (gamma shielding factor) cm	0 cm
Climate zone	Temperate
Soil type	Default
AAF_{res-c} (biota age adjustment factor - resident child) unitless	0.23
AAF_{res-a} (biota age adjustment factor - resident adult) unitless	0.77
$IRAP_{res-a}$ (apple ingestion rate - resident adult) g/day	73.9
$IRAP_{res-c}$ (apple ingestion rate - resident child) g/day	72
$IFAP_{res-adj}$ (age-adjusted apple ingestion fraction) g	25712
$IRCI_{res-a}$ (citrus ingestion rate - resident adult) g/day	306.5
$IRCI_{res-c}$ (citrus ingestion rate - resident child) g/day	206
$IFCI_{res-adj}$ (age-adjusted citrus ingestion fraction) g	99184
$IRBE_{res-a}$ (berry ingestion rate - resident adult) g/day	35.2
$IRBE_{res-c}$ (berry ingestion rate - resident child) g/day	24.2
$IFBE_{res-adj}$ (age-adjusted berry ingestion fraction) g	11434
$IRPC_{res-a}$ (peach ingestion rate - resident adult) g/day	115.7
$IRPC_{res-c}$ (peach ingestion rate - resident child) g/day	110.2
$IFPC_{res-adj}$ (age-adjusted peach ingestion fraction) g	40052
$IRPR_{res-a}$ (pear ingestion rate - resident adult) g/day	52.1
$IRPR_{res-c}$ (pear ingestion rate - resident child) g/day	69.4
$IFPR_{res-adj}$ (age-adjusted pear ingestion fraction) g	19627
$IRST_{res-a}$ (strawberry ingestion rate - resident adult) g/day	40.6
$IRST_{res-c}$ (strawberry ingestion rate - resident child) g/day	27.5
$IFST_{res-adj}$ (age-adjusted strawberry ingestion fraction) g	13155
$IRAS_{res-a}$ (asparagus ingestion rate - resident adult) g/day	40.1
$IRAS_{res-c}$ (asparagus ingestion rate - resident child) g/day	11.9
$IFAS_{res-adj}$ (age-adjusted asparagus ingestion fraction) g	11764
$IRBT_{res-a}$ (beet ingestion rate - resident adult) g/day	34.4
$IRBT_{res-c}$ (beet ingestion rate - resident child) g/day	6
$IFBT_{res-adj}$ (age-adjusted beet ingestion fraction) g	9753
$IRBR_{res-a}$ (broccoli ingestion rate - resident adult) g/day	30.5
$IRBR_{res-c}$ (broccoli ingestion rate - resident child) g/day	13.2
$IFBR_{res-adj}$ (age-adjusted broccoli ingestion fraction) g	9282
$IRCB_{res-a}$ (cabbage ingestion rate - resident adult) g/day	85.1
$IRCB_{res-c}$ (cabbage ingestion rate - resident child) g/day	11.8
$IFCB_{res-adj}$ (age-adjusted cabbage ingestion fraction) g	23884
$IRCR_{res-a}$ (carrot ingestion rate - resident adult) g/day	27.1
$IRCR_{res-c}$ (carrot ingestion rate - resident child) g/day	14.5
$IFCR_{res-adj}$ (age-adjusted carrot ingestion fraction) g	8470
$IRCO_{res-a}$ (corn ingestion rate - resident adult) g/day	60.2
$IRCO_{res-c}$ (corn ingestion rate - resident child) g/day	23.2
$IFCO_{res-adj}$ (age-adjusted corn ingestion fraction) g	18091
$IRCU_{res-a}$ (cucumber ingestion rate - resident adult) g/day	82.3
$IRCU_{res-c}$ (cucumber ingestion rate - resident child) g/day	24.5
$IFCU_{res-adj}$ (age-adjusted cucumber ingestion fraction) g	24152
$IRLE_{res-a}$ (lettuce ingestion rate - resident adult) g/day	36.7
$IRLE_{res-c}$ (lettuce ingestion rate - resident child) g/day	3.4
$IFLE_{res-adj}$ (age-adjusted lettuce ingestion fraction) g	10164
$IRLI_{res-a}$ (lima bean ingestion rate - resident adult) g/day	33.9
$IRLI_{res-c}$ (lima bean ingestion rate - resident child) g/day	22
$IFLI_{res-adj}$ (age-adjusted lima bean ingestion fraction) g	10907
$IROK_{res-a}$ (okra ingestion rate - resident adult) g/day	30.4
$IROK_{res-c}$ (okra ingestion rate - resident child) g/day	9.4
$IFOK_{res-adj}$ (age-adjusted okra ingestion fraction) g	8949
$IRON_{res-a}$ (onion ingestion rate - resident adult) g/day	21.5
$IRON_{res-c}$ (onion ingestion rate - resident child) g/day	5.9
$IFON_{res-adj}$ (age-adjusted onion ingestion fraction) g	6269
$IRPE_{res-a}$ (pea ingestion rate - resident adult) g/day	35
$IRPE_{res-c}$ (pea ingestion rate - resident child) g/day	22.6
$IFPE_{res-adj}$ (age-adjusted pea ingestion fraction) g	11251
$IRPP_{res-a}$ (pepper ingestion rate - resident adult) g/day	19.1
$IRPP_{res-c}$ (pepper ingestion rate - resident child) g/day	5.9
$IFPP_{res-adj}$ (age-adjusted pepper ingestion fraction) g	5622
$IRPU_{res-a}$ (pumpkin ingestion rate - resident adult) g/day	63.5
$IRPU_{res-c}$ (pumpkin ingestion rate - resident child) g/day	21.2
$IFPU_{res-adj}$ (age-adjusted pumpkin ingestion fraction) g	18819
$IRSN_{res-a}$ (snap bean ingestion rate - resident adult) g/day	53.8
$IRSN_{res-c}$ (snap bean ingestion rate - resident child) g/day	28.3
$IFSN_{res-adj}$ (age-adjusted snap bean ingestion fraction) g	16777
$IRTO_{res-a}$ (tomato ingestion rate - resident adult) g/day	80.1
$IRTO_{res-c}$ (tomato ingestion rate - resident child) g/day	36
$IFTO_{res-adj}$ (age-adjusted tomato ingestion fraction) g	24484
$IRPT_{res-a}$ (potato ingestion rate - resident adult) g/day	127.8
$IRPT_{res-c}$ (potato ingestion rate - resident child) g/day	47.3
$IFPT_{res-adj}$ (age-adjusted potato ingestion fraction) g	38249
$CF_{res-produce}$ (contaminated plant fraction) unitless	1
$CF_{res-apple}$ (contaminated apple fraction) unitless	1
$CF_{res-citrus}$ (contaminated citrus fraction) unitless	1
$CF_{res-berry}$ (contaminated berry fraction) unitless	1
$CF_{res-peach}$ (contaminated peach fraction) unitless	1
$CF_{res-pear}$ (contaminated pear fraction) unitless	1
$CF_{res-strawberry}$ (contaminated strawberry fraction) unitless	1
$CF_{res-asparagus}$ (contaminated asparagus fraction) unitless	1
$CF_{res-beet}$ (contaminated beet fraction) unitless	1
$CF_{res-broccoli}$ (contaminated broccoli fraction) unitless	1
$CF_{res-cabbage}$ (contaminated cabbage fraction) unitless	1
$CF_{res-carrot}$ (contaminated carrot fraction) unitless	1
$CF_{res-corn}$ (contaminated corn fraction) unitless	1
$CF_{res-cucumber}$ (contaminated cucumber fraction) unitless	1
$CF_{res-lettuce}$ (contaminated lettuce fraction) unitless	1
$CF_{res-lima\ bean}$ (contaminated lima bean fraction) unitless	1
$CF_{res-okra}$ (contaminated okra fraction) unitless	1
$CF_{res-onion}$ (contaminated onion fraction) unitless	1
$CF_{res-pea}$ (contaminated pea fraction) unitless	1
$CF_{res-pepper}$ (contaminated pepper fraction) unitless	1
$CF_{res-pumpkin}$ (contaminated pumpkin fraction) unitless	1
$CF_{res-snap\ bean}$ (contaminated snap bean fraction) unitless	1
$CF_{res-tomato}$ (contaminated tomato fraction) unitless	1
$CF_{res-potato}$ (contaminated potato fraction) unitless	1
MLF_{apple} (apple mass loading factor) unitless	0.00016
MLF_{citrus} (citrus mass loading factor) unitless	0.000157
MLF_{berry} (berry mass loading factor) unitless	0.000166
MLF_{peach} (peach mass loading factor) unitless	0.00015
MLF_{pear} (pear mass loading factor) unitless	0.00016
$MLF_{strawberry}$ (strawberry mass loading factor) unitless	0.00008
$MLF_{asparagus}$ (asparagus mass loading factor) unitless	0.000079
MLF_{beet} (beet mass loading factor) unitless	0.000138
$MLF_{broccoli}$ (broccoli mass loading factor) unitless	0.00101
$MLF_{cabbage}$ (cabbage mass loading factor) unitless	0.000105
MLF_{carrot} (carrot mass loading factor) unitless	0.000097
MLF_{corn} (corn mass loading factor) unitless	0.000145
$MLF_{cucumber}$ (cucumber mass loading factor) unitless	0.00004
$MLF_{lettuce}$ (lettuce mass loading factor) unitless	0.0135
$MLF_{lima\ bean}$ (lima bean mass loading factor) unitless	0.00383
MLF_{okra} (okra mass loading factor) unitless	0.00008
MLF_{onion} (onion mass loading factor) unitless	0.000097
MLF_{pea} (pea mass loading factor) unitless	0.000178
MLF_{pepper} (pepper mass loading factor) unitless	0.00222
$MLF_{pumpkin}$ (pumpkin mass loading factor) unitless	0.000058
$MLF_{snap\ bean}$ (snap bean mass loading factor) unitless	0.005
MLF_{tomato} (tomato mass loading factor) unitless	0.00177
MLF_{potato} (potato mass loading factor) unitless	0.00021
EF_{res} (produce exposure frequency - resident) day/yr	350
ED_{res} (produce exposure duration - resident) yr	26
ED_{res-c} (produce exposure duration - resident child) yr	6
ED_{res-a} (produce exposure duration - resident adult) yr	20
EF_{res-c} (produce exposure frequency - resident child) day/yr	350
EF_{res-a} (produce exposure frequency - resident adult) day/yr	350
City (Climate Zone)	Default
A_s (acres)	0.5
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77
PEF (particulate emission factor) m^3/kg	1359344438
A (PEF Dispersion Constant)	16.2302
B (PEF Dispersion Constant)	18.7762
C (PEF Dispersion Constant)	216.108
V (fraction of vegetative cover) unitless	0.5
U_m (mean annual wind speed) m/s	4.69
U_t (equivalent threshold value)	11.32
F(x) (function dependent on U_m/U_t) unitless	0.194

Output generated 28FEB2023:11:46:26

Resident DCCs for Soil (complete chain, no decay)

Isotope	Parent	ICRP Lung Absorption Type	Ingestion DCF (mrem/pCi)	Inhalation DCF (mrem/pCi)	External Exposure DCF (mrem/yr per pCi/g)	Half-life (years)	Default Soil Volume Area Correction Factor	Wet Soil-to-plant transfer factor Woody tree (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Leaf (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Root (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Shrub (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Non-leafy fruit (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Maize grain (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Legume seed (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Tuber (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Herbaceous (pCi/g-fresh plant per pCi/g-wet soil)
Co-60	Co-60	S	2.03E-05	1.22E-04	1.54E+01	5.27E+00	1.00E+00	1.00E-02	1.70E-01	1.10E-01	1.00E-02	1.40E-01	1.00E-02	3.60E-02	5.40E-02	1.00E-02

Isotope	Default Soil Volume Gamma Shielding Factor	Total Indoor GSF Soil Volume	Particulate Emission Factor (m^3/kg)	Ingestion DCC DL=1.0E+00 (pCi/g)	Inhalation DCC DL=1.0E+00 (pCi/g)	External Exposure DCC DL=1.0E+00 (pCi/g)	Produce Consumption DCC DL=1.0E+00 (pCi/g)	Total DCC DL=1.0E+00 (pCi/g)	Total DCC DL=1.0E+00 (mg/kg)
Co-60	1.00E+00	4.00E-01	1.36E+09	1.14E+03	1.80E+06	1.95E-01	1.68E+00	**1.75E-01**	1.55E-10
	Decay Corrected using average DF			1.22E+03	1.92E+06	2.08E-01	1.79E+00	1.86E-01	
	Decay corrected using DF after 1-year			1.30E+03	2.05E+06	2.22E-01	1.92E+00	1.99E-01	

Decay Ingrowth factor Average	Decay-ingrowth after 1-year	DCC using Average DIF	DCC using DIF at 1 year	DIF after 1 y	Avg DIF
9.37E-01	8.77E-01	1.87E-01	2.00E-01	0.8767556	9.37E-01

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Resident Produce DCCs for Soil

Isotope	Apple Consumption DCC DL=1.0E+00 (pCi/g)	Asparagus Consumption DCC DL=1.0E+00 (pCi/g)	Beet Consumption DCC DL=1.0E+00 (pCi/g)	Berry Consumption DCC DL=1.0E+00 (pCi/g)	Broccoli Consumption DCC DL=1.0E+00 (pCi/g)	Cabbage Consumption DCC DL=1.0E+00 (pCi/g)	Carrot Consumption DCC DL=1.0E+00 (pCi/g)	Citrus fruit Consumption DCC DL=1.0E+00 (pCi/g)	Corn Consumption DCC DL=1.0E+00 (pCi/g)	Cucumber Consumption DCC DL=1.0E+00 (pCi/g)	Lettuce Consumption DCC DL=1.0E+00 (pCi/g)	Lima beans Consumption DCC DL=1.0E+00 (pCi/g)
Co-60	1.88E+02	2.46E+01	4.58E+01	4.24E+02	3.76E+01	1.21E+01	5.28E+01	4.89E+01	2.68E+02	1.46E+01	2.64E+01	1.13E+02

Isotope	Okra Consumption DCC DL=1.0E+00 (pCi/g)	Onion Consumption DCC DL=1.0E+00 (pCi/g)	Peaches Consumption DCC DL=1.0E+00 (pCi/g)	Pears Consumption DCC DL=1.0E+00 (pCi/g)	Peas Consumption DCC DL=1.0E+00 (pCi/g)	Peppers Consumption DCC DL=1.0E+00 (pCi/g)	Potatoes Consumption DCC DL=1.0E+00 (pCi/g)	Pumpkin Consumption DCC DL=1.0E+00 (pCi/g)	Snap beans Consumption DCC DL=1.0E+00 (pCi/g)	Strawberries Consumption DCC DL=1.0E+00 (pCi/g)	Tomatoes Consumption DCC DL=1.0E+00 (pCi/g)	Total Produce DCC DL=1.0E+00 (pCi/g)
Co-60	3.93E+01	7.13E+01	1.21E+02	2.47E+02	1.21E+02	6.16E+01	2.37E+01	1.87E+01	7.16E+01	3.71E+02	1.42E+01	**1.68E+00**

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Resident Peak Dose DCCs for Soil (complete chain decay)

Exposure Route	Peak DCC for Co-60 DL=1 (pCi/g)	Maximum dose during peak interval (mrem/year)	Maximum Dose rate during peak interval (mrem/year)	Maximum Dose Year ED=1 (year)
Ingestion	*1.22E+03*	*8.19E-04*	*8.74E-04*	*1.00E-08 - 1.00E+00*
Inhalation	*1.92E+06*	*5.21E-07*	*5.56E-07*	*1.00E-08 - 1.00E+00*
External Exposure	*2.09E-01*	*4.79E+00*	*5.12E+00*	*1.00E-08 - 1.00E+00*
Produce Consumption	*4.65E+01*	*2.15E-02*	*2.30E-02*	*1.00E-08 - 1.00E+00*
Total	*2.08E-01*	*4.82E+00*	*5.14E+00*	*1.00E-08 - 1.00E+00*

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Ra_226-DCC_Farmer_soil

Default
Farmer Soil Inputs

Variable	Value
Slab size for ACF (area correction factor) m^2	1000000 m^2
Cover thickness for GSF_o (gamma shielding factor) cm	0 cm
Cover thickness for GSF_b (gamma shielding factor) cm	0 cm
Climate zone	Temperate
Soil Type	Default
DL (dose limit) mrem/yr	1
AAF_{far-c} (soil age adjustment factor - farmer child) unitless	0.15
AAF_{far-a} (soil age adjustment factor - farmer adult) unitless	0.85
t_{far} (time - farmer) yr	1
ED_{far} (exposure duration - farmer) yr	40
ET_{far} (exposure time - farmer) hr/day	24
ET_{far-a} (exposure time - farmer adult) hr/day	24
ET_{far-c} (exposure time - farmer child) hr/day	24
ET_{far-o} (outdoor exposure time fraction) hr/day	12.168
ET_{far-i} (indoor exposure time fraction) hr/day	10.008
ED_{far-c} (exposure duration - farmer child) yr	6
ED_{far-a} (exposure duration - farmer adult) yr	34
EF_{far} (exposure frequency) day/yr	350
EF_{far-c} (exposure frequency - farmer child) day/yr	350
EF_{far-a} (exposure frequency - farmer adult) day/yr	350
IRS_{far-a} (soil ingestion rate - farmer adult) mg/day	100
IRS_{far-c} (soil ingestion rate - farmer child) mg/day	200
IRA_{far-a} (inhalation rate - farmer adult) m^3/day	20
IRA_{far-c} (inhalation rate - farmer child) m^3/day	10
$IFS_{far-adj}$ (age-adjusted soil ingestion factor) mg	40250
$IFA_{far-adj}$ (age-adjusted soil inhalation factor) m^3	6475
GSF_i (gamma shielding factor - indoor)	0.4
Q_{p-beef} (beef fodder intake rate) kg/day	11.77
Q_{s-beef} (beef soil intake rate) kg/day	0.5
f_{p-beef} (fraction of time animal is on-site) unitless	1
f_{s-beef} (fraction of animal`s food from site when on-site) unitless	1
$Q_{p-dairy}$ (dairy fodder intake rate) kg/day	20.3
$Q_{s-dairy}$ (dairy soil intake rate) kg/day	0.4
$f_{p-dairy}$ (fraction of time animal is on-site) unitless	1
$f_{s-dairy}$ (fraction of animal`s food from site when on-site) unitless	1
$Q_{p-swine}$ (swine fodder intake rate) kg/day	4.7
$Q_{s-swine}$ (swine soil intake rate) kg/day	0.37
$f_{p-swine}$ (fraction of time animal is on-site) unitless	1
$f_{s-swine}$ (fraction of animal`s food from site when on-site) unitless	1
$Q_{p-poultry}$ (poultry fodder intake rate) kg/day	0.2
$Q_{s-poultry}$ (poultry soil intake rate) kg/day	0.022
$f_{p-poultry}$ (fraction of time animal is on-site) unitless	1
$f_{s-poultry}$ (fraction of animal`s food from site when on-site) unitless	1
$MLF_{pasture}$ (pasture plant mass loading factor) unitless	0.25
$MLF_{produce}$ (produce mass loading factor) unitless	0.0135
AAF_{far-c} (biota age adjustment factor - farmer child) unitless	0.15
AAF_{far-a} (biota age adjustment factor - farmer adult) unitless	0.85
ED_{far} (exposure duration - farmer) yr	40
ED_{far-c} (exposure duration - farmer child) yr	6
ED_{far-a} (exposure duration - farmer adult) yr	34
EF_{far} (exposure frequency) day/yr	350
EF_{far-c} (exposure frequency - farmer child) day/yr	350
EF_{far-a} (exposure frequency - farmer adult) day/yr	350
$IRAP_{far-a}$ (apple ingestion rate - farmer adult) g/day	84.8
$IRAP_{far-c}$ (apple ingestion rate - farmer child) g/day	82.7
$IFAP_{far-adj}$ (age-adjusted apple ingestion fraction) g	29570
IRP_{far-a} (poultry ingestion rate - farmer adult) g/day	175.5
IRP_{far-c} (poultry ingestion rate - farmer child) g/day	48.8
$IFP_{far-adj}$ (age-adjusted poultry ingestion fraction) g	54773
IRE_{far-a} (egg ingestion rate - farmer adult) g/day	97.3
IRE_{far-c} (egg ingestion rate - farmer child) g/day	25.1
$IFE_{far-adj}$ (age-adjusted egg ingestion fraction) g	30264
IRB_{far-a} (beef ingestion rate - farmer adult) g/day	270.1
IRB_{far-c} (beef ingestion rate - farmer child) g/day	64.6
$IFB_{far-adj}$ (age-adjusted beef ingestion fraction) g	83746
IRD_{far-a} (dairy ingestion rate - farmer adult) g/day	1438
IRD_{far-c} (dairy ingestion rate - farmer child) g/day	1116.4
$IFD_{far-adj}$ (age-adjusted dairy ingestion fraction) g	486416
$IRSW_{far-a}$ (swine ingestion rate - farmer adult) g/day	151.1
$IRSW_{far-c}$ (swine ingestion rate - farmer child) g/day	32.2
$IFSW_{far-adj}$ (age-adjusted swine ingestion fraction) g	46643
$IRSF_{far-a}$ (shellfish ingestion rate - farmer adult) g/day	208.9

	Default Farmer Soil Inputs
$IRSF_{far\text{-}c}$ (shellfish ingestion rate - farmer child) g/day	21.3
$IFSF_{far\text{-}adj}$ (age-adjusted shellfish ingestion fraction) g	63266
$IRFI_{far\text{-}a}$ (finfish ingestion rate - farmer adult) g/day	155.9
$IRFI_{far\text{-}c}$ (finfish ingestion rate - farmer child) g/day	36.1
$IFFI_{far\text{-}adj}$ (age-adjusted finfish ingestion fraction) g	48276
p_m (density of milk) kg/L	1.03
$IRAP_{far\text{-}a}$ (apple ingestion rate - farmer adult) g/day	84.8
$IRAP_{far\text{-}c}$ (apple ingestion rate - farmer child) g/day	82.7
$IFAP_{far\text{-}adj}$ (age-adjusted apple ingestion fraction) g	29570
$IRCI_{far\text{-}a}$ (citrus ingestion rate - farmer adult) g/day	306.5
$IRCI_{far\text{-}c}$ (citrus ingestion rate - farmer child) g/day	206
$IFCI_{far\text{-}adj}$ (age-adjusted citrus ingestion fraction) g	101999
$IRBE_{far\text{-}a}$ (berry ingestion rate - farmer adult) g/day	35.2
$IRBE_{far\text{-}c}$ (berry ingestion rate - farmer child) g/day	24.2
$IFBE_{far\text{-}adj}$ (age-adjusted berry ingestion fraction) g	11743
$IRPC_{far\text{-}a}$ (peach ingestion rate - farmer adult) g/day	103.1
$IRPC_{far\text{-}c}$ (peach ingestion rate - farmer child) g/day	98.2
$IFPC_{far\text{-}adj}$ (age-adjusted peach ingestion fraction) g	35828
$IRPR_{far\text{-}a}$ (pear ingestion rate - farmer adult) g/day	59.8
$IRPR_{far\text{-}c}$ (pear ingestion rate - farmer child) g/day	79.6
$IFPR_{far\text{-}adj}$ (age-adjusted pear ingestion fraction) g	21970
$IRST_{far\text{-}a}$ (strawberry ingestion rate - farmer adult) g/day	40.6
$IRST_{far\text{-}c}$ (strawberry ingestion rate - farmer child) g/day	27.5
$IFST_{far\text{-}adj}$ (age-adjusted strawberry ingestion fraction) g	13522
$IRAS_{far\text{-}a}$ (asparagus ingestion rate - farmer adult) g/day	40.1
$IRAS_{far\text{-}c}$ (asparagus ingestion rate - farmer child) g/day	11.9
$IFAS_{far\text{-}adj}$ (age-adjusted asparagus ingestion fraction) g	12554
$IRBT_{far\text{-}a}$ (beet ingestion rate - farmer adult) g/day	34.4
$IRBT_{far\text{-}c}$ (beet ingestion rate - farmer child) g/day	6
$IFBT_{far\text{-}adj}$ (age-adjusted beet ingestion fraction) g	10549
$IRBR_{far\text{-}a}$ (broccoli ingestion rate - farmer adult) g/day	34.1
$IRBR_{far\text{-}c}$ (broccoli ingestion rate - farmer child) g/day	14.8
$IFBR_{far\text{-}adj}$ (age-adjusted broccoli ingestion fraction) g	10922
$IRCB_{far\text{-}a}$ (cabbage ingestion rate - farmer adult) g/day	79.5
$IRCB_{far\text{-}c}$ (cabbage ingestion rate - farmer child) g/day	11
$IFCB_{far\text{-}adj}$ (age-adjusted cabbage ingestion fraction) g	24229
$IRCR_{far\text{-}a}$ (carrot ingestion rate - farmer adult) g/day	24.4
$IRCR_{far\text{-}c}$ (carrot ingestion rate - farmer child) g/day	13.1
$IFCR_{far\text{-}adj}$ (age-adjusted carrot ingestion fraction) g	7947
$IRCO_{far\text{-}a}$ (corn ingestion rate - farmer adult) g/day	82.1
$IRCO_{far\text{-}c}$ (corn ingestion rate - farmer child) g/day	31.6
$IFCO_{far\text{-}adj}$ (age-adjusted corn ingestion fraction) g	26084
$IRCU_{far\text{-}a}$ (cucumber ingestion rate - farmer adult) g/day	54.9
$IRCU_{far\text{-}c}$ (cucumber ingestion rate - farmer child) g/day	16.3
$IFCU_{far\text{-}adj}$ (age-adjusted cucumber ingestion fraction) g	17189
$IRLE_{far\text{-}a}$ (lettuce ingestion rate - farmer adult) g/day	36.7
$IRLE_{far\text{-}c}$ (lettuce ingestion rate - farmer child) g/day	3.4
$IFLE_{far\text{-}adj}$ (age-adjusted lettuce ingestion fraction) g	11097
$IRLI_{far\text{-}a}$ (lima bean ingestion rate - farmer adult) g/day	33.9
$IRLI_{far\text{-}c}$ (lima bean ingestion rate - farmer child) g/day	22
$IFLI_{far\text{-}adj}$ (age-adjusted lima bean ingestion fraction) g	11240
$IROK_{far\text{-}a}$ (okra ingestion rate - farmer adult) g/day	30.4
$IROK_{far\text{-}c}$ (okra ingestion rate - farmer child) g/day	9.4
$IFOK_{far\text{-}adj}$ (age-adjusted okra ingestion fraction) g	9538
$IRON_{far\text{-}a}$ (onion ingestion rate - farmer adult) g/day	27.3
$IRON_{far\text{-}c}$ (onion ingestion rate - farmer child) g/day	7.5
$IFON_{far\text{-}adj}$ (age-adjusted onion ingestion fraction) g	8516
$IRPE_{far\text{-}a}$ (pea ingestion rate - farmer adult) g/day	31.6
$IRPE_{far\text{-}c}$ (pea ingestion rate - farmer child) g/day	20.4
$IFPE_{far\text{-}adj}$ (age-adjusted pea ingestion fraction) g	10427
$IRPP_{far\text{-}a}$ (pepper ingestion rate - farmer adult) g/day	23.9
$IRPP_{far\text{-}c}$ (pepper ingestion rate - farmer child) g/day	7.4
$IFPP_{far\text{-}adj}$ (age-adjusted pepper ingestion fraction) g	7499
$IRPU_{far\text{-}a}$ (pumpkin ingestion rate - farmer adult) g/day	63.5
$IRPU_{far\text{-}c}$ (pumpkin ingestion rate - farmer child) g/day	21.2
$IFPU_{far\text{-}adj}$ (age-adjusted pumpkin ingestion fraction) g	20004
$IRSN_{far\text{-}a}$ (snap bean ingestion rate - farmer adult) g/day	54.5
$IRSN_{far\text{-}c}$ (snap bean ingestion rate - farmer child) g/day	28.7
$IFSN_{far\text{-}adj}$ (age-adjusted snap bean ingestion fraction) g	17721
$IRTO_{far\text{-}a}$ (tomato ingestion rate - farmer adult) g/day	94
$IRTO_{far\text{-}c}$ (tomato ingestion rate - farmer child) g/day	42.2
$IFTO_{far\text{-}adj}$ (age-adjusted tomato ingestion fraction) g	30181
$IRPT_{far\text{-}a}$ (potato ingestion rate - farmer adult) g/day	141.8

	Default Farmer Soil Inputs
$IRPT_{far-c}$ (potato ingestion rate - farmer child) g/day	52.4
$IFPT_{far-adj}$ (age-adjusted potato ingestion fraction) g	44937
$CF_{far-produce}$ (contaminated plant fraction) unitless	1
$CF_{far-poultry}$ (poultry contaminated fraction unitless)	1
$CF_{far-egg}$ (egg contaminated fraction) unitless	1
$CF_{far-beef}$ (beef contaminated fraction) unitless	1
$CF_{far-dairy}$ (dairy contaminated fraction) unitless	1
$CF_{far-swine}$ (swine contaminated fraction) unitless	1
$CF_{far-finfish}$ (finfish contaminated fraction) unitless	1
$CF_{far-shellfish}$ (shellfish contaminated fraction) unitless	1
$CF_{far-apple}$ (contaminated apple fraction) unitless	1
$CF_{far-citrus}$ (contaminated citrus fraction) unitless	1
$CF_{far-berry}$ (contaminated berry fraction) unitless	1
$CF_{far-peach}$ (contaminated peach fraction) unitless	1
$CF_{far-pear}$ (contaminated pear fraction) unitless	1
$CF_{far-strawberry}$ (contaminated strawberry fraction) unitless	1
$CF_{far-asparagus}$ (contaminated asparagus fraction) unitless	1
$CF_{far-beet}$ (contaminated beet fraction) unitless	1
$CF_{far-broccoli}$ (contaminated broccoli fraction) unitless	1
$CF_{far-cabbage}$ (contaminated cabbage fraction) unitless	1
$CF_{far-carrot}$ (contaminated carrot fraction) unitless	1
$CF_{far-corn}$ (contaminated corn fraction) unitless	1
$CF_{far-cucumber}$ (contaminated cucumber fraction) unitless	1
$CF_{far-lettuce}$ (contaminated lettuce fraction) unitless	1
$CF_{far-lima\ bean}$ (contaminated lima bean fraction) unitless	1
$CF_{far-okra}$ (contaminated okra fraction) unitless	1
$CF_{far-onion}$ (contaminated onion fraction) unitless	1
$CF_{far-pea}$ (contaminated pea fraction) unitless	1
$CF_{far-pepper}$ (contaminated pepper fraction) unitless	1
$CF_{far-pumpkin}$ (contaminated pumpkin fraction) unitless	1
$CF_{far-snap\ bean}$ (contaminated snap bean fraction) unitless	1
$CF_{far-tomato}$ (contaminated tomato fraction) unitless	1
$CF_{far-potato}$ (contaminated potato fraction) unitless	1
MLF_{apple} (apple mass loading factor) unitless	0.00016
MLF_{citrus} (citrus mass loading factor) unitless	0.000157
MLF_{berry} (berry mass loading factor) unitless	0.000166
MLF_{peach} (peach mass loading factor) unitless	0.00015
MLF_{pear} (pear mass loading factor) unitless	0.00016
$MLF_{strawberry}$ (strawberry mass loading factor) unitless	0.00008
$MLF_{asparagus}$ (asparagus mass loading factor) unitless	0.000079
MLF_{beet} (beet mass loading factor) unitless	0.000138
$MLF_{broccoli}$ (broccoli mass loading factor) unitless	0.00101
$MLF_{cabbage}$ (cabbage mass loading factor) unitless	0.000105
MLF_{carrot} (carrot mass loading factor) unitless	0.000097
MLF_{corn} (corn mass loading factor) unitless	0.000145
$MLF_{cucumber}$ (cucumber mass loading factor) unitless	0.00004
$MLF_{lettuce}$ (lettuce mass loading factor) unitless	0.0135
$MLF_{lima\ bean}$ (lima bean mass loading factor) unitless	0.00383
MLF_{okra} (okra mass loading factor) unitless	0.00008
MLF_{onion} (onion mass loading factor) unitless	0.000097
MLF_{pea} (pea mass loading factor) unitless	0.000178
MLF_{pepper} (pepper mass loading factor) unitless	0.00222
$MLF_{pumpkin}$ (pumpkin mass loading factor) unitless	0.000058
$MLF_{snap\ bean}$ (snap bean mass loading factor) unitless	0.005
MLF_{tomato} (tomato mass loading factor) unitless	0.00177
MLF_{potato} (potato mass loading factor) unitless	0.00021
$MLF_{pasture}$ (pasture mass loading factor) unitless	0.25
City (Climate Zone)	Default
A_s (acres)	0.5
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77
PEF (particulate emission factor) m^3/kg	1359344438
A (PEF Dispersion Constant)	16.2302
B (PEF Dispersion Constant)	18.7762
C (PEF Dispersion Constant)	216.108
V (fraction of vegetative cover) unitless	0.5
U_m (mean annual wind speed) m/s	4.69
U_t (equivalent threshold value)	11.32
F(x) (function dependent on U_m/U_t) unitless	0.194

Output generated 10MAR2023:11:39:58

Farmer DCCs for Soil (complete chain, no decay)

Isotope	Parent	ICRP Lung Absorption Type	Ingestion DCF (mrem/pCi)	Inhalation DCF (mrem/pCi)	External Exposure DCF (mrem/yr per pCi/g)	Lambda (1/yr)	Half-life (years)	Default Soil Volume Area Correction Factor	K_d Distribution coefficient (L/kg)	Particulate Emission Factor (m^3/kg)	Dry Soil-to-plant transfer factor (pCi/g-fresh plant per pCi/g-dry soil)	Wet Soil-to-plant transfer factor Woody tree (pCi/g-fresh plant per pCi/g-wet soil)
Ra-226	Ra-226	S	1.68E-03	3.81E-02	3.18E-02	4.33E-04	1.60E+03	1.00E+00	1.00E+00	1.36E+09	1.95E-02	1.00E-02
Rn-222	Ra-226	-	0.00E+00	6.55E-06	2.13E-03	6.62E+01	1.05E-02	1.00E+00	0.00E+00	1.36E+09	0.00E+00	0.00E+00
Po-218	Ra-226	-	0.00E+00	7.62E-06	9.23E-09	1.17E+05	5.90E-06	9.00E-01	2.10E+02	1.36E+09	2.76E-04	2.00E-04
At-218	Ra-226	-	0.00E+00	0.00E+00	5.57E-05	1.46E+07	4.76E-08	9.00E-01	1.00E+01	1.36E+09	9.00E-01	2.00E-01
Rn-218	Ra-226	-	0.00E+00	0.00E+00	4.26E-03	6.24E+08	1.11E-09	1.00E+00	0.00E+00	1.36E+09	0.00E+00	0.00E+00
Pb-214	Ra-226	S	7.36E-07	4.66E-05	1.26E+00	1.36E+04	5.10E-05	1.00E+00	1.50E+02	1.36E+09	1.26E-02	1.00E-02
Bi-214	Ra-226	S	5.51E-07	3.66E-05	9.13E+00	1.83E+04	3.79E-05	1.00E+00	4.80E+02	1.36E+09	5.00E-01	1.00E-01
Po-214	Ra-226	-	0.00E+00	0.00E+00	4.80E-04	1.33E+11	5.21E-12	1.00E+00	2.10E+02	1.36E+09	2.76E-04	2.00E-04
Tl-210	Ra-226	-	0.00E+00	0.00E+00	1.68E+01	2.80E+05	2.47E-06	1.00E+00	1.50E+03	1.36E+09	8.00E-03	8.00E-05
Pb-210	Ra-226	S	3.77E-03	2.23E-02	2.09E-03	3.12E-02	2.22E+01	1.00E+00	1.50E+02	1.36E+09	1.26E-02	1.00E-02
Bi-210	Ra-226	S	6.66E-06	5.40E-04	5.47E-03	5.05E+01	1.37E-02	1.00E+00	4.80E+02	1.36E+09	5.00E-01	1.00E-01
Po-210	Ra-226	S	6.48E-03	1.73E-02	5.64E-05	1.83E+00	3.79E-01	1.00E+00	2.10E+02	1.36E+09	2.76E-04	2.00E-04
Hg-206	Ra-226	-	0.00E+00	0.00E+00	6.13E-01	4.47E+04	1.55E-05	1.00E+00	6.30E+03	1.36E+09	1.00E+00	3.00E-01
Tl-206	Ra-226	-	0.00E+00	0.00E+00	1.28E-02	8.67E+04	7.99E-06	1.00E+00	1.50E+03	1.36E+09	8.00E-03	8.00E-05

Isotope	Wet Soil-to-plant transfer factor Leaf (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Root (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Shrub (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Non-leafy fruit (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Maize grain (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Legume seed (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Tuber (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Herbaceous (pCi/g-fresh plant per pCi/g-wet soil)	Default Soil Volume Gamma Shielding Factor	Total Indoor GSF Soil Volume	Fish bioconcentration factor (pCi/kg per pCi/L)	Shellfish bioconcentration factor (pCi/kg per pCi/L)	Plant-to-beef transfer factor (day/kg)	Plant-to-dairy transfer factor (day/kg)	Plant-to-swine transfer factor (day/kg)	Plant-to-poultry transfer factor (day/kg)	Plant-to-egg transfer factor (day/kg)
Ra-226	9.10E-02	7.00E-02	1.00E-02	1.70E-02	2.40E-03	1.40E-02	1.10E-02	1.00E-02	1.00E+00	4.00E-01	4.00E+00	1.00E+02	1.70E-03	3.80E-04	-	-	-
Rn-222	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00	4.00E-01	0.00E+00	-	0.00E+00	0.00E+00	-	-	-
Po-218	7.40E-03	5.80E-03	2.00E-04	2.00E-04	2.40E-04	2.70E-04	2.70E-03	2.00E-04	1.00E+00	4.00E-01	3.60E+01	-	3.00E-03	2.10E-04	-	2.40E+00	3.10E+00
At-218	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	1.00E+00	4.00E-01	-	-	1.00E-02	1.00E-02	-	-	-
Rn-218	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00	4.00E-01	0.00E+00	-	0.00E+00	0.00E+00	-	-	-
Pb-214	8.00E-02	1.50E-02	1.00E-02	1.50E-02	1.20E-03	5.30E-03	1.50E-03	1.00E-02	1.00E+00	4.00E-01	2.50E+01	2.20E+01	7.00E-04	1.90E-04	-	-	-
Bi-214	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E+00	4.00E-01	1.50E+01	-	2.00E-03	1.00E-03	-	-	-
Po-214	7.40E-03	5.80E-03	2.00E-04	2.00E-04	2.40E-04	2.70E-04	2.70E-03	2.00E-04	1.00E+00	4.00E-01	3.60E+01	-	3.00E-03	2.10E-04	-	2.40E+00	3.10E+00
Tl-210	8.00E-04	8.00E-05	8.00E-05	8.00E-04	8.00E-04	8.00E-04	8.00E-05	8.00E-05	1.00E+00	4.00E-01	9.00E+02	-	4.00E-02	2.00E-03	-	-	-
Pb-210	8.00E-02	1.50E-02	1.00E-02	1.50E-02	1.20E-03	5.30E-03	1.50E-03	1.00E-02	1.00E+00	4.00E-01	2.50E+01	2.20E+01	7.00E-04	1.90E-04	-	-	-
Bi-210	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E+00	4.00E-01	1.50E+01	-	2.00E-03	1.00E-03	-	-	-
Po-210	7.40E-03	5.80E-03	2.00E-04	2.00E-04	2.40E-04	2.70E-04	2.70E-03	2.00E-04	1.00E+00	4.00E-01	3.60E+01	-	3.00E-03	2.10E-04	-	2.40E+00	3.10E+00
Hg-206	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	1.00E+00	4.00E-01	6.10E+03	7.50E+02	1.00E-02	5.00E-04	-	3.00E-02	-
Tl-206	8.00E-04	8.00E-05	8.00E-05	8.00E-04	8.00E-04	8.00E-04	8.00E-05	8.00E-05	1.00E+00	4.00E-01	9.00E+02	-	4.00E-02	2.00E-03	-	-	-

Isotope	Ingestion DCC DL=1.0E+00 (pCi/g)	Inhalation DCC DL=1.0E+00 (pCi/g)	External Exposure DCC DL=1.0E+00 (pCi/g)	Produce Consumption DCC DL=1.0E+00 (pCi/g)	Shellfish Consumption DCC DL=1.0E+00 (pCi/g)	Finfish Consumption DCC DL=1.0E+00 (pCi/g)	Beef Consumption DCC DL=1.0E+00 (pCi/g)	Dairy Consumption DCC DL=1.0E+00 (pCi/g)	Swine Consumption DCC DL=1.0E+00 (pCi/g)	Poultry Consumption DCC DL=1.0E+00 (pCi/g)	Egg Consumption DCC DL=1.0E+00 (pCi/g)	Total DCC DL=1.0E+00 (pCi/g)	Total DCC DL=1.0E+00 (mg/kg)
Ra-226	1.48E+01	5.51E+03	4.87E+01	5.17E-02	9.43E-05	3.09E-03	1.14E+00	5.66E-01	-	-	-	**9.13E-05**	9.25E-11
Rn-222	-	3.21E+07	7.27E+02	-	-	-	-	-	-	-	-	**7.27E+02**	4.73E-09
Po-218	-	2.76E+07	1.86E+08	-	-	-	-	-	-	-	-	**2.40E+07**	8.64E-08
At-218	-	-	3.09E+04	-	-	-	-	-	-	-	-	**3.09E+04**	8.97E-13
Rn-218	-	-	3.63E+02	-	-	-	-	-	-	-	-	**3.63E+02**	2.46E-16
Pb-214	3.37E+04	4.51E+06	1.23E+00	1.59E+02	1.46E+02	1.69E+02	6.45E+03	2.64E+03	-	-	-	**1.20E+00**	3.67E-14
Bi-214	4.51E+04	5.74E+06	1.69E-01	3.63E+01	-	1.20E+03	1.16E+03	2.46E+02	-	-	-	**1.68E-01**	3.82E-15
Po-214	-	-	3.22E+03	-	-	-	-	-	-	-	-	**3.22E+03**	1.01E-17
Tl-210	-	-	9.23E-02	-	-	-	-	-	-	-	-	**9.23E-02**	1.34E-16
Pb-210	6.58E+00	9.41E+03	7.40E+02	3.10E-02	2.86E-02	3.29E-02	1.26E+00	5.15E-01	-	-	-	**9.95E-03**	1.30E-10
Bi-210	3.73E+03	3.89E+05	2.83E+02	3.01E+00	-	9.95E+01	9.61E+01	2.03E+01	-	-	-	**2.46E+00**	1.99E-11
Po-210	3.84E+00	1.21E+04	2.74E+04	1.37E-01	-	1.87E-02	1.78E-01	2.84E-01	-	1.63E-02	2.28E-02	**5.70E-03**	1.27E-12
Hg-206	-	-	2.53E+00	-	-	-	-	-	-	-	-	**2.53E+00**	2.26E-14
Tl-206	-	-	1.21E+02	-	-	-	-	-	-	-	-	**1.21E+02**	5.58E-13

Output generated 10MAR2023:11:39:58

$IFSF_{far-adj}$ (age-adjusted shellfish	63266

Hand Calculations	DCCfar-shellfish-ing	DCCfar-soil-shellfish-ing	DCCfar-beef-ing	DCCfar-sol-bee	Decay Factor @135 years	DCCfar-sol-b
	9.41E-03	9.41E-05	7.11E-03	1.14E+00	9.44E-01	1.21E+00
					9.44E-01	
					9.44E-01	
					1.89E-04	
	2.15E+01	1.46E+02	1.62E+01	6.45E+03	9.43E-01	6.85E+03
	2.87E+01		2.17E+01	1.16E+03	9.43E-01	1.23E+03
					9.43E-01	
					1.98E-04	
	4.19E-03	2.86E-02	3.17E-03	1.26E+00	9.41E-01	1.34E+00
	2.37E+00		1.79E+00	9.61E+01	9.41E-01	1.02E+02
	2.44E-03		1.84E-03	1.78E-01	9.40E-01	1.90E-01
					Total	1.46E-01

DCCfar-shellfish-ing

- **consumption of shellfish** (Table 10-9 of the 2011 Exposure Factors Handboc

$$DCC_{far-soil-shellfish-ing}\left(\frac{pCi}{g}\right) = \frac{DCC_{far-shellfish-ing}\left(\frac{pCi}{g}\right) \times K_d\left(\frac{L}{kg}\right)}{BCF\left(\frac{L}{kg}\right)}$$

and:

x-INTERCEPT =

$$DCC_{far-wat-shellfish-ing}\left(\frac{pCi}{L}\right) = \frac{DCC_{far-shellfish-ing}\left(\frac{pCi}{g}\right)}{BCF\left(\frac{L}{kg}\right) \times \left(\frac{1\ kg}{1000\ g}\right)}$$

and:

$$SLOPE = \frac{K_d\left(\frac{L}{kg}\right)}{1000}$$

- **consumption of beef** (Chapter 13 of the 2011 Exposure Factors Handbook and the 2018 chapter 11 update of the Exposure Fact derive the intakes for home-produced beef.)

$$DCC_{far-sol-beef-ing}\left(\frac{pCi}{g}\right) = \frac{DCC_{far-beef-ing}\left(\frac{pCi}{g}\right)}{TF_{beef}\left(\frac{day}{kg}\right) \times \left[\left(Q_{p-beef}\left(\frac{11.77\ kg}{day}\right) \times f_{p-beef}(1) \times f_{s-beef}(1) \times (R_{upp} + R_{es})\right) + \left(Q_{s-beef}\left(\frac{0.5\ kg}{day}\right) \times f_{p-beef}(1)\right)\right]}$$

where:

$$R_{upp} = BV_{dry}\left(\frac{pCi / g-dry-plant}{pCi / g-dry-soil}\right);\ R_{es} = MLF_{pasture}\left(\frac{0.25\ g-dry-soil}{g-dry-plant}\right)$$

Farmer Produce DCCs for Soil

Isotope	Apple Consumption DCC DL=1.0E+00 (pCi/g)	Asparagus Consumption DCC DL=1.0E+00 (pCi/g)	Beet Consumption DCC DL=1.0E+00 (pCi/g)	Berry Consumption DCC DL=1.0E+00 (pCi/g)	Broccoli Consumption DCC DL=1.0E+00 (pCi/g)	Cabbage Consumption DCC DL=1.0E+00 (pCi/g)	Carrot Consumption DCC DL=1.0E+00 (pCi/g)	Citrus fruit Consumption DCC DL=1.0E+00 (pCi/g)	Corn Consumption DCC DL=1.0E+00 (pCi/g)	Cucumber Consumption DCC DL=1.0E+00 (pCi/g)	Lettuce Consumption DCC DL=1.0E+00 (pCi/g)	Lima beans Consumption DCC DL=1.0E+00 (pCi/g)	Okra Consumption DCC DL=1.0E+00 (pCi/g)	Onion Consumption DCC DL=1.0E+00 (pCi/g)	Peaches Consumption DCC DL=1.0E+00 (pCi/g)	Pears Consumption DCC DL=1.0E+00 (pCi/g)	Peas Consumption DCC DL=1.0E+00 (pCi/g)	Peppers Consumption DCC DL=1.0E+00 (pCi/g)
Ra-226	1.99E+00	5.22E-01	8.06E-01	5.00E+00	3.03E+00	2.70E-01	1.07E+00	5.76E-01	8.99E+00	2.04E+00	5.14E-01	2.98E+00	3.66E+00	9.99E-01	1.64E+00	2.67E+00	4.04E+00	4.14E+00
Rn-222	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Po-218	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
At-218	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rn-218	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pb-214	4.52E+03	1.35E+03	8.50E+03	1.14E+04	7.77E+03	7.00E+02	1.13E+04	1.31E+03	3.87E+04	5.25E+03	1.31E+03	1.32E+04	9.44E+03	1.06E+04	3.73E+03	6.08E+03	2.38E+04	1.05E+04
Bi-214	6.12E+02	1.44E+03	1.72E+03	1.54E+03	1.64E+03	7.48E+02	2.28E+03	1.78E+02	6.94E+02	1.05E+03	1.44E+03	1.55E+03	1.90E+03	2.13E+03	5.06E+02	8.24E+02	1.74E+03	2.37E+03
Po-214	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tl-210	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pb-210	8.82E-01	2.64E-01	1.66E+00	2.22E+00	1.52E+00	1.37E-01	2.21E+00	2.56E-01	7.55E+00	1.02E+00	2.55E-01	2.58E+00	1.84E+00	2.06E+00	7.29E-01	1.19E+00	4.64E+00	2.05E+00
Bi-210	5.07E+01	1.20E+02	1.42E+02	1.28E+02	1.36E+02	6.19E+01	1.89E+02	1.47E+01	5.75E+01	8.73E+01	1.19E+02	1.29E+02	1.57E+02	1.76E+02	4.18E+01	6.82E+01	1.44E+02	1.96E+02
Po-210	1.45E+01	1.64E+00	2.47E+00	3.59E+01	1.17E+01	8.49E-01	3.30E+00	4.24E+00	1.54E+01	3.74E+01	6.66E-01	3.35E+00	5.78E+01	3.08E+00	1.23E+01	1.95E+01	3.31E+01	8.51E+00
Hg-206	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tl-206	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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Isotope	Potatoes	Pumpkin	Snap beans	Strawberries	Tomatoes	Total
Ra-226	1.18E+00	1.75E+00	1.77E+00	4.38E+00	1.05E+00	**5.17E-02**
Rn-222	-	-	-	-	-	**-**
Po-218	-	-	-	-	-	**-**
At-218	-	-	-	-	-	**-**
Rn-218	-	-	-	-	-	**-**
Pb-214	1.77E+04	4.51E+03	7.44E+03	9.96E+03	2.68E+03	**1.59E+02**
Bi-214	4.03E+02	9.06E+02	9.75E+02	1.34E+03	5.91E+02	**3.63E+01**
Po-214	-	-	-	-	-	**-**
Tl-210	-	-	-	-	-	**-**
Pb-210	3.45E+00	8.80E-01	1.45E+00	1.94E+00	5.24E-01	**3.10E-02**
Bi-210	3.33E+01	7.50E+01	8.07E+01	1.11E+02	4.89E+01	**3.01E+00**
Po-210	1.18E+00	2.99E+01	1.65E+00	4.08E+01	2.60E+00	**1.37E-01**
Hg-206	-	-	-	-	-	**-**
Tl-206	-	-	-	-	-	**-**

Farmer Peak Dose DCCs for Soil (complete chain decay)

Exposure Route	Peak DCC for Ra-226 DL=1 (pCi/g)	Maximum dose during peak interval (mrem/year)	Maximum Dose rate during peak interval (mrem/year)	Maximum Dose Year ED=1 (year)
Ingestion	***2.21E+00***	***4.52E-01***	***4.52E-01***	***1.34E+02 - 1.35E+02***
Inhalation	***2.84E+03***	***3.52E-04***	***3.52E-04***	***1.17E+02 - 1.18E+02***
External Exposure	***1.48E-01***	***6.74E+00***	***6.74E+00***	***1.18E-01 - 1.12E+00***
Produce Consumption	***7.16E-01***	***1.40E+00***	***1.40E+00***	***1.27E+02 - 1.28E+02***
Finfish Consumption	***2.58E-03***	***3.88E+02***	***3.88E+02***	***8.74E+01 - 8.84E+01***
Shellfish Consumption	***9.43E-05***	***1.06E+04***	***1.06E+04***	***1.00E-08 - 1.00E+00***
Beef Consumption	***1.46E-01***	***6.86E+00***	***6.86E+00***	***1.35E+02 - 1.36E+02***
Dairy Consumption	***1.46E-01***	***6.86E+00***	***6.86E+00***	***1.31E+02 - 1.32E+02***
Poultry Consumption	***1.73E-02***	***5.78E+01***	***5.77E+01***	***1.38E+02 - 1.39E+02***
Egg Consumption	***2.43E-02***	***4.12E+01***	***4.12E+01***	***1.38E+02 - 1.39E+02***
Total	***9.13E-05***	***1.10E+04***	***1.10E+04***	***1.42E+01 - 1.52E+01***

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Ra226-Composite_Worker_soil
(March 10)

Default
Composite Worker Inputs

Variable	Value
Slab size for ACF (area correction factor) m^2	1000000 m^2
Cover thickness for GSF_o (gamma shielding factor) cm	0 cm
Cover thickness for GSF_b (gamma shielding factor) cm	0 cm
DL (dose limit) mrem/yr	1
t_{com} (time - composite worker) yr	1
EF_{com} (exposure frequency - composite worker) day/yr	250
ET_{com-o} (exposure time - outdoor composite worker) hr/day	8
ET_{com-i} (exposure time - indoor composite worker) hr/day	0
IRA_{com} (inhalation rate - composite worker) m^3/day	60
GSF_i (gamma shielding factor - indoor) unitless	0.4
IRS_{com} (soil intake rate - composite worker) mg/day	100
City (Climate Zone)	Default
A_s (acres)	0.5
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77
PEF (particulate emission factor) m^3/kg	1359344438
A (PEF Dispersion Constant)	16.2302
B (PEF Dispersion Constant)	18.7762
C (PEF Dispersion Constant)	216.108
V (fraction of vegetative cover) unitless	0.5
U_m (mean annual wind speed) m/s	4.69
U_t (equivalent threshold value)	11.32
F(x) (function dependent on U_m/U_t) unitless	0.194

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Composite Worker DCCs for Soil (complete chain, no decay)

Isotope	Parent	ICRP Lung Absorption Type	Adult Ingestion DCF (mrem/pCi)	Inhalation DCF (mrem/pCi)	External Exposure DCF (mrem/yr per pCi/g)	Lambda (1/yr)	Half-life (years)	Default Soil Volume Area Correction Factor	Default Soil Volume Gamma Shielding Factor	Total Indoor GSF Soil Volume	Particulate Emission Factor (m^3/kg)	Ingestion DCC DL=1.0E+00 (pCi/g)	Inhalation DCC DL=1.0E+00 (pCi/g)	External Exposure DCC DL=1.0E+00 (pCi/g)	Total DCC DL=1.0E+00 (pCi/g)	Total DCC DL=1.0E+00 (mg/kg)
Ra-226	Ra-226	S	1.04E-03	3.81E-02	3.18E-02	4.33E-04	1.60E+03	1.00E+00	1.00E+00	4.00E-01	1.36E+09	3.86E+01	7.13E+03	1.38E+02	**3.00E+01**	3.04E-05
Rn-222	Ra-226	-	0.00E+00	6.55E-06	2.13E-03	6.62E+01	1.05E-02	1.00E+00	1.00E+00	4.00E-01	1.36E+09	-	4.15E+07	2.06E+03	**2.06E+03**	1.34E-08
Po-218	Ra-226	-	0.00E+00	7.62E-06	9.23E-09	1.17E+05	5.90E-06	9.00E-01	1.00E+00	4.00E-01	1.36E+09	-	3.57E+07	5.27E+08	**3.34E+07**	1.20E-07
At-218	Ra-226	-	0.00E+00	0.00E+00	5.57E-05	1.46E+07	4.76E-08	9.00E-01	1.00E+00	4.00E-01	1.36E+09	-	-	8.74E+04	**8.74E+04**	2.54E-12
Rn-218	Ra-226	-	0.00E+00	0.00E+00	4.26E-03	6.24E+08	1.11E-09	1.00E+00	1.00E+00	4.00E-01	1.36E+09	-	-	1.03E+03	**1.03E+03**	6.97E-16
Pb-214	Ra-226	S	5.14E-07	4.66E-05	1.26E+00	1.36E+04	5.10E-05	1.00E+00	1.00E+00	4.00E-01	1.36E+09	7.78E+04	5.83E+06	3.48E+00	**3.48E+00**	1.06E-13
Bi-214	Ra-226	S	4.14E-07	3.66E-05	9.13E+00	1.83E+04	3.79E-05	1.00E+00	1.00E+00	4.00E-01	1.36E+09	9.65E+04	7.43E+06	4.79E-01	**4.79E-01**	1.09E-14
Po-214	Ra-226	-	0.00E+00	0.00E+00	4.80E-04	1.33E+11	5.21E-12	1.00E+00	1.00E+00	4.00E-01	1.36E+09	-	-	9.12E+03	**9.12E+03**	2.85E-17
Tl-210	Ra-226	-	0.00E+00	0.00E+00	1.68E+01	2.80E+05	2.47E-06	1.00E+00	1.00E+00	4.00E-01	1.36E+09	-	-	2.61E-01	**2.61E-01**	3.80E-16
Pb-210	Ra-226	S	2.58E-03	2.23E-02	2.09E-03	3.12E-02	2.22E+01	1.00E+00	1.00E+00	4.00E-01	1.36E+09	1.55E+01	1.22E+04	2.09E+03	**1.54E+01**	2.01E-07
Bi-210	Ra-226	S	4.85E-06	5.40E-04	5.47E-03	5.05E+01	1.37E-02	1.00E+00	1.00E+00	4.00E-01	1.36E+09	8.25E+03	5.03E+05	8.00E+02	**7.28E+02**	5.88E-09
Po-210	Ra-226	S	4.48E-03	1.73E-02	5.64E-05	1.83E+00	3.79E-01	1.00E+00	1.00E+00	4.00E-01	1.36E+09	8.93E+00	1.57E+04	7.76E+04	**8.93E+00**	1.99E-09
Hg-206	Ra-226	-	0.00E+00	0.00E+00	6.13E-01	4.47E+04	1.55E-05	1.00E+00	1.00E+00	4.00E-01	1.36E+09	-	-	7.15E+00	**7.15E+00**	6.39E-14
Tl-206	Ra-226	-	0.00E+00	0.00E+00	1.28E-02	8.67E+04	7.99E-06	1.00E+00	1.00E+00	4.00E-01	1.36E+09	-	-	3.43E+02	**3.43E+02**	1.58E-12

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Hand Calculations

Isotope			
Ra-226	3.85E+01	7.14E+03	1.38E+02
Rn-222			2.06E+03
Po-218			5.27E+08
At-218			8.74E+04
Rn-218			1.03E+03
Pb-214	7.78E+04	5.83E+06	3.48E+00
Bi-214	9.66E+04	7.43E+06	4.80E-01
Po-214			9.13E+03
Tl-210			2.61E-01
Pb-210	1.55E+01	1.22E+04	2.10E+03
Bi-210	8.25E+03	5.03E+05	8.01E+02
Po-210	8.93E+00	1.57E+04	7.77E+04
Hg-206			7.15E+00
Tl-206			3.42E+02

Decay Factors

PRG at time of peak dose

135 yr	117 yr	1 yr	53 yr				
Ing	Inh	Ext	Total	Ingestion DCC DL=1.0E+00 (pCi/g)	Inhalation DCC DL=1.0E+00 (pCi/g)	External Exposure DCC DL=1.0E+00 (pCi/g)	Total DCC DL=1.0E+00 (pCi/g)
9.43E-01	9.51E-01	1.00E+00	9.77E-01	4.09E+01	7.50E+03	1.38E+02	3.07E+01
9.43E-01	9.51E-01	1.00E+00	9.77E-01			2.06E+03	2.11E+03
9.43E-01	9.51E-01	1.00E+00	9.77E-01			5.27E+08	3.42E+07
1.89E-04	1.90E-04	2.00E-04	1.95E-04			4.37E+08	4.47E+08
9.43E-01	9.50E-01	9.99E-01	9.77E-01	8.25E+04	6.13E+06	3.48E+00	3.56E+00
9.42E-01	9.50E-01	9.98E-01	9.76E-01	1.02E+05	7.83E+06	4.80E-01	4.91E-01
9.42E-01	9.49E-01	9.98E-01	9.76E-01			9.14E+03	9.34E+03
1.98E-04	1.99E-04	2.10E-04	2.05E-04			1.24E+03	1.27E+03
9.41E-01	9.37E-01	3.02E-02	7.96E-01	1.65E+01	1.30E+04	6.92E+04	1.93E+01
9.41E-01	9.37E-01	2.96E-02	7.96E-01	8.77E+03	5.37E+05	2.70E+04	9.15E+02
9.41E-01	9.36E-01	1.58E-02	7.93E-01	9.49E+00	1.68E+04	4.92E+06	1.13E+01
				5.25E+00	3.68E+03	4.20E-01	4.01E-01

Hand Calculations

Isotope
Ra-226
Rn-222
Po-218
At-218
Rn-218
Pb-214
Bi-214
Po-214
Tl-210
Pb-210
Bi-210
Po-210
Hg-206
Tl-206

The composite worker soil land DCC use equations, presented here, contain the following exposure routes:

- incidental ingestion of soil

$$DCC_{com\text{-}sol\text{-}ing}\left(\frac{pCi}{g}\right) = \frac{DL\left(\frac{mrem}{yr}\right)}{DCF_o\left(\frac{mrem}{pCi}\right) \times EF_{com}\left(\frac{250\ days}{yr}\right) \times IRS_{com}\left(\frac{100\ mg}{day}\right) \times \left(\frac{g}{1000\ mg}\right)}$$

- inhalation of particulates resuspended from soil

$$DCC_{com\text{-}sol\text{-}inh}\left(\frac{pCi}{g}\right) = \frac{DL\left(\frac{mrem}{yr}\right)}{DCF_i\left(\frac{mrem}{pCi}\right) \times EF_{com}\left(\frac{250\ days}{yr}\right) \times ET_{com}\left(\frac{8\ hrs}{day}\right) \times \left(\frac{1\ day}{24\ hrs}\right) \times IRA_{com}\left(\frac{60\ m^3}{day}\right) \times \frac{1}{PEF\left(\frac{m^3}{kg}\right)} \times \left(\frac{1000\ g}{kg}\right)}$$

- external exposure to ionizing radiation at infinite soil volume

$$DCC_{com\text{-}sol\text{-}ext}\left(\frac{pCi}{g}\right) = \frac{DL\left(\frac{mrem}{yr}\right)}{DCF_{ext\text{-}sv}\left(\frac{mrem/yr}{pCi/g}\right) \times EF_{com}\left(\frac{250\ days}{yr}\right) \times \left(\frac{1\ yr}{365\ days}\right) \times ACF_{ext\text{-}sv} \times \left[\left(ET_{com\text{-}o}\left(\frac{8\ hrs}{day}\right) \times \left(\frac{1\ day}{24\ hrs}\right) \times GSF_{o\text{-}ext\text{-}sv}\right) + \left(ET_{com\text{-}i}\left(\frac{0\ hrs}{day}\right) \times \left(\frac{1\ day}{24\ hrs}\right) \times GSF_{i\text{-}total}\right)\right]}$$

- total

$$DCC_{com\text{-}sol\text{-}tot}\left(\frac{pCi}{g}\right) = \frac{1}{\frac{1}{DCC_{com\text{-}sol\text{-}ing}} + \frac{1}{DCC_{com\text{-}sol\text{-}inh}} + \frac{1}{DCC_{com\text{-}sol\text{-}ext}}}$$

Composite Worker Peak Dose DCCs for Soil (complete chain decay)

Exposure Route	Peak DCC for Ra-226 DL=1 (pCi/g)	Maximum dose during peak interval (mrem/year)	Maximum Dose rate during peak interval (mrem/year)	Maximum Dose Year ED=1 (year)
Ingestion	*5.25E+00*	*1.91E-01*	*1.90E-01*	*1.35E+02 - 1.36E+02*
Inhalation	*3.68E+03*	*2.72E-04*	*2.72E-04*	*1.17E+02 - 1.18E+02*
External Exposure	*4.20E-01*	*2.38E+00*	*2.38E+00*	*1.18E-01 - 1.12E+00*
Total	*4.01E-01*	*2.49E+00*	*2.49E+00*	*5.25E+01 - 5.35E+01*

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Ra226-DCC_Composite Worker_soil
(March 14)

Site-Specific
Composite Worker Inputs

Variable	Composite Worker Soil Default Value	Site-Specific Value
A (PEF Dispersion Constant)	16.2302	16.2302
B (PEF Dispersion Constant)	18.7762	18.7762
City (Climate Zone)	Default	Default
C (PEF Dispersion Constant)	216.108	216.108
Cover thickness for GSF_o (gamma shielding factor) cm	0 cm	0 cm
Cover thickness for GSF_b (gamma shielding factor) cm	0 cm	0 cm
F(x) (function dependent on U_m/U_t) unitless	0.194	0.194
PEF (particulate emission factor) m^3/kg	1359344438	1359344438
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77	93.77
A_s (acres)	0.5	0.5
Slab size for ACF (area correction factor) m^2	1000000 m^2	500 m^2
DL (dose limit) mrem/yr	1	1
EF_{com} (exposure frequency - composite worker) day/yr	250	250
ET_{com-i} (exposure time - indoor composite worker) hr/day	0	0
ET_{com-o} (exposure time - outdoor composite worker) hr/day	8	8
GSF_i (gamma shielding factor - indoor) unitless	0.4	0.4
IRA_{com} (inhalation rate - composite worker) m^3/day	60	60
IRS_{com} (soil intake rate - composite worker) mg/day	100	100
t_{com} (time - composite worker) yr	1	1
U_m (mean annual wind speed) m/s	4.69	4.69
U_t (equivalent threshold value)	11.32	11.32
V (fraction of vegetative cover) unitless	0.5	0.5

Composite Worker DCCs for Soil (complete chain, no decay)

Isotope	Parent	ICRP Lung Absorption Type	Adult Ingestion DCF (mrem/pCi)	Inhalation DCF (mrem/pCi)	External Exposure DCF (mrem/yr per pCi/g)	Lambda (1/yr)	Half-life (years)	500 m^2 Soil Volume Area Correction Factor	0 cm Soil Volume Gamma Shielding Factor	0 cm Soil Volume Gamma Shielding Factor	Total Indoor GSF Soil Volume	Particulate Emission Factor (m^3/kg)	Ingestion DCC DL=1.0E+00 (pCi/g)	Inhalation DCC DL=1.0E+00 (pCi/g)	External Exposure DCC DL=1.0E+00 (pCi/g)	Total DCC DL=1.0E+00 (pCi/g)	Total DCC DL=1.0E+00 (mg/kg)
Ra-226	Ra-226	S	1.04E-03	3.81E-02	3.18E-02	4.33E-04	1.60E+03	6.91E-01	1.00E+00	1.00E+00	4.00E-01	1.36E+09	3.86E+01	7.13E+03	2.00E+02	**3.22E+01**	3.26E-05
Rn-222	Ra-226	-	0.00E+00	6.55E-06	2.13E-03	6.62E+01	1.05E-02	7.84E-01	1.00E+00	1.00E+00	4.00E-01	1.36E+09	-	4.15E+07	2.62E+03	**2.62E+03**	1.71E-08
Po-218	Ra-226	-	0.00E+00	7.62E-06	9.23E-09	1.17E+05	5.90E-06	9.00E-01	1.00E+00	1.00E+00	4.00E-01	1.36E+09	-	3.57E+07	5.27E+08	**3.34E+07**	1.20E-07
At-218	Ra-226	-	0.00E+00	0.00E+00	5.57E-05	1.46E+07	4.76E-08	9.00E-01	1.00E+00	1.00E+00	4.00E-01	1.36E+09	-	-	8.74E+04	**8.74E+04**	2.54E-12
Rn-218	Ra-226	-	0.00E+00	0.00E+00	4.26E-03	6.24E+08	1.11E-09	7.68E-01	1.00E+00	1.00E+00	4.00E-01	1.36E+09	-	-	1.34E+03	**1.34E+03**	9.07E-16
Pb-214	Ra-226	S	5.14E-07	4.66E-05	1.26E+00	1.36E+04	5.10E-05	7.50E-01	1.00E+00	1.00E+00	4.00E-01	1.36E+09	7.78E+04	5.83E+06	4.64E+00	**4.64E+00**	1.42E-13
Bi-214	Ra-226	S	4.14E-07	3.66E-05	9.13E+00	1.83E+04	3.79E-05	8.57E-01	1.00E+00	1.00E+00	4.00E-01	1.36E+09	9.65E+04	7.43E+06	5.59E-01	**5.59E-01**	1.27E-14
Po-214	Ra-226	-	0.00E+00	0.00E+00	4.80E-04	1.33E+11	5.21E-12	8.09E-01	1.00E+00	1.00E+00	4.00E-01	1.36E+09	-	-	1.13E+04	**1.13E+04**	3.52E-17
Tl-210	Ra-226	-	0.00E+00	0.00E+00	1.68E+01	2.80E+05	2.47E-06	8.46E-01	1.00E+00	1.00E+00	4.00E-01	1.36E+09	-	-	3.09E-01	**3.09E-01**	4.49E-16
Pb-210	Ra-226	S	2.58E-03	2.23E-02	2.09E-03	3.12E-02	2.22E+01	8.04E-01	1.00E+00	1.00E+00	4.00E-01	1.36E+09	1.55E+01	1.22E+04	2.61E+03	**1.54E+01**	2.01E-07
Bi-210	Ra-226	S	4.85E-06	5.40E-04	5.47E-03	5.05E+01	1.37E-02	7.15E-01	1.00E+00	1.00E+00	4.00E-01	1.36E+09	8.25E+03	5.03E+05	1.12E+03	**9.83E+02**	7.94E-09
Po-210	Ra-226	S	4.48E-03	1.73E-02	5.64E-05	1.83E+00	3.79E-01	8.11E-01	1.00E+00	1.00E+00	4.00E-01	1.36E+09	8.93E+00	1.57E+04	9.58E+04	**8.93E+00**	1.99E-09
Hg-206	Ra-226	-	0.00E+00	0.00E+00	6.13E-01	4.47E+04	1.55E-05	7.34E-01	1.00E+00	1.00E+00	4.00E-01	1.36E+09	-	-	9.75E+00	**9.75E+00**	8.72E-14
Tl-206	Ra-226	-	0.00E+00	0.00E+00	1.28E-02	8.67E+04	7.99E-06	7.35E-01	1.00E+00	1.00E+00	4.00E-01	1.36E+09	-	-	4.66E+02	**4.66E+02**	2.15E-12

Decay Factors; PRG at time of peak dose

Isotope	Decay Factors 135 yr Ing	117 yr Inh	1 yr Ext	53 yr Total	PRG at time of peak dose: Ingestion DCC DL=1.0E+00 (pCi/g)	Inhalation DCC DL=1.0E+00 (pCi/g)	External Exposure DCC DL=1.0E+00 (pCi/g)	Total DCC DL=1.0E+00 (pCi/g)
Ra-226	9.43E-01	9.51E-01	1.00E+00	9.77E-01	4.09E+01	7.50E+03	2.00E+02	3.29E+01
Rn-222	9.43E-01	9.51E-01	1.00E+00	9.77E-01			2.62E+03	2.68E+03
Po-218	9.43E-01	9.51E-01	1.00E+00	9.77E-01			5.27E+08	3.42E+07
At-218	1.89E-04	1.90E-04	2.00E-04	1.95E-04			4.37E+08	4.47E+08
Rn-218								
Pb-214	9.43E-01	9.50E-01	9.99E-01	9.77E-01	8.25E+04	6.13E+06	4.64E+00	4.75E+00
Bi-214	9.42E-01	9.50E-01	9.98E-01	9.76E-01	1.02E+05	7.83E+06	5.60E-01	5.73E-01
Po-214	9.42E-01	9.49E-01	9.98E-01	9.76E-01			1.13E+04	1.16E+04
Tl-210	1.98E-04	1.99E-04	2.10E-04	2.05E-04			1.47E+03	1.51E+03
Pb-210	9.41E-01	9.37E-01	3.02E-02	7.96E-01	1.65E+01	1.30E+04	8.64E+04	1.93E+01
Bi-210	9.41E-01	9.37E-01	2.96E-02	7.96E-01	8.77E+03	5.37E+05	3.78E+04	1.23E+03
Po-210	9.41E-01	9.36E-01	1.58E-02	7.93E-01	9.49E+00	1.68E+04	6.07E+06	1.13E+01
Hg-206								
Tl-206								
					5.25E+00	3.68E+03	4.98E-01	4.70E-01

Hand Calculations

Isotope			
Ra-226	3.85E+01	7.14E+03	1.99E+02
Rn-222			2.62E+03
Po-218			5.27E+08
At-218			8.74E+04
Rn-218			1.34E+03
Pb-214	7.78E+04	5.83E+06	4.63E+00
Bi-214	9.66E+04	7.43E+06	5.60E-01
Po-214			1.13E+04
Tl-210			3.08E-01
Pb-210	1.55E+01	1.22E+04	2.61E+03
Bi-210	8.25E+03	5.03E+05	1.12E+03
Po-210	8.93E+00	1.57E+04	9.58E+04
Hg-206			9.73E+00
Tl-206			4.66E+02

Composite Worker Peak Dose DCCs for Soil (complete chain decay)

Exposure Route	Peak DCC for Ra-226 DL=1 (pCi/g)	Maximum dose during peak interval (mrem/year)	Maximum Dose rate during peak interval (mrem/year)	Maximum Dose Year ED=1 (year)
Ingestion	*5.25E+00*	*1.91E-01*	*1.90E-01*	*1.35E+02 - 1.36E+02*
Inhalation	*3.68E+03*	*2.72E-04*	*2.72E-04*	*1.17E+02 - 1.18E+02*
External Exposure	*4.98E-01*	*2.01E+00*	*2.01E+00*	*1.18E-01 - 1.12E+00*
Total	*4.69E-01*	*2.13E+00*	*2.13E+00*	*5.71E+01 - 5.81E+01*

Co-60-DCC_Composite Worker_soil

Default
Composite Worker Inputs

Variable	Value
Slab size for ACF (area correction factor) m^2	1000000 m^2
Cover thickness for GSF_o (gamma shielding factor) cm	0 cm
Cover thickness for GSF_b (gamma shielding factor) cm	0 cm
DL (dose limit) mrem/yr	1
t_{com} (time - composite worker) yr	1
EF_{com} (exposure frequency - composite worker) day/yr	250
ET_{com-o} (exposure time - outdoor composite worker) hr/day	8
ET_{com-i} (exposure time - indoor composite worker) hr/day	0
IRA_{com} (inhalation rate - composite worker) m^3/day	60
GSF_i (gamma shielding factor - indoor) unitless	0.4
IRS_{com} (soil intake rate - composite worker) mg/day	100
City (Climate Zone)	Default
A_s (acres)	0.5
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77
PEF (particulate emission factor) m^3/kg	1359344438
A (PEF Dispersion Constant)	16.2302
B (PEF Dispersion Constant)	18.7762
C (PEF Dispersion Constant)	216.108
V (fraction of vegetative cover) unitless	0.5
U_m (mean annual wind speed) m/s	4.69
U_t (equivalent threshold value)	11.32
F(x) (function dependent on U_m/U_t) unitless	0.194

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Composite Worker DCCs for Soil (complete chain, no decay)

Isotope	Parent	ICRP Lung Absorption Type	Adult Ingestion DCF (mrem/pCi)	Inhalation DCF (mrem/pCi)	External Exposure DCF (mrem/yr per pCi/g)	Lambda (1/yr)	Half-life (years)	Default Soil Volume Area Correction Factor	Default Soil Volume Gamma Shielding Factor	Total Indoor GSF Soil Volume	Particulate Emission Factor (m^3/kg)	Ingestion DCC DL=1.0E+00 (pCi/g)	Inhalation DCC DL=1.0E+00 (pCi/g)	External Exposure DCC DL=1.0E+00 (pCi/g)	Total DCC DL=1.0E+00 (pCi/g)	Total DCC DL=1.0E+00 (mg/kg)	Decay Factor: Decay Ingrowth factor Average	Ingestion DCC DL=1.0E+00 (pCi/g)	Inhalation DCC DL=1.0E+00 (pCi/g)	External Exposure DCC DL=1.0E+00 (pCi/g)	Total DCC DL=1.0E+00 (pCi/g)
Co-60	Co-60	S	1.27E-05	1.22E-04	1.54E+01	1.31E-01	5.27E+00	1.00E+00	1.00E+00	4.00E-01	1.36E+09	3.16E+03	2.23E+06	2.85E-01	**2.85E-01**	2.52E-10	9.37E-01	3.37E+03	2.38E+06	3.04E-01	3.04E-01

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Hand Calculations

Co-60	3.15E+03	2.23E+06	2.84E-01	2.84E-01

Composite Worker Peak Dose DCCs for Soil (complete chain decay)

Exposure Route	Peak DCC for Co-60 DL=1 (pCi/g)	Maximum dose during peak interval (mrem/year)	Maximum Dose rate during peak interval (mrem/year)	Maximum Dose Year ED=1 (year)
Ingestion	*3.37E+03*	*2.96E-04*	*3.16E-04*	*1.00E-08 - 1.00E+00*
Inhalation	*2.38E+06*	*4.21E-07*	*4.49E-07*	*1.00E-08 - 1.00E+00*
External Exposure	*3.04E-01*	*3.29E+00*	*3.51E+00*	*1.00E-08 - 1.00E+00*
Total	*3.04E-01*	*3.29E+00*	*3.51E+00*	*1.00E-08 - 1.00E+00*

Output generated 14MAR2023:17:56:25

Ra226-DCC_Soil to Groundwater

Default

Soil to Groundwater Inputs

$IRAP_{res-a}$ (apple ingestion rate - resident adult) g/day	73.9
$IRAP_{res-c}$ (apple ingestion rate - resident child) g/day	72
$IFAP_{res-adj}$ (age-adjusted apple ingestion fraction) g	25712
$IRCI_{res-a}$ (citrus ingestion rate - resident adult) g/day	306.5
$IRCI_{res-c}$ (citrus ingestion rate - resident child) g/day	206
$IFCI_{res-adj}$ (age-adjusted citrus ingestion fraction) g	99184
$IRBE_{res-a}$ (berry ingestion rate - resident adult) g/day	35.2
$IRBE_{res-c}$ (berry ingestion rate - resident child) g/day	24.2
$IFBE_{res-adj}$ (age-adjusted berry ingestion fraction) g	11434
$IRPC_{res-a}$ (peach ingestion rate - resident adult) g/day	115.7
$IRPC_{res-c}$ (peach ingestion rate - resident child) g/day	110.2
$IFPC_{res-adj}$ (age-adjusted peach ingestion fraction) g	40052
$IRPR_{res-a}$ (pear ingestion rate - resident adult) g/day	52.1
$IRPR_{res-c}$ (pear ingestion rate - resident child) g/day	69.4
$IFPR_{res-adj}$ (age-adjusted pear ingestion fraction) g	19627
$IRST_{res-a}$ (strawberry ingestion rate - resident adult) g/day	40.6
$IRST_{res-c}$ (strawberry ingestion rate - resident child) g/day	27.5
$IFST_{res-adj}$ (age-adjusted strawberry ingestion fraction) g	13155
$IRAS_{res-a}$ (asparagus ingestion rate - resident adult) g/day	40.1
$IRAS_{res-c}$ (asparagus ingestion rate - resident child) g/day	11.9
$IFAS_{res-adj}$ (age-adjusted asparagus ingestion fraction) g	11764
$IRBT_{res-a}$ (beet ingestion rate - resident adult) g/day	34.4
$IRBT_{res-c}$ (beet ingestion rate - resident child) g/day	6
$IFBT_{res-adj}$ (age-adjusted beet ingestion fraction) g	9753
$IRBR_{res-a}$ (broccoli ingestion rate - resident adult) g/day	30.5
$IRBR_{res-c}$ (broccoli ingestion rate - resident child) g/day	13.2
$IFBR_{res-adj}$ (age-adjusted broccoli ingestion fraction) g	9282
$IRCB_{res-a}$ (cabbage ingestion rate - resident adult) g/day	85.1
$IRCB_{res-c}$ (cabbage ingestion rate - resident child) g/day	11.8
$IFCB_{res-adj}$ (age-adjusted cabbage ingestion fraction) g	23884
$IRCR_{res-a}$ (carrot ingestion rate - resident adult) g/day	27.1
$IRCR_{res-c}$ (carrot ingestion rate - resident child) g/day	14.5
$IFCR_{res-adj}$ (age-adjusted carrot ingestion fraction) g	8470
$IRCO_{res-a}$ (corn ingestion rate - resident adult) g/day	60.2
$IRCO_{res-c}$ (corn ingestion rate - resident child) g/day	23.2
$IFCO_{res-adj}$ (age-adjusted corn ingestion fraction) g	18091
$IRCU_{res-a}$ (cucumber ingestion rate - resident adult) g/day	82.3
$IRCU_{res-c}$ (cucumber ingestion rate - resident child) g/day	24.5
$IFCU_{res-adj}$ (age-adjusted cucumber ingestion fraction) g	24152
$IRLE_{res-a}$ (lettuce ingestion rate - resident adult) g/day	36.7
$IRLE_{res-c}$ (lettuce ingestion rate - resident child) g/day	3.4
$IFLE_{res-adj}$ (age-adjusted lettuce ingestion fraction) g	10164
$IRLI_{res-a}$ (lima bean ingestion rate - resident adult) g/day	33.9
$IRLI_{res-c}$ (lima bean ingestion rate - resident child) g/day	22
$IFLI_{res-adj}$ (age-adjusted lima bean ingestion fraction) g	10907
$IROK_{res-a}$ (okra ingestion rate - resident adult) g/day	30.4
$IROK_{res-c}$ (okra ingestion rate - resident child) g/day	9.4
$IFOK_{res-adj}$ (age-adjusted okra ingestion fraction) g	8949
$IRON_{res-a}$ (onion ingestion rate - resident adult) g/day	21.5
$IRON_{res-c}$ (onion ingestion rate - resident child) g/day	5.9
$IFON_{res-adj}$ (age-adjusted onion ingestion fraction) g	6269
$IRPE_{res-a}$ (pea ingestion rate - resident adult) g/day	35
$IRPE_{res-c}$ (pea ingestion rate - resident child) g/day	22.6
$IFPE_{res-adj}$ (age-adjusted pea ingestion fraction) g	11251
$IRPP_{res-a}$ (pepper ingestion rate - resident adult) g/day	19.1
$IRPP_{res-c}$ (pepper ingestion rate - resident child) g/day	5.9
$IFPP_{res-adj}$ (age-adjusted pepper ingestion fraction) g	5622
$IRPU_{res-a}$ (pumpkin ingestion rate - resident adult) g/day	63.5
$IRPU_{res-c}$ (pumpkin ingestion rate - resident child) g/day	21.2
$IFPU_{res-adj}$ (age-adjusted pumpkin ingestion fraction) g	18819
$IRSN_{res-a}$ (snap bean ingestion rate - resident adult) g/day	53.8
$IRSN_{res-c}$ (snap bean ingestion rate - resident child) g/day	28.3
$IFSN_{res-adj}$ (age-adjusted snap bean ingestion fraction) g	16777
$IRTO_{res-a}$ (tomato ingestion rate - resident adult) g/day	80.1
$IRTO_{res-c}$ (tomato ingestion rate - resident child) g/day	36
$IFTO_{res-adj}$ (age-adjusted tomato ingestion fraction) g	24484
$IRPT_{res-a}$ (potato ingestion rate - resident adult) g/day	127.8
$IRPT_{res-c}$ (potato ingestion rate - resident child) g/day	47.3

$IFPT_{res-adj}$ (age-adjusted potato ingestion fraction) g	38249
$CF_{res-produce}$ (contaminated plant fraction) unitless	1
$CF_{res-apple}$ (contaminated apple fraction) unitless	1
$CF_{res-citrus}$ (contaminated citrus fraction) unitless	1
$CF_{res-berry}$ (contaminated berry fraction) unitless	1
$CF_{res-peach}$ (contaminated peach fraction) unitless	1
$CF_{res-pear}$ (contaminated pear fraction) unitless	1
$CF_{res-strawberry}$ (contaminated strawberry fraction) unitless	1
$CF_{res-asparagus}$ (contaminated asparagus fraction) unitless	1
$CF_{res-beet}$ (contaminated beet fraction) unitless	1
$CF_{res-broccoli}$ (contaminated broccoli fraction) unitless	1
$CF_{res-cabbage}$ (contaminated cabbage fraction) unitless	1
$CF_{res-carrot}$ (contaminated carrot fraction) unitless	1
$CF_{res-corn}$ (contaminated corn fraction) unitless	1
$CF_{res-cucumber}$ (contaminated cucumber fraction) unitless	1
$CF_{res-lettuce}$ (contaminated lettuce fraction) unitless	1
$CF_{res-lima\ bean}$ (contaminated lima bean fraction) unitless	1
$CF_{res-okra}$ (contaminated okra fraction) unitless	1
$CF_{res-onion}$ (contaminated onion fraction) unitless	1
$CF_{res-pea}$ (contaminated pea fraction) unitless	1
$CF_{res-pepper}$ (contaminated pepper fraction) unitless	1
$CF_{res-pumpkin}$ (contaminated pumpkin fraction) unitless	1
$CF_{res-snap\ bean}$ (contaminated snap bean fraction) unitless	1
$CF_{res-tomato}$ (contaminated tomato fraction) unitless	1
$CF_{res-potato}$ (contaminated potato fraction) unitless	1
EF_{res} (exposure frequency - resident) day/yr	350
AAF_{res-c} (tap water age adjustment factor - resident child) unitless	0.23
AAF_{res-a} (tap water age adjustment factor - resident adult) unitless	0.77
DL (dose limit) mrem/yr	1
EV_{res-c} (bathing events per day - resident child) event/day	1
EV_{res-a} (bathing events per day - resident adult) event/day	1
EF_{res-c} (exposure frequency - resident child) day/yr	350
EF_{res-a} (exposure frequency - resident adult) day/yr	350
ED_{res} (exposure duration - resident) yr	26
ET_{res-c} (exposure time - resident child) hr/day	24
ET_{res-a} (exposure time - resident adult) hr/day	24
ED_{res-a} (exposure duration - resident adult) yr	20
ED_{res-c} (exposure duration - resident child) yr	6
IRW_{res-a} (water intake rate - resident adult) L/day	2.5
IRW_{res-c} (water intake rate - resident child) L/day	0.78
K (volatilization factor of Andelman) L/m^3	0.5
IRA_{res-a} (inhalation rate - resident adult) m^3/day	20
IRA_{res-c} (inhalation rate - resident child) m^3/day	10
$IFW_{res-adj}$ (adjusted intake factor - resident) L-yr/kg-day	737
$IFA_{res-adj}$ (age-adjusted inhalation factor - resident) m^3	6195
$DFA_{res-adj}$ (age-adjusted immersion factor - resident) hr	235
$ET_{event-res-c}$ (duration of bathing event - child) hr/event	0.54
$ET_{event-res-a}$ (duration of bathing event - adult) hr/event	0.71
$MLF_{produce}$ (produce plant mass loading factor) unitless	0.26
F (irrigation period) unitless	0.25
I_f (interception fraction) unitless	0.42
I_r (irrigation rate) L/m^2-day	3.62
$Lambda_{HL}$ (soil leaching rate) 1/day	0.000027
P (area density for root zone) kg/m^2	240
T (translocation factor) unitless	1
t_b (long term deposition and buildup) day	10950
t_v (above ground exposure time) day	60
t_w (weathering half-life) day	14
Y_v (plant yield - wet) kg/m^2	2
DAF (dilution attenuation factor) unitless	1
$Theta_w$ (water-filled soil porosity) L_{water}/L_{soil}	0.3
p_b (dry soil bulk density) kg/L	1.5
I (infiltration rate) m/yr	0.18
ED_{res} (exposure duration) yr	70
t_{res} (time - resident) yr	1
foc (fraction organic carbon in soil) g/g	0.002
p_s (soil particle density) kg/L	2.65
Soil to Groundwater Method	1

Output generated 14MAR2023:18:14:54

DCCs for Soil to Groundwater (complete chain, no decay)

Isotope	Parent	0.18 exchanges per hour A_{eq}(unitless)	ICRP Lung Absorption Type	Ingestion DCF (mrem/pCi)	Inhalation DCF (mrem/pCi)	Immersion DCF (mrem/yr per pCi/L)	Half-life (years)	Wet Soil-to-plant transfer factor Woody tree (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Leaf (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Root (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Shrub (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Non-leafy fruit (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Maize grain (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Legume seed (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Tuber (pCi/g-fresh plant per pCi/g-wet soil)
Ra-226	Ra-226	-	S	1.68E-03	3.81E-02	7.99E-05	1.60E+03	1.00E-02	9.10E-02	7.00E-02	1.00E-02	1.70E-02	2.40E-03	1.40E-02	1.10E-02
Rn-222	Ra-226	1.00E+00	-	0.00E+00	6.55E-06	4.39E-06	1.05E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Po-218	Ra-226	9.87E-01	-	0.00E+00	7.62E-06	3.34E-10	5.90E-06	2.00E-04	7.40E-03	5.80E-03	2.00E-04	2.00E-04	2.40E-04	2.70E-04	2.70E-03
At-218	Ra-226	1.97E-04	-	0.00E+00	0.00E+00	1.46E-07	4.76E-08	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01
Rn-218	Ra-226	1.97E-07	-	0.00E+00	0.00E+00	8.63E-06	1.11E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb-214	Ra-226	8.84E-01	S	7.36E-07	4.66E-05	2.81E-03	5.10E-05	1.00E-02	8.00E-02	1.50E-02	1.00E-02	1.50E-02	1.20E-03	5.30E-03	1.50E-03
Bi-214	Ra-226	8.14E-01	S	5.51E-07	3.66E-05	1.80E-02	3.79E-05	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
Po-214	Ra-226	8.14E-01	-	0.00E+00	0.00E+00	9.61E-07	5.21E-12	2.00E-04	7.40E-03	5.80E-03	2.00E-04	2.00E-04	2.40E-04	2.70E-04	2.70E-03
Tl-210	Ra-226	1.70E-04	-	0.00E+00	0.00E+00	3.33E-02	2.47E-06	8.00E-05	8.00E-04	8.00E-05	8.00E-05	8.00E-04	8.00E-04	8.00E-04	8.00E-05
Pb-210	Ra-226	0.00E+00	S	3.77E-03	2.23E-02	1.27E-05	2.22E+01	1.00E-02	8.00E-02	1.50E-02	1.00E-02	1.50E-02	1.20E-03	5.30E-03	1.50E-03
Bi-210	Ra-226	0.00E+00	S	6.66E-06	5.40E-04	3.48E-05	1.37E-02	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
Po-210	Ra-226	0.00E+00	S	6.48E-03	1.73E-02	1.13E-07	3.79E-01	2.00E-04	7.40E-03	5.80E-03	2.00E-04	2.00E-04	2.40E-04	2.70E-04	2.70E-03
Hg-206	Ra-226	0.00E+00	-	0.00E+00	0.00E+00	1.39E-03	1.55E-05	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01
Tl-206	Ra-226	0.00E+00	-	0.00E+00	0.00E+00	5.55E-05	7.99E-06	8.00E-05	8.00E-04	8.00E-05	8.00E-05	8.00E-04	8.00E-04	8.00E-04	8.00E-05

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Wet Soil-to-plant transfer factor Herbaceous (pCi/g-fresh plant per pCi/g-wet soil)	K_d Distribution coefficient (L/kg)	$Lambda_B$ (1/day)	$Lambda_E$ (1/day)	Irr_{dep} (L/kg)	Ingestion DCC DL=1.0E+00 (pCi/L)	Inhalation DCC DL=1.0E+00 (pCi/L)	Immersion DCC DL=1.0E+00 (pCi/L)	Produce Consumption DCC DL=1.0E+00 (pCi/L)	Total DCC DL=1.0E+00 (pCi/L)	Total DCC DL=1.0E+00 (mg/L)	Groundwater Dose-based Concentration DL=1.0E+00 (pCi/L)	SSL Dose-based DL=1.0E+00 (pCi/g)	SSL Dose-based DL=1.0E+00 (mg/kg)	MCL (pCi/L)	MCL (mg/L)	Groundwater MCL-based Concentration (pCi/L)	SSL MCL-based (pCi/g)	SSL MCL-based (mg/kg)	Decay Factors 134 y	1 yr	SSL (decay corrected) pCi/g
1.00E-02	1.00E+00	2.70E-05	4.95E-02	3.64E+00	8.10E-01	-	4.67E+05	2.86E-01	**2.11E-01**	2.14E-10	2.11E-01	**2.53E-04**	2.57E-13	5.00E+00	5.06E-09	5.00E+00	**6.00E-03**	6.07E-12	9.44E-01	1.00E+00	2.68E-04
0.00E+00	0.00E+00	2.70E-05	4.95E-02	3.64E+00	-	4.93E+01	8.49E+06	-	**4.93E+01**	5.53E-08	4.93E+01	**9.86E-03**	1.11E-11	-	-	-	**-**	-	9.44E-01	1.00E+00	1.04E-02
2.00E-04	2.10E+02	2.70E-05	4.95E-02	3.64E+00	-	4.29E+01	1.12E+11	-	**4.29E+01**	4.02E-07	4.29E+01	**9.03E+00**	8.45E-08	1.50E+01	5.40E-17	1.50E+01	**3.15E+00**	1.14E-17	9.44E-01	1.00E+00	9.57E+00
2.00E-01	1.00E+01	2.70E-05	4.95E-02	3.64E+00	-	-	2.55E+08	-	**2.55E+08**	7.42E-12	2.55E+08	**2.61E+06**	7.56E-14	1.50E+01	4.36E-19	1.50E+01	**1.53E-01**	4.44E-21	1.89E-04	2.00E-04	1.38E+10
0.00E+00	0.00E+00	2.70E-05	4.95E-02	3.64E+00	-	-	4.32E+06	-	**4.32E+06**	2.93E-15	4.32E+06	**8.64E+02**	5.85E-19	-	-	-	**-**	-			
1.00E-02	1.50E+02	2.70E-05	4.95E-02	3.64E+00	1.84E+03	7.84E+00	1.32E+04	6.83E+02	**7.71E+00**	1.47E-14	7.71E+00	**1.16E+00**	2.20E-15	-	-	-	**-**	-	9.43E-01	9.99E-01	1.23E+00
1.00E-01	4.80E+02	2.70E-05	4.95E-02	3.64E+00	2.46E+03	1.08E+01	2.07E+03	5.37E+02	**1.05E+01**	8.25E-15	1.05E+01	**5.05E+00**	3.96E-15	1.50E+01	3.40E-16	1.50E+01	**7.20E+00**	1.63E-16	9.43E-01	9.98E-01	5.36E+00
2.00E-04	2.10E+02	2.70E-05	4.95E-02	3.64E+00	-	-	3.88E+07	-	**3.88E+07**	1.21E-16	3.88E+07	**8.15E+06**	2.55E-17	1.50E+01	4.68E-23	1.50E+01	**3.15E+00**	9.84E-24	9.42E-01	9.98E-01	8.65E+06
8.00E-05	1.50E+03	2.70E-05	4.95E-02	3.64E+00	-	-	1.12E+03	-	**1.12E+03**	1.63E-15	1.12E+03	**1.68E+03**	2.44E-15	-	-	-	**-**	-	1.98E-04	2.10E-04	8.49E+06
1.00E-02	1.50E+02	2.70E-05	4.95E-02	3.64E+00	3.60E-01	-	2.93E+06	1.33E-01	**9.72E-02**	1.27E-12	9.72E-02	**1.46E-02**	1.91E-13	-	-	-	**-**	-	9.41E-01	3.02E-02	1.55E-02
1.00E-01	4.80E+02	2.70E-05	4.95E-02	3.64E+00	2.04E+02	-	1.07E+06	4.45E+01	**3.65E+01**	2.95E-13	3.65E+01	**1.75E+01**	1.42E-13	1.50E+01	1.21E-13	1.50E+01	**7.20E+00**	5.82E-14	9.41E-01	2.96E-02	1.86E+01
2.00E-04	2.10E+02	2.70E-05	4.95E-02	3.64E+00	2.10E-01	-	3.31E+08	8.90E-02	**6.25E-02**	1.39E-14	6.25E-02	**1.31E-02**	2.93E-15	1.50E+01	3.34E-12	1.50E+01	**3.15E+00**	7.03E-13	9.40E-01	1.58E-02	1.39E-02
3.00E-01	6.30E+03	2.70E-05	4.95E-02	3.64E+00	-	-	2.68E+04	-	**2.68E+04**	2.40E-13	2.68E+04	**1.69E+05**	1.51E-12	-	-	-	**-**	-			
8.00E-05	1.50E+03	2.70E-05	4.95E-02	3.64E+00	-	-	6.72E+05	-	**6.72E+05**	3.10E-12	6.72E+05	**1.01E+06**	4.65E-12	-	-	-	**-**	-			
																					2.52E-04

Hand Calculations		Decay-corr Ing	Decay-corr Inh	Decay-corr Imm	Decay-corr Prod	Decay corr total					
Isotope		8.56E-01		4.67E+05	3.03E-01	2.24E-01	8.08E-01		4.67E+05		2.11E-01
Ra-226			4.93E+01	8.49E+06		5.22E+01		4.93E+01	8.49E+06		4.93E+01
Rn-222			4.29E+01	1.12E+11		4.55E+01		4.29E+01	1.12E+11		4.29E+01
Po-218				1.28E+12		1.35E+12			2.55E+08		2.55E+08
At-218									4.32E+06		4.32E+06
Rn-218		1.95E+03	7.84E+00	1.33E+04	7.24E+02	5.09E+02	1.84E+03	7.84E+00	1.33E+04		4.80E+02
Pb-214		2.61E+03	1.09E+01	2.07E+03	5.70E+02	3.86E+02	2.46E+03	1.08E+01	2.07E+03		3.63E+02
Bi-214				3.89E+07		4.12E+07			3.88E+07		3.88E+07
Po-214				5.34E+06		5.65E+06			1.12E+03		1.12E+03
Tl-210		3.83E-01		9.71E+07	1.41E-01	3.83E-01	3.60E-01		2.94E+06		3.60E-01
Pb-210		2.17E+02		3.62E+07	4.73E+01	2.17E+02	2.04E+02		1.07E+06		2.04E+02
Bi-210		2.23E-01		2.09E+10	9.46E-02	2.23E-01	2.09E-01		3.30E+08		2.09E-01
Po-210									2.68E+04		2.68E+04
Hg-206									6.72E+05		6.72E+05
Tl-206											
	Totals (pCi/L)	1.21E-01	3.80E+00	1.79E+03	4.77E-02	8.60E-02	1.14E-01	3.80E+00	6.69E+02	4.49E-02	8.10E-02

Method 1. Partitioning Equation for Migration to Groundwater

$$SSL\left(\frac{pCi}{g}\right) = C_{water}\left(\frac{pCi}{L}\right) \times \left(\frac{kg}{1000\ g}\right) \times \left[K_d\left(\frac{L}{kg}\right) + \left(\frac{\theta_w\left(\frac{0.3\ L_{water}}{L_{soil}}\right)}{\rho_b\left(\frac{1.5\ kg}{L}\right)}\right)\right]$$

where:

$$C_{water}\left(\frac{pCi}{L}\right) = MCL\left(\frac{pCi}{L}\right) \times DAF$$

or:

$$C_{water}\left(\frac{pCi}{L}\right) = PRG\left(\frac{pCi}{L}\right) \times DAF$$

Method 2. Mass-Limit Equation for Migration to Groundwater

$$SSL\left(\frac{pCi}{g}\right) = \frac{C_{water}\left(\frac{pCi}{L}\right) \times I\left(\frac{0.18\ m}{yr}\right) \times ED(70\ yr)}{\rho_b\left(\frac{1.5\ kg}{L}\right) \times d_s\left(\frac{mg}{kg}\right) \times \left(\frac{1{,}000\ g}{kg}\right)}$$

where:

$$C_{water}\left(\frac{pCi}{L}\right) = MCL\left(\frac{pCi}{L}\right) \times DAF$$

or:

$$C_{water}\left(\frac{pCi}{L}\right) = PRG\left(\frac{pCi}{L}\right) \times DAF$$

Then calculate the dilution factor using this equation.

$$\text{Dilution Attenuation Factor (DAF)} = 1 + \frac{K\left(\frac{m}{yr}\right) \times i\left(\frac{m}{m}\right) \times d(m)}{I\left(\frac{0.18\ m}{yr}\right) \times L(m)}$$

where:

$$d(m) = \left(0.0112 \times L^2(m)\right)^{0.5} + d_a(m) \times \left[1 - \exp\left(\frac{-L(m) \times I\left(\frac{0.18\ m}{yr}\right)}{K\left(\frac{m}{yr}\right) \times i\left(\frac{m}{m}\right) \times d_a(m)}\right)\right]$$

Produce DCCs for Soil to Groundwater

Isotope	Apple Consumption DCC DL=1.0E+00 (pCi/L)	Asparagus Consumption DCC DL=1.0E+00 (pCi/L)	Beet Consumption DCC DL=1.0E+00 (pCi/L)	Berry Consumption DCC DL=1.0E+00 (pCi/L)	Broccoli Consumption DCC DL=1.0E+00 (pCi/L)	Cabbage Consumption DCC DL=1.0E+00 (pCi/L)	Carrot Consumption DCC DL=1.0E+00 (pCi/L)	Citrus fruit Consumption DCC DL=1.0E+00 (pCi/L)	Corn Consumption DCC DL=1.0E+00 (pCi/L)	Cucumber Consumption DCC DL=1.0E+00 (pCi/L)	Lettuce Consumption DCC DL=1.0E+00 (pCi/L)	Lima beans Consumption DCC DL=1.0E+00 (pCi/L)
Ra-226	5.79E+00	7.35E+00	9.95E+00	1.30E+01	1.50E+01	3.62E+00	1.15E+01	1.50E+00	8.83E+00	5.81E+00	7.96E+00	1.28E+01
Rn-222	-	-	-	-	-	-	-	-	-	-	-	-
Po-218	-	-	-	-	-	-	-	-	-	-	-	-
At-218	-	-	-	-	-	-	-	-	-	-	-	-
Rn-218	-	-	-	-	-	-	-	-	-	-	-	-
Pb-214	1.32E+04	1.77E+04	3.33E+04	2.97E+04	3.47E+04	8.74E+03	3.83E+04	3.42E+03	2.03E+04	1.35E+04	1.91E+04	3.14E+04
Bi-214	9.77E+03	2.14E+04	2.58E+04	2.20E+04	2.69E+04	1.05E+04	2.97E+04	2.53E+03	1.39E+04	1.04E+04	2.32E+04	2.26E+04
Po-214	-	-	-	-	-	-	-	-	-	-	-	-
Tl-210	-	-	-	-	-	-	-	-	-	-	-	-
Pb-210	2.57E+00	3.46E+00	6.49E+00	5.79E+00	6.77E+00	1.71E+00	7.48E+00	6.67E-01	3.97E+00	2.62E+00	3.73E+00	6.12E+00
Bi-210	8.09E+02	1.77E+03	2.13E+03	1.82E+03	2.23E+03	8.71E+02	2.46E+03	2.10E+02	1.15E+03	8.61E+02	1.92E+03	1.87E+03
Po-210	1.64E+00	3.36E+00	4.11E+00	3.70E+00	4.51E+00	1.65E+00	4.73E+00	4.26E-01	2.33E+00	1.75E+00	3.46E+00	3.74E+00
Hg-206	-	-	-	-	-	-	-	-	-	-	-	-
Tl-206	-	-	-	-	-	-	-	-	-	-	-	-

Isotope	Okra Consumption DCC DL=1.0E+00 (pCi/L)	Onion Consumption DCC DL=1.0E+00 (pCi/L)	Peaches Consumption DCC DL=1.0E+00 (pCi/L)	Pears Consumption DCC DL=1.0E+00 (pCi/L)	Peas Consumption DCC DL=1.0E+00 (pCi/L)	Peppers Consumption DCC DL=1.0E+00 (pCi/L)	Potatoes Consumption DCC DL=1.0E+00 (pCi/L)	Pumpkin Consumption DCC DL=1.0E+00 (pCi/L)	Snap beans Consumption DCC DL=1.0E+00 (pCi/L)	Strawberries Consumption DCC DL=1.0E+00 (pCi/L)	Tomatoes Consumption DCC DL=1.0E+00 (pCi/L)	Total Produce DCC DL=1.0E+00 (pCi/L)
Ra-226	1.57E+01	1.55E+01	3.72E+00	7.59E+00	1.28E+01	2.45E+01	3.86E+00	7.46E+00	8.23E+00	1.13E+01	5.65E+00	**2.86E-01**
Rn-222	-	-	-	-	-	-	-	-	-	-	-	**-**
Po-218	-	-	-	-	-	-	-	-	-	-	-	**-**
At-218	-	-	-	-	-	-	-	-	-	-	-	**-**
Rn-218	-	-	-	-	-	-	-	-	-	-	-	**-**
Pb-214	3.63E+04	5.18E+04	8.47E+03	1.73E+04	3.15E+04	5.67E+04	9.59E+03	1.73E+04	2.02E+04	2.58E+04	1.31E+04	**6.83E+02**
Bi-214	2.81E+04	4.01E+04	6.27E+03	1.28E+04	2.23E+04	4.42E+04	6.56E+03	1.34E+04	1.46E+04	1.91E+04	1.02E+04	**5.37E+02**
Po-214	-	-	-	-	-	-	-	-	-	-	-	**-**
Tl-210	-	-	-	-	-	-	-	-	-	-	-	**-**
Pb-210	7.08E+00	1.01E+01	1.65E+00	3.37E+00	6.14E+00	1.11E+01	1.87E+00	3.37E+00	3.94E+00	5.03E+00	2.55E+00	**1.33E-01**
Bi-210	2.32E+03	3.32E+03	5.19E+02	1.06E+03	1.85E+03	3.66E+03	5.43E+02	1.11E+03	1.21E+03	1.58E+03	8.42E+02	**4.45E+01**
Po-210	4.73E+00	6.39E+00	1.06E+00	2.15E+00	3.75E+00	7.37E+00	1.08E+00	2.25E+00	2.40E+00	3.21E+00	1.70E+00	**8.90E-02**
Hg-206	-	-	-	-	-	-	-	-	-	-	-	**-**
Tl-206	-	-	-	-	-	-	-	-	-	-	-	**-**

Output generated 14MAR2023:18:14:54

Peak Dose DCCs for Soil to Groundwater (complete chain decay)

Exposure Route	Peak DCC for Ra-226 DL=1 (pCi/L)	Maximum dose during peak interval (mrem/year)	Maximum Dose rate during peak interval (mrem/year)	Maximum Dose Year ED=1 (year)
Ingestion	***1.21E-01***	***8.28E+00***	***8.28E+00***	***1.34E+02 - 1.35E+02***
Inhalation	***2.89E+00***	***3.47E-01***	***3.47E-01***	***1.17E-01 - 1.12E+00***
Immersion	***1.79E+03***	***5.60E-04***	***5.60E-04***	***1.20E-01 - 1.12E+00***
Produce Consumption	***4.77E-02***	***2.10E+01***	***2.10E+01***	***1.34E+02 - 1.35E+02***
Total	***3.38E-02***	***2.96E+01***	***2.96E+01***	***1.34E+02 - 1.35E+02***

Output generated 14MAR2023:18:14:54

3.38E-02

Ra226-Cs137-Co60-DCC_Resident_soil

Site-Specific
Resident Soil Inputs

Variable	Resident Soil Default Value	Site-Specific Value
A (PEF Dispersion Constant)	16.2302	16.2302
B (PEF Dispersion Constant)	18.7762	18.7762
City (Climate Zone)	Default	Default
C (PEF Dispersion Constant)	216.108	216.108
Cover thickness for GSF_o (gamma shielding factor) cm	0 cm	0 cm
Cover thickness for GSF_b (gamma shielding factor) cm	0 cm	0 cm
$AAF_{res\text{-}a}$ (biota age adjustment factor - resident adult) unitless	0.77	0.77
$AAF_{res\text{-}c}$ (biota age adjustment factor - resident child) unitless	0.23	0.23
$CF_{res\text{-}produce}$ (contaminated plant fraction) unitless	1	1
$CF_{res\text{-}cabbage}$ (contaminated cabbage fraction) unitless	1	0.1
$CF_{res\text{-}cucumber}$ (contaminated cucumber fraction) unitless	1	0.25
$CF_{res\text{-}potato}$ (contaminated potato fraction) unitless	1	0.3
$CF_{res\text{-}tomato}$ (contaminated tomato fraction) unitless	1	0.1
$ED_{res\text{-}a}$ (produce exposure duration - resident adult) yr	20	20
$ED_{res\text{-}c}$ (produce exposure duration - resident child) yr	6	6
$EF_{res\text{-}a}$ (produce exposure frequency - resident adult) day/yr	350	350
$EF_{res\text{-}c}$ (produce exposure frequency - resident child) day/yr	350	350
$IFCB_{res\text{-}adj}$ (age-adjusted cabbage ingestion fraction) g	23884	23884
$IFCU_{res\text{-}adj}$ (age-adjusted cucumber ingestion fraction) g	24152	24152
$IFPT_{res\text{-}adj}$ (age-adjusted potato ingestion fraction) g	38249	38249
$IFTO_{res\text{-}adj}$ (age-adjusted tomato ingestion fraction) g	24484	24484
$IRCB_{res\text{-}a}$ (cabbage ingestion rate - resident adult) g/day	85.1	85.1
$IRCB_{res\text{-}c}$ (cabbage ingestion rate - resident child) g/day	11.8	11.8
$IRCU_{res\text{-}a}$ (cucumber ingestion rate - resident adult) g/day	82.3	82.3
$IRCU_{res\text{-}c}$ (cucumber ingestion rate - resident child) g/day	24.5	24.5
$IRPT_{res\text{-}a}$ (potato ingestion rate - resident adult) g/day	127.8	127.8
$IRPT_{res\text{-}c}$ (potato ingestion rate - resident child) g/day	47.3	47.3
$IRTO_{res\text{-}a}$ (tomato ingestion rate - resident adult) g/day	80.1	80.1
$IRTO_{res\text{-}c}$ (tomato ingestion rate - resident child) g/day	36	36
$MLF_{cabbage}$ (cabbage mass loading factor) unitless	0.000105	0.000105
$MLF_{cucumber}$ (cucumber mass loading factor) unitless	0.00004	0.00004
MLF_{potato} (potato mass loading factor) unitless	0.00021	0.00021
MLF_{tomato} (tomato mass loading factor) unitless	0.00177	0.00177
F(x) (function dependent on U_m/U_t) unitless	0.194	0.194
PEF (particulate emission factor) m^3/kg	1359344438	1359344438
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77	93.77
A_s (acres)	0.5	0.5
Site area for ACF (area correction factor) m^2	1000000 m^2	1000000 m^2
$AAF_{res\text{-}a}$ (soil age adjustment factor - resident adult) unitless	0.77	0.77
$AAF_{res\text{-}c}$ (soil age adjustment factor - resident child) unitless	0.23	0.23
DL (dose limit) mrem/yr	1	12
ED_{res} (soil exposure duration - resident) yr	26	26
$ED_{res\text{-}a}$ (soil exposure duration - resident adult) yr	20	20
$ED_{res\text{-}c}$ (soil exposure duration - resident child) yr	6	6
EF_{res} (soil exposure frequency - resident) day/yr	350	350
$EF_{res\text{-}a}$ (soil exposure frequency - resident adult) day/yr	350	350
$EF_{res\text{-}c}$ (soil exposure frequency - resident child) day/yr	350	350
ET_{res} (soil exposure time - resident) hr/day	24	24
$ET_{res\text{-}a}$ (soil exposure time - resident adult) hr/day	24	24
$ET_{res\text{-}c}$ (soil exposure time - resident child) hr/day	24	24
$ET_{res\text{-}i}$ (soil exposure time - indoor resident) hr/day	16.416	16.416
$ET_{res\text{-}o}$ (soil exposure time - outdoor resident) hr/day	1.752	1.752
GSF_i (gamma shielding factor - indoor) unitless	0.4	0.4
$IFA_{res\text{-}adj}$ (age-adjusted soil inhalation factor - resident) m^3	6195	6195
$IFS_{res\text{-}adj}$ (age-adjusted soil ingestion factor - resident) mg	43050	43050
$IRA_{res\text{-}a}$ (soil inhalation rate - resident adult) m^3/day	20	20
$IRA_{res\text{-}c}$ (soil inhalation rate - resident child) m^3/day	10	10
$IRS_{res\text{-}a}$ (soil intake rate - resident adult) mg/day	100	100
$IRS_{res\text{-}c}$ (soil intake rate - resident child) mg/day	200	200
t_{res} (time - resident) yr	1	1
Soil type	Default	Default
U_m (mean annual wind speed) m/s	4.69	4.69
U_t (equivalent threshold value)	11.32	11.32
V (fraction of vegetative cover) unitless	0.5	0.5

Resident DCCs for Soil (complete chain, no decay)

Isotope	Parent	ICRP Lung Absorption Type	Ingestion DCF (mrem/pCi)	Inhalation DCF (mrem/pCi)	External Exposure DCF (mrem/yr per pCi/g)	Half-life (years)	1000000 m^2 Soil Volume Area Correction Factor	Wet Soil-to-plant transfer factor Leaf (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Non-leafy fruit (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Tuber (pCi/g-fresh plant per pCi/g-wet soil)	0 cm Soil Volume Gamma Shielding Factor	0 cm Soil Volume Gamma Shielding Factor	Total Indoor GSF Soil Volume	Particulate Emission Factor (m^3/kg)	Ingestion DCC DL=1.2E+01 (pCi/g)	Inhalation DCC DL=1.2E+01 (pCi/g)	External Exposure DCC DL=1.2E+01 (pCi/g)	Produce Consumption DCC DL=1.2E+01 (pCi/g)	Total DCC DL=1.2E+01 (pCi/g)	Total DCC DL=1.2E+01 (mg/kg)
Co-60	Co-60	S	2.03E-05	1.22E-04	1.54E+01	5.27E+00	1.00E+00	1.70E-01	1.40E-01	5.40E-02	1.00E+00	1.00E+00	4.00E-01	1.36E+09	1.37E+04	2.16E+07	2.35E+00	2.66E+02	**2.32E+00**	2.06E-09

Hand Calcuations

	Decay Corrected DCC				
Decay Factor, 0-1 years	Ingestion DCC DL=1.2E+01 (pCi/g)	Inhalation DCC DL=1.2E+01 (pCi/g)	External Exposure DCC DL=1.2E+01 (pCi/g)	Produce Consumption DCC DL=1.2E+01 (pCi/g)	Total
9.37E-01	1.46E+04	2.31E+07	2.51E+00	2.84E+02	2.49E+00

Hand Calcuations

Decay Factor, 0-1 years	Decay Corrected DCC Ingestion DCC DL=1.2E+01 (pCi/g)	Inhalation DCC DL=1.2E+01 (pCi/g)	External Exposure DCC DL=1.2E+01 (pCi/g)	Produce Consumption DCC DL=1.2E+01 (pCi/g)	Total
9.37E-01	1.46E+04	2.31E+07	2.51E+00	2.84E+02	2.49E+00

Resident Produce DCCs for Soil

Isotope	Cabbage Consumption DCC DL=1.2E+01 (pCi/g)	Cucumber Consumption DCC DL=1.2E+01 (pCi/g)	Potatoes Consumption DCC DL=1.2E+01 (pCi/g)	Tomatoes Consumption DCC DL=1.2E+01 (pCi/g)	Total Produce DCC DL=1.2E+01 (pCi/g)
Co-60	1.45E+03	6.99E+02	9.50E+02	1.70E+03	**2.66E+02**

Resident Peak Dose DCCs for Soil (complete chain decay)

Exposure Route	Peak DCC for Co-60 DL=12 (pCi/g)	Maximum dose during peak interval (mrem/year)	Maximum Dose rate during peak interval (mrem/year)	Maximum Dose Year ED=1 (year)
Ingestion	***1.46E+04***	***8.19E-04***	***8.74E-04***	***1.00E-08 - 1.00E+00***
Inhalation	***2.30E+07***	***5.21E-07***	***5.56E-07***	***1.00E-08 - 1.00E+00***
External Exposure	***2.50E+00***	***4.79E+00***	***5.12E+00***	***1.00E-08 - 1.00E+00***
Produce Consumption	***7.38E+03***	***1.63E-03***	***1.74E-03***	***1.00E-08 - 1.00E+00***
Total	***2.50E+00***	***4.80E+00***	***5.12E+00***	***1.00E-08 - 1.00E+00***

Check	2.50E+00

Resident DCCs for Soil (complete chain, no decay)

Isotope	Parent	ICRP Lung Absorption Type	Ingestion DCF (mrem/pCi)	Inhalation DCF (mrem/pCi)	External Exposure DCF (mrem/yr per pCi/g)	Half-life (years)	1000000 m^2 Soil Volume Area Correction Factor	Wet Soil-to-plant transfer factor Leaf (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Non-leafy fruit (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Tuber (pCi/g-fresh plant per pCi/g-wet soil)	0 cm Soil Volume Gamma Shielding Factor	0 cm Soil Volume Gamma Shielding Factor	Total Indoor GSF Soil Volume	Particulate Emission Factor (m^3/kg)	Ingestion DCC DL=1.2E+01 (pCi/g)	Inhalation DCC DL=1.2E+01 (pCi/g)	External Exposure DCC DL=1.2E+01 (pCi/g)	Produce Consumption DCC DL=1.2E+01 (pCi/g)	Total DCC DL=1.2E+01 (pCi/g)	Total DCC DL=1.2E+01 (mg/kg)
Cs-137	Cs-137	S	4.92E-05	1.54E-04	8.69E-04	3.02E+01	1.00E+00	6.00E-02	2.10E-02	5.60E-02	1.00E+00	1.00E+00	4.00E-01	1.36E+09	5.66E+03	1.71E+07	4.16E+04	2.51E+02	**2.39E+02**	2.77E-06
Ba-137m	Cs-137	-	0.00E+00	0.00E+00	3.38E+00	4.86E-06	1.00E+00	5.00E-03	1.00E-02	5.00E-03	1.00E+00	1.00E+00	4.00E-01	1.36E+09	-	-	1.07E+01	-	**1.07E+01**	1.99E-14

Hand Calculations

Isotope	Decay Factor at 1-year	Average Decay Factor, 0-1 years	Decay Corrected DCC using Decay Factor at 1 year: Ingestion DCC DL=1.2E+01 (pCi/g)	Inhalation DCC DL=1.2E+01 (pCi/g)	External Exposure DCC DL=1.2E+01 (pCi/g)	Produce Consumption DCC DL=1.2E+01 (pCi/g)	Total	Decay Corrected DCC using 0-1 yr Aveage Decay Factor: Ingestion DCC DL=1.2E+01 (pCi/g)	Inhalation DCC DL=1.2E+01 (pCi/g)	External Exposure DCC DL=1.2E+01 (pCi/g)	Produce Consumption DCC DL=1.2E+01 (pCi/g)	Total
Cs-137	9.77E-01	9.89E-01	5.79E+03	1.75E+07	4.26E+04	2.57E+02	2.45E+02	5.73E+03	1.73E+07	4.21E+04	2.54E+02	2.42E+02
Ba-137m	9.23E-01	9.33E-01			1.16E+01		1.16E+01			1.15E+01		1.15E+01
		Total	5.79E+03	1.75E+07	1.16E+01	2.57E+02	1.11E+01	5.73E+03	1.73E+07	1.15E+01	2.54E+02	1.09E+01

Resident Produce DCCs for Soil

Isotope	Cabbage Consumption DCC DL=1.2E+01 (pCi/g)	Cucumber Consumption DCC DL=1.2E+01 (pCi/g)	Potatoes Consumption DCC DL=1.2E+01 (pCi/g)	Tomatoes Consumption DCC DL=1.2E+01 (pCi/g)	Total Produce DCC DL=1.2E+01 (pCi/g)
Cs-137	1.70E+03	1.92E+03	3.78E+02	4.37E+03	**2.51E+02**
Ba-137m	-	-	-	-	**-**

Resident Peak Dose DCCs for Soil (complete chain decay)

Exposure Route	Peak DCC for Cs-137 DL=12 (pCi/g)	Maximum dose during peak interval (mrem/year)	Maximum Dose rate during peak interval (mrem/year)	Maximum Dose Year ED=1 (year)
Ingestion	***5.73E+03***	***2.09E-03***	***2.12E-03***	***1.00E-08 - 1.00E+00***
Inhalation	***1.73E+07***	***6.95E-07***	***7.03E-07***	***1.00E-08 - 1.00E+00***
External Exposure	***1.14E+01***	***1.05E+00***	***1.06E+00***	***1.00E-08 - 1.00E+00***
Produce Consumption	***6.60E+03***	***1.82E-03***	***1.84E-03***	***1.00E-08 - 1.00E+00***
Total	***1.14E+01***	***1.05E+00***	***1.07E+00***	***1.00E-08 - 1.00E+00***

Check 1.14E+01

Isotope	Parent	ICRP Lung Absorption Type	Ingestion DCF (mrem/pCi)	Inhalation DCF (mrem/pCi)	External Exposure DCF (mrem/yr per pCi/g)	Half-life (years)	1000000 m^2 Soil Volume Area Correction Factor	Wet Soil-to-plant transfer factor Leaf (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Non-leafy fruit (pCi/g-fresh plant per pCi/g-wet soil)	Wet Soil-to-plant transfer factor Tuber (pCi/g-fresh plant per pCi/g-wet soil)	0 cm Soil Volume Gamma Shielding Factor	0 cm Soil Volume Gamma Shielding Factor	Total Indoor GSF Soil Volume
Ra-226	Ra-226	S	1.68E-03	3.81E-02	3.18E-02	1.60E+03	1.00E+00	9.10E-02	1.70E-02	1.10E-02	1.00E+00	1.00E+00	4.00E-01
Rn-222	Ra-226	-	0.00E+00	6.55E-06	2.13E-03	1.05E-02	1.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00	1.00E+00	4.00E-01
Po-218	Ra-226	-	0.00E+00	7.62E-06	9.23E-09	5.90E-06	9.00E-01	7.40E-03	2.00E-04	2.70E-03	1.00E+00	1.00E+00	4.00E-01
At-218	Ra-226	-	0.00E+00	0.00E+00	5.57E-05	4.76E-08	9.00E-01	2.00E-01	2.00E-01	2.00E-01	1.00E+00	1.00E+00	4.00E-01
Rn-218	Ra-226	-	0.00E+00	0.00E+00	4.26E-03	1.11E-09	1.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00	1.00E+00	4.00E-01
Pb-214	Ra-226	S	7.36E-07	4.66E-05	1.26E+00	5.10E-05	1.00E+00	8.00E-02	1.50E-02	1.50E-03	1.00E+00	1.00E+00	4.00E-01
Bi-214	Ra-226	S	5.51E-07	3.66E-05	9.13E+00	3.79E-05	1.00E+00	1.00E-01	1.00E-01	1.00E-01	1.00E+00	1.00E+00	4.00E-01
Po-214	Ra-226	-	0.00E+00	0.00E+00	4.80E-04	5.21E-12	1.00E+00	7.40E-03	2.00E-04	2.70E-03	1.00E+00	1.00E+00	4.00E-01
Tl-210	Ra-226	-	0.00E+00	0.00E+00	1.68E+01	2.47E-06	1.00E+00	8.00E-04	8.00E-04	8.00E-05	1.00E+00	1.00E+00	4.00E-01
Pb-210	Ra-226	S	3.77E-03	2.23E-02	2.09E-03	2.22E+01	1.00E+00	8.00E-02	1.50E-02	1.50E-03	1.00E+00	1.00E+00	4.00E-01
Bi-210	Ra-226	S	6.66E-06	5.40E-04	5.47E-03	1.37E-02	1.00E+00	1.00E-01	1.00E-01	1.00E-01	1.00E+00	1.00E+00	4.00E-01
Po-210	Ra-226	S	6.48E-03	1.73E-02	5.64E-05	3.79E-01	1.00E+00	7.40E-03	2.00E-04	2.70E-03	1.00E+00	1.00E+00	4.00E-01
Hg-206	Ra-226	-	0.00E+00	0.00E+00	6.13E-01	1.55E-05	1.00E+00	3.00E-01	3.00E-01	3.00E-01	1.00E+00	1.00E+00	4.00E-01
Tl-206	Ra-226	-	0.00E+00	0.00E+00	1.28E-02	7.99E-06	1.00E+00	8.00E-04	8.00E-04	8.00E-05	1.00E+00	1.00E+00	4.00E-01

Isotope	Particulate Emission Factor (m^3/kg)	Ingestion DCC DL=1.2E+01 (pCi/g)	Inhalation DCC DL=1.2E+01 (pCi/g)	External Exposure DCC DL=1.2E+01 (pCi/g)	Produce Consumption DCC DL=1.2E+01 (pCi/g)	Total DCC DL=1.2E+01 (pCi/g)	Total DCC DL=1.2E+01 (mg/kg)		Decay Factor, at 70 years	Ingestion DCC DL=1.2E+01 (pCi/g)	Inhalation DCC DL=1.2E+01 (pCi/g)	External Exposure DCC DL=1.2E+01 (pCi/g)	Produce Consumption DCC DL=1.2E+01 (pCi/g)	Total
Ra-226	1.36E+09	1.66E+02	6.91E+04	1.14E+03	1.45E+01	**1.31E+01**	1.33E-05		0.97	1.71E+02	7.12E+04	1.18E+03	1.49E+01	
Rn-222	1.36E+09	-	4.02E+08	1.70E+04	-	**1.70E+04**	1.10E-07		0.97		4.14E+08	1.75E+04		
Po-218	1.36E+09	-	3.46E+08	4.35E+09	-	**3.20E+08**	1.15E-06		0.97		3.57E+08	4.48E+09		
At-218	1.36E+09	-	-	7.21E+05	-	**7.21E+05**	2.09E-11		0.000194			3.72E+09		
Rn-218	1.36E+09	-	-	8.48E+03	-	**8.48E+03**	5.74E-15		1.94E-07			4.37E+10		
Pb-214	1.36E+09	3.79E+05	5.65E+07	2.87E+01	4.75E+04	**2.87E+01**	8.77E-13		0.97	3.91E+05	5.82E+07	2.96E+01	4.90E+04	
Bi-214	1.36E+09	5.06E+05	7.19E+07	3.95E+00	9.71E+03	**3.95E+00**	8.96E-14		0.97	5.22E+05	7.41E+07	4.07E+00	1.00E+04	
Po-214	1.36E+09	-	-	7.52E+04	-	**7.52E+04**	2.35E-16		0.97			7.75E+04		
Tl-210	1.36E+09	-	-	2.15E+00	-	**2.15E+00**	3.13E-15		0.000204			1.05E+04		
Pb-210	1.36E+09	7.39E+01	1.18E+05	1.73E+04	9.28E+00	**8.24E+00**	1.08E-07		0.87	8.49E+01	1.36E+05	1.99E+04	1.07E+01	
Bi-210	1.36E+09	4.19E+04	4.87E+06	6.60E+03	8.04E+02	**7.04E+02**	5.69E-09		0.87	4.82E+04	5.60E+06	7.59E+03	9.24E+02	
Po-210	1.36E+09	4.30E+01	1.52E+05	6.40E+05	3.22E+01	**1.84E+01**	4.10E-09		0.868	4.95E+01	1.75E+05	7.37E+05	3.71E+01	
Hg-206	1.36E+09	-	-	5.89E+01	-	**5.89E+01**	5.27E-13		1.65E-08			3.57E+09		
Tl-206	1.36E+09	-	-	2.83E+03	-	**2.83E+03**	1.30E-11		0.00000116			2.44E+09		
								Total		2.64E+01	3.66E+04	3.56E+00	5.30E+00	1.97E+00

Time	Ra-226	Rn-222	Po-218	At-218	Rn-218	Pb-214	Bi-214	Po-214	Tl-210	Pb-210	Bi-210	Po-210	Hg-206	Tl-206
70	0.97	0.97	0.97	0.000194	0.000000194	0.97	0.97	0.97	0.000204	0.87	0.87	0.868	1.65E-08	0.00000116

Hand Calculations

		Decay Corrected DCC using Decay Factor at 1 year				
	Decay Factor, at 70 years	**Ingestion DCC DL=1.2E+01 (pCi/g)**	**Inhalation DCC DL=1.2E+01 (pCi/g)**	**External Exposure DCC DL=1.2E+01 (pCi/g)**	**Produce Consumption DCC DL=1.2E+01 (pCi/g)**	Total
	0.97	1.71E+02	7.12E+04	1.18E+03	1.49E+01	
	0.97		4.14E+08	1.75E+04		
	0.97		3.57E+08	4.48E+09		
	0.000194			3.72E+09		
	0.000000194			4.37E+10		
	0.97	3.91E+05	5.82E+07	2.96E+01	4.90E+04	
	0.97	5.22E+05	7.41E+07	4.07E+00	1.00E+04	
	0.97			7.75E+04		
	0.000204			1.05E+04		
	0.87	8.49E+01	1.36E+05	1.99E+04	1.07E+01	
	0.87	4.82E+04	5.60E+06	7.59E+03	9.24E+02	
	0.868	4.95E+01	1.75E+05	7.37E+05	3.71E+01	
	1.65E-08			3.57E+09		
	0.00000116			2.44E+09		
Total		2.64E+01	3.66E+04	3.56E+00	5.30E+00	1.97E+00

Resident Produce DCCs for Soil

Isotope	Cabbage Consumption DCC DL=1.2E+01 (pCi/g)	Cucumber Consumption DCC DL=1.2E+01 (pCi/g)	Potatoes Consumption DCC DL=1.2E+01 (pCi/g)	Tomatoes Consumption DCC DL=1.2E+01 (pCi/g)	Total Produce DCC DL=1.2E+01 (pCi/g)
Ra-226	3.29E+01	6.96E+01	5.57E+01	1.56E+02	**1.45E+01**
Rn-222	-	-	-	-	**-**
Po-218	-	-	-	-	**-**
At-218	-	-	-	-	**-**
Rn-218	-	-	-	-	**-**
Pb-214	8.52E+04	1.79E+05	8.31E+05	3.97E+05	**4.75E+04**
Bi-214	9.10E+04	3.60E+04	1.89E+04	8.74E+04	**9.71E+03**
Po-214	-	-	-	-	**-**
Tl-210	-	-	-	-	**-**
Pb-210	1.66E+01	3.50E+01	1.62E+02	7.74E+01	**9.28E+00**
Bi-210	7.54E+03	2.98E+03	1.57E+03	7.23E+03	**8.04E+02**
Po-210	1.03E+02	1.28E+03	5.55E+01	3.84E+02	**3.22E+01**
Hg-206	-	-	-	-	**-**
Tl-206	-	-	-	-	**-**

4.78E+00

Resident Peak Dose DCCs for Soil (complete chain decay)

Exposure Route	Peak DCC for Ra-226 DL=12 (pCi/g)	Maximum dose during peak interval (mrem/year)	Maximum Dose rate during peak interval (mrem/year)	Maximum Dose Year ED=1 (year)
Ingestion	***2.48E+01***	***4.84E-01***	***4.84E-01***	***1.34E+02 - 1.35E+02***
Inhalation	***3.56E+04***	***3.37E-04***	***3.37E-04***	***1.17E+02 - 1.18E+02***
External Exposure	***3.46E+00***	***3.47E+00***	***3.47E+00***	***1.18E-01 - 1.12E+00***
Produce Consumption	***1.32E+02***	***9.11E-02***	***9.11E-02***	***1.27E+02 - 1.28E+02***
Total	***3.07E+00***	***3.91E+00***	***3.90E+00***	***7.09E+01 - 7.19E+01***

Check 2.97E+00

Decay Chain_Ra226

PARENT	MODE	T	MASS	First Branching Fraction (%)	First Progeny	Second Branching Fraction (%)	Second Progeny
Ra-226	A	1600y	226.0254	1	Rn-222		
Rn-222	A	3.8235d	222.0176	1	Po-218		
Po-218	A B-	3.10m	218.009	0.9998	Pb-214	0.0002	At-218
At-218	A B-	1.5s	218.0087	0.999	Bi-214	0.001	Rn-218
Rn-218	A	3.5E-2s	218.0056	1	Po-214		
Pb-214	B-	26.8m	213.9998	1	Bi-214		
Bi-214	B-A	19.9m	213.9987	0.99979	Po-214	0.00021	Tl-210
Po-214	A	1.643E-4s	213.9952	1	Pb-210		
Tl-210	B-	1.30m	209.9901	1	Pb-210		
Pb-210	B-A	22.20y	209.9842	0.999999981	Bi-210	1.9E-08	Hg-206
Bi-210	B-A	5.013d	209.9841	0.99999868	Po-210	0.00000132	Tl-206
Po-210	A	138.376d	209.9829	1	Pb-206		
Hg-206	B-	8.15m	205.9775	1	Tl-206		
Tl-206	B-	4.200m	205.9761	1	Pb-206		

Time (yrs)	Ra-226	Rn-222	Po-218	At-218	Rn-218	Pb-214	Bi-214	Po-214	Tl-210	Pb-210	Bi-210	Po-210	Hg-206	Tl-206
0	1													
1E-08	1	6.62E-07	3.89E-10	3.64E-15	2.37E-18	1.76E-14	9.73E-19	3.33E-18	1.15E-25	2.28E-28	2.05E-35	5.65E-44	3.45E-40	4.86E-44
1.26E-08	1	8.33E-07	6.16E-10	7.2E-15	5.08E-18	3.51E-14	2.44E-18	7.5E-18	3.62E-25	6.5E-28	7.42E-35	2.59E-43	1.25E-39	2.23E-43
1.59E-08	1	1.05E-06	9.76E-10	1.42E-14	1.07E-17	7E-14	6.12E-18	1.68E-17	1.14E-24	1.84E-27	2.66E-34	1.18E-42	4.48E-39	1.01E-42
2E-08	1	1.32E-06	1.55E-09	2.79E-14	2.23E-17	1.4E-13	1.53E-17	3.76E-17	3.6E-24	5.2E-27	9.49E-34	5.3E-42	1.6E-38	4.57E-42
2.51E-08	1	1.66E-06	2.45E-09	5.47E-14	4.57E-17	2.79E-13	3.84E-17	8.4E-17	1.14E-23	1.46E-26	3.37E-33	2.38E-41	5.68E-38	2.05E-41
3.16E-08	1	2.09E-06	3.88E-09	1.07E-13	9.25E-17	5.56E-13	9.62E-17	1.89E-16	3.59E-23	4.13E-26	1.2E-32	1.06E-40	2.02E-37	9.16E-41
3.98E-08	1	2.63E-06	6.15E-09	2.07E-13	1.85E-16	1.11E-12	2.41E-16	4.25E-16	1.13E-22	1.17E-25	4.26E-32	4.76E-40	7.16E-37	4.1E-40
5.01E-08	1	3.32E-06	9.74E-09	3.99E-13	3.65E-16	2.21E-12	6.02E-16	9.66E-16	3.56E-22	3.32E-25	1.52E-31	2.13E-39	2.55E-36	1.83E-39
6.31E-08	1	4.17E-06	1.54E-08	7.63E-13	7.12E-16	4.41E-12	1.5E-15	2.21E-15	1.12E-21	9.51E-25	5.44E-31	9.6E-39	9.16E-36	8.25E-39
7.94E-08	1	5.25E-06	2.44E-08	1.45E-12	1.37E-15	8.8E-12	3.75E-15	5.12E-15	3.51E-21	2.75E-24	1.97E-30	4.34E-38	3.31E-35	3.74E-38
1E-07	1	6.62E-06	3.87E-08	2.71E-12	2.6E-15	1.75E-11	9.35E-15	1.19E-14	1.1E-20	8E-24	7.16E-30	1.98E-37	1.2E-34	1.7E-37
1.26E-07	1	8.33E-06	6.13E-08	5.02E-12	4.85E-15	3.5E-11	2.33E-14	2.81E-14	3.45E-20	2.35E-23	2.63E-29	9.11E-37	4.43E-34	7.83E-37
1.59E-07	1	1.05E-05	9.7E-08	9.16E-12	8.93E-15	6.97E-11	5.79E-14	6.68E-14	1.08E-19	6.97E-23	9.76E-29	4.23E-36	1.64E-33	3.63E-36
2E-07	1	1.32E-05	1.54E-07	1.65E-11	1.61E-14	1.39E-10	1.44E-13	1.6E-13	3.37E-19	2.08E-22	3.65E-28	1.98E-35	6.14E-33	1.7E-35
2.51E-07	1	1.66E-05	2.43E-07	2.91E-11	2.87E-14	2.77E-10	3.56E-13	3.85E-13	1.05E-18	6.28E-22	1.38E-27	9.35E-35	2.31E-32	8.02E-35
3.16E-07	1	2.09E-05	3.84E-07	5.07E-11	5.01E-14	5.51E-10	8.83E-13	9.32E-13	3.27E-18	1.9E-21	5.23E-27	4.45E-34	8.78E-32	3.81E-34
3.98E-07	1	2.63E-05	6.06E-07	8.68E-11	8.6E-14	1.1E-09	2.19E-12	2.27E-12	1.02E-17	5.81E-21	2E-26	2.13E-33	3.36E-31	1.83E-33
5.01E-07	1	3.32E-05	9.57E-07	1.46E-10	1.45E-13	2.18E-09	5.41E-12	5.55E-12	3.16E-17	1.78E-20	7.69E-26	1.03E-32	1.29E-30	8.79E-33
6.31E-07	1	4.17E-05	1.51E-06	2.44E-10	2.43E-13	4.33E-09	1.34E-11	1.36E-11	9.78E-17	5.49E-20	2.97E-25	4.99E-32	4.98E-30	4.25E-32
7.94E-07	1	5.25E-05	2.38E-06	4.01E-10	4E-13	8.6E-09	3.31E-11	3.35E-11	3.02E-16	1.69E-19	1.15E-24	2.43E-31	1.93E-29	2.07E-31
0.000001	1	6.62E-05	3.74E-06	6.54E-10	6.51E-13	1.7E-08	8.2E-11	8.26E-11	9.33E-16	5.25E-19	4.48E-24	1.19E-30	7.5E-29	1.01E-30
1.26E-06	1	8.33E-05	5.87E-06	1.05E-09	1.05E-12	3.37E-08	2.03E-10	2.04E-10	2.87E-15	1.63E-18	1.75E-23	5.82E-30	2.92E-28	4.91E-30
1.59E-06	1	0.000105	9.18E-06	1.69E-09	1.69E-12	6.66E-08	5.01E-10	5.02E-10	8.81E-15	5.05E-18	6.83E-23	2.86E-29	1.14E-27	2.4E-29
2E-06	1	0.000132	1.43E-05	2.68E-09	2.68E-12	1.31E-07	1.24E-09	1.24E-09	2.69E-14	1.57E-17	2.67E-22	1.41E-28	4.43E-27	1.17E-28
2.51E-06	1	0.000166	2.23E-05	4.23E-09	4.22E-12	2.57E-07	3.04E-09	3.05E-09	8.16E-14	4.86E-17	1.04E-21	6.92E-28	1.73E-26	5.72E-28
3.16E-06	1	0.000209	3.45E-05	6.62E-09	6.61E-12	5.03E-07	7.47E-09	7.47E-09	2.46E-13	1.5E-16	4.06E-21	3.4E-27	6.7E-26	2.78E-27
3.98E-06	1	0.000263	0.000053	1.03E-08	1.03E-11	9.78E-07	1.83E-08	1.83E-08	7.33E-13	4.64E-16	1.58E-20	1.67E-26	2.6E-25	1.35E-26
5.01E-06	1	0.000332	0.000081	1.58E-08	1.58E-11	1.89E-06	4.44E-08	4.44E-08	2.16E-12	1.43E-15	6.14E-20	8.16E-26	1E-24	6.49E-26
6.31E-06	1	0.000417	0.000123	2.41E-08	2.4E-11	3.63E-06	1.07E-07	1.07E-07	6.27E-12	4.37E-15	2.37E-19	3.98E-25	3.84E-24	3.1E-25
7.94E-06	1	0.000525	0.000184	3.62E-08	3.62E-11	6.9E-06	2.57E-07	2.57E-07	1.79E-11	1.33E-14	9.12E-19	1.93E-24	1.46E-23	1.47E-24
0.00001	1	0.000661	0.000272	5.38E-08	5.38E-11	0.000013	6.1E-07	6.1E-07	4.98E-11	4E-14	3.48E-18	9.32E-24	5.49E-23	6.85E-24
1.26E-05	1	0.000832	0.000398	7.89E-08	7.89E-11	2.41E-05	1.43E-06	1.43E-06	1.36E-10	1.19E-13	1.31E-17	4.46E-23	2.04E-22	3.15E-23
1.59E-05	1	0.00105	0.000573	1.14E-07	1.14E-10	0.000044	3.3E-06	3.3E-06	3.58E-10	3.5E-13	4.91E-17	2.11E-22	7.48E-22	1.42E-22
2E-05	1	0.00132	0.000811	1.61E-07	1.61E-10	7.91E-05	7.47E-06	7.47E-06	9.15E-10	1.02E-12	1.81E-16	9.9E-22	2.69E-21	6.25E-22
2.51E-05	1	0.00166	0.00113	2.25E-07	2.25E-10	0.00014	1.66E-05	1.66E-05	2.26E-09	2.89E-12	6.58E-16	4.57E-21	9.44E-21	2.67E-21
3.16E-05	1	0.00209	0.00154	3.07E-07	3.07E-10	0.000241	0.000036	3.59E-05	5.34E-09	8.06E-12	2.35E-15	2.08E-20	3.23E-20	1.1E-20
3.98E-05	1	0.00263	0.00207	4.14E-07	4.14E-10	0.000406	7.58E-05	7.58E-05	1.21E-08	2.19E-11	8.19E-15	9.25E-20	1.07E-19	4.37E-20
5.01E-05	1	0.00331	0.00275	5.49E-07	5.49E-10	0.000669	0.000155	0.000155	2.64E-08	5.82E-11	2.79E-14	4.03E-19	3.43E-19	1.65E-19
6.31E-05	1	0.00417	0.0036	7.2E-07	7.2E-10	0.00108	0.000307	0.000307	5.5E-08	1.5E-10	9.26E-14	1.71E-18	1.06E-18	5.92E-19

7.94E-05	1	0.00524	0.00468	9.35E-07	9.35E-10	0.00169	0.000588	0.000588	1.09E-07	3.74E-10	2.98E-13	7.1E-18	3.1E-18	2E-18
0.0001	1	0.00659	0.00603	1.21E-06	1.21E-09	0.00259	0.00108	0.00108	2.07E-07	9.01E-10	9.32E-13	2.85E-17	8.68E-18	6.34E-18
0.000126	1	0.00829	0.00774	1.55E-06	1.55E-09	0.00388	0.00191	0.00191	3.75E-07	2.1E-09	2.81E-12	1.11E-16	2.3E-17	1.88E-17
0.000159	1	0.0104	0.00987	1.97E-06	1.97E-09	0.00567	0.00323	0.00323	6.46E-07	4.69E-09	8.2E-12	4.18E-16	5.76E-17	5.22E-17
0.0002	1	0.0131	0.0126	2.51E-06	2.51E-09	0.00809	0.00523	0.00523	1.06E-06	1.01E-08	2.3E-11	1.52E-15	1.36E-16	1.35E-16
0.000251	1	0.0165	0.0159	3.18E-06	3.18E-09	0.0113	0.00811	0.00811	1.66E-06	2.08E-08	6.21E-11	5.32E-15	3.04E-16	3.3E-16
0.000316	1	0.0207	0.0202	4.03E-06	4.03E-09	0.0154	0.012	0.012	2.48E-06	4.12E-08	1.61E-10	1.79E-14	6.41E-16	7.58E-16
0.000398	1	0.026	0.0254	5.09E-06	5.09E-09	0.0207	0.0172	0.0172	3.57E-06	7.86E-08	4.03E-10	5.83E-14	1.28E-15	1.66E-15
0.000501	1	0.0326	0.0321	6.41E-06	6.41E-09	0.0273	0.0238	0.0238	4.96E-06	1.45E-07	9.71E-10	1.82E-13	2.45E-15	3.48E-15
0.000631	1	0.0409	0.0403	8.07E-06	8.07E-09	0.0356	0.0322	0.0321	6.7E-06	2.58E-07	2.26E-09	5.51E-13	4.49E-15	7.08E-15
0.000794	1	0.0512	0.0507	1.01E-05	1.01E-08	0.046	0.0426	0.0425	8.89E-06	4.49E-07	5.11E-09	1.61E-12	7.98E-15	1.41E-14
0.001	1	0.064	0.0635	1.27E-05	1.27E-08	0.0589	0.0555	0.0555	1.16E-05	7.63E-07	1.12E-08	4.58E-12	1.38E-14	2.77E-14
0.001259	1	0.0799	0.0794	1.59E-05	1.59E-08	0.0749	0.0715	0.0715	0.000015	1.28E-06	2.42E-08	1.27E-11	2.33E-14	5.39E-14
0.001585	1	0.0995	0.099	1.98E-05	1.98E-08	0.0946	0.0913	0.0913	1.91E-05	2.11E-06	5.11E-08	3.45E-11	3.88E-14	1.04E-13
0.001995	1	0.124	0.123	2.46E-05	2.46E-08	0.119	0.116	0.116	2.42E-05	3.43E-06	1.06E-07	9.19E-11	6.37E-14	2.01E-13
0.002512	1	0.153	0.153	3.05E-05	3.05E-08	0.148	0.145	0.145	3.05E-05	5.54E-06	2.18E-07	2.41E-10	1.03E-13	3.86E-13
0.003162	1	0.189	0.188	3.77E-05	3.77E-08	0.184	0.181	0.181	0.000038	8.86E-06	4.42E-07	6.23E-10	1.66E-13	7.42E-13
0.003981	1	0.232	0.231	4.62E-05	4.62E-08	0.227	0.225	0.224	4.71E-05	1.41E-05	8.85E-07	1.59E-09	2.64E-13	1.42E-12
0.005012	1	0.282	0.282	5.64E-05	5.64E-08	0.278	0.276	0.276	5.79E-05	2.21E-05	1.75E-06	4.01E-09	4.16E-13	2.71E-12
0.00631	1	0.341	0.341	6.82E-05	6.82E-08	0.338	0.335	0.335	7.04E-05	3.45E-05	3.43E-06	9.99E-09	6.51E-13	5.15E-12
0.007943	1	0.409	0.408	8.17E-05	8.17E-08	0.405	0.403	0.403	8.47E-05	5.34E-05	6.62E-06	2.46E-08	1.01E-12	9.71E-12
0.01	1	0.484	0.484	9.67E-05	9.67E-08	0.481	0.479	0.479	0.000101	8.17E-05	1.26E-05	5.99E-08	1.55E-12	1.81E-11
0.01259	1	0.565	0.565	0.000113	1.13E-07	0.563	0.561	0.561	0.000118	0.000124	2.36E-05	1.44E-07	2.35E-12	3.35E-11
0.01585	1	0.65	0.649	0.00013	1.3E-07	0.647	0.646	0.646	0.000136	0.000185	4.35E-05	3.39E-07	3.52E-12	6.09E-11
0.01995	1	0.733	0.733	0.000147	1.47E-07	0.731	0.73	0.73	0.000153	0.000274	7.85E-05	7.86E-07	5.19E-12	1.09E-10
0.02512	1	0.81	0.81	0.000162	1.62E-07	0.809	0.808	0.808	0.00017	0.000398	0.000138	1.78E-06	7.56E-12	1.89E-10
0.03162	1	0.877	0.876	0.000175	1.75E-07	0.876	0.875	0.875	0.000184	0.00057	0.000236	3.95E-06	1.08E-11	3.22E-10
0.03981	1	0.928	0.928	0.000186	1.86E-07	0.928	0.928	0.927	0.000195	0.0008	0.00039	8.5E-06	1.52E-11	5.3E-10
0.05012	1	0.964	0.964	0.000193	1.93E-07	0.963	0.963	0.963	0.000202	0.0011	0.000623	1.77E-05	2.1E-11	8.43E-10
0.0631	1	0.985	0.985	0.000197	1.97E-07	0.984	0.984	0.984	0.000207	0.0015	0.000959	3.58E-05	2.85E-11	1.29E-09
0.07943	1	0.995	0.995	0.000199	1.99E-07	0.995	0.995	0.994	0.000209	0.002	0.00142	6.98E-05	3.81E-11	1.92E-09
0.1	1	0.999	0.999	0.0002	2E-07	0.998	0.999	0.998	0.00021	0.00264	0.00204	0.000131	5.02E-11	2.74E-09
0.1259	1	1	1	0.0002	2E-07	1	1	0.999	0.00021	0.00345	0.00283	0.000238	6.55E-11	3.81E-09
0.1585	1	1	1	0.0002	2E-07	1	1	1	0.00021	0.00446	0.00385	0.000418	8.47E-11	5.16E-09
0.1995	1	1	1	0.0002	2E-07	1	1	1	0.00021	0.00574	0.00512	0.000712	1.09E-10	6.87E-09
0.2512	1	1	1	0.0002	2E-07	1	1	1	0.00021	0.00734	0.00672	0.00118	1.39E-10	9.01E-09
0.3162	1	1	1	0.0002	2E-07	1	1	1	0.00021	0.00935	0.00874	0.00192	1.78E-10	1.17E-08
0.3981	1	1	1	0.0002	2E-07	1	1	1	0.00021	0.0119	0.0113	0.00305	2.26E-10	1.51E-08
0.5012	1	1	1	0.0002	2E-07	1	1	1	0.00021	0.0151	0.0144	0.00474	2.86E-10	1.94E-08
0.631	1	1	1	0.0002	2E-07	1	1	1	0.00021	0.019	0.0184	0.00723	3.62E-10	2.47E-08
0.7943	1	1	1	0.0002	2E-07	0.999	1	0.999	0.00021	0.024	0.0234	0.0108	4.56E-10	3.14E-08

1	1	1	1	0.0002	2E-07	0.999	1	0.999	0.00021	0.0303	0.0297	0.0158	5.75E-10	3.97E-08
1.259	0.999	0.999	0.999	0.0002	2E-07	0.999	0.999	0.999	0.00021	0.0381	0.0375	0.0226	7.23E-10	5.02E-08
1.585	0.999	0.999	0.999	0.0002	2E-07	0.999	0.999	0.999	0.00021	0.0478	0.0472	0.0317	9.08E-10	6.32E-08
1.995	0.999	0.999	0.999	0.0002	2E-07	0.999	0.999	0.999	0.00021	0.0599	0.0593	0.0435	1.14E-09	7.95E-08
2.512	0.999	0.999	0.999	0.0002	2E-07	0.999	0.999	0.999	0.00021	0.0749	0.0744	0.0585	1.42E-09	9.96E-08
3.162	0.999	0.999	0.999	0.0002	2E-07	0.998	0.999	0.998	0.00021	0.0935	0.0929	0.0773	1.78E-09	1.24E-07
3.981	0.998	0.998	0.998	0.0002	2E-07	0.998	0.998	0.998	0.00021	0.116	0.116	0.1	2.21E-09	1.55E-07
5.012	0.998	0.998	0.998	0.0002	2E-07	0.998	0.998	0.998	0.00021	0.144	0.144	0.129	2.74E-09	1.92E-07
6.31	0.997	0.997	0.997	0.000199	1.99E-07	0.997	0.997	0.997	0.000209	0.178	0.178	0.163	3.38E-09	2.38E-07
7.943	0.997	0.997	0.997	0.000199	1.99E-07	0.996	0.997	0.996	0.000209	0.219	0.218	0.205	4.16E-09	2.92E-07
10	0.996	0.996	0.996	0.000199	1.99E-07	0.995	0.996	0.995	0.000209	0.267	0.267	0.254	5.08E-09	3.57E-07
12.589	0.995	0.995	0.995	0.000199	1.99E-07	0.994	0.995	0.994	0.000209	0.324	0.323	0.312	6.15E-09	4.33E-07
15.849	0.993	0.993	0.993	0.000199	1.99E-07	0.993	0.993	0.993	0.000209	0.389	0.388	0.378	7.38E-09	5.2E-07
19.953	0.991	0.991	0.991	0.000198	1.98E-07	0.991	0.991	0.991	0.000208	0.461	0.461	0.452	8.76E-09	6.17E-07
25.119	0.989	0.989	0.989	0.000198	1.98E-07	0.989	0.989	0.989	0.000208	0.54	0.54	0.532	1.03E-08	7.23E-07
31.623	0.986	0.986	0.986	0.000197	1.97E-07	0.986	0.986	0.986	0.000207	0.622	0.622	0.616	1.18E-08	8.33E-07
39.811	0.983	0.983	0.983	0.000197	1.97E-07	0.983	0.983	0.983	0.000206	0.704	0.704	0.699	1.34E-08	9.42E-07
50.119	0.979	0.979	0.979	0.000196	1.96E-07	0.978	0.979	0.978	0.000205	0.78	0.78	0.776	1.48E-08	1.04E-06
63.096	0.973	0.973	0.973	0.000195	1.95E-07	0.973	0.973	0.973	0.000204	0.845	0.845	0.843	1.61E-08	1.13E-06
70	0.97	0.97	0.97	0.000194	1.94E-07	0.97	0.97	0.97	0.000204	0.87	0.87	0.868	1.65E-08	1.16E-06
79.433	0.966	0.966	0.966	0.000193	1.93E-07	0.966	0.966	0.966	0.000203	0.895	0.895	0.893	1.7E-08	1.2E-06
100	0.958	0.958	0.958	0.000192	1.92E-07	0.957	0.958	0.957	0.000201	0.926	0.926	0.926	1.76E-08	1.24E-06
125.893	0.947	0.947	0.947	0.000189	1.89E-07	0.947	0.947	0.947	0.000199	0.94	0.94	0.94	1.79E-08	1.26E-06
158.489	0.934	0.934	0.934	0.000187	1.87E-07	0.933	0.934	0.933	0.000196	0.94	0.94	0.94	1.79E-08	1.26E-06
199.526	0.917	0.917	0.917	0.000183	1.83E-07	0.917	0.917	0.917	0.000193	0.928	0.928	0.928	1.76E-08	1.24E-06
251.189	0.897	0.897	0.897	0.000179	1.79E-07	0.897	0.897	0.897	0.000188	0.909	0.909	0.909	1.73E-08	1.22E-06
316.228	0.872	0.872	0.872	0.000174	1.74E-07	0.872	0.872	0.872	0.000183	0.884	0.884	0.884	1.68E-08	1.18E-06
398.107	0.842	0.842	0.842	0.000168	1.68E-07	0.841	0.842	0.841	0.000177	0.853	0.853	0.854	1.62E-08	1.14E-06
501.187	0.805	0.805	0.805	0.000161	1.61E-07	0.805	0.805	0.805	0.000169	0.816	0.816	0.816	1.55E-08	1.09E-06
630.957	0.761	0.761	0.761	0.000152	1.52E-07	0.761	0.761	0.761	0.00016	0.772	0.772	0.772	1.47E-08	1.03E-06
794.328	0.709	0.709	0.709	0.000142	1.42E-07	0.709	0.709	0.709	0.000149	0.719	0.719	0.719	1.37E-08	9.63E-07
1000	0.648	0.648	0.648	0.00013	1.3E-07	0.648	0.648	0.648	0.000136	0.658	0.658	0.658	1.25E-08	8.81E-07
1258.925	0.58	0.58	0.58	0.000116	1.16E-07	0.58	0.58	0.58	0.000122	0.588	0.588	0.588	1.12E-08	7.87E-07
1584.893	0.503	0.503	0.503	0.000101	1.01E-07	0.503	0.503	0.503	0.000106	0.51	0.51	0.511	9.7E-09	6.83E-07
1995.262	0.421	0.421	0.421	8.43E-05	8.43E-08	0.421	0.421	0.421	8.85E-05	0.427	0.427	0.427	8.12E-09	5.72E-07
2511.886	0.337	0.337	0.337	6.74E-05	6.74E-08	0.337	0.337	0.337	7.08E-05	0.342	0.342	0.342	6.49E-09	4.57E-07
3162.278	0.254	0.254	0.254	5.08E-05	5.08E-08	0.254	0.254	0.254	5.34E-05	0.258	0.258	0.258	4.9E-09	3.45E-07
3981.072	0.178	0.178	0.178	3.57E-05	3.57E-08	0.178	0.178	0.178	3.74E-05	0.181	0.181	0.181	3.44E-09	2.42E-07
5011.872	0.114	0.114	0.114	2.28E-05	2.28E-08	0.114	0.114	0.114	0.000024	0.116	0.116	0.116	2.2E-09	1.55E-07
6309.573	0.065	0.065	0.065	0.000013	1.3E-08	0.065	0.065	0.065	1.37E-05	0.066	0.066	0.066	1.25E-09	8.83E-08
7943.282	0.0321	0.0321	0.0321	6.41E-06	6.41E-09	0.032	0.0321	0.032	6.73E-06	0.0325	0.0325	0.0325	6.18E-10	4.35E-08

10000	0.0132	0.0132	0.0132	2.63E-06	2.63E-09	0.0131	0.0132	0.0131	2.76E-06	0.0133	0.0133	0.0133	2.53E-10	1.79E-08
12589.25	0.00428	0.00428	0.00428	8.57E-07	8.57E-10	0.00428	0.00428	0.00428	9E-07	0.00434	0.00434	0.00435	8.26E-11	5.82E-09
15848.93	0.00104	0.00104	0.00104	2.09E-07	2.09E-10	0.00104	0.00104	0.00104	2.19E-07	0.00106	0.00106	0.00106	2.01E-11	1.42E-09
19952.62	0.000177	0.000177	0.000177	3.53E-08	3.53E-11	0.000177	0.000177	0.000177	3.71E-08	0.000179	0.000179	0.000179	3.4E-12	2.4E-10
25118.86	1.88E-05	1.88E-05	1.88E-05	3.77E-09	3.77E-12	1.88E-05	1.88E-05	1.88E-05	3.96E-09	1.91E-05	1.91E-05	1.91E-05	3.63E-13	2.56E-11
31622.78	1.13E-06	1.13E-06	1.13E-06	2.25E-10	2.25E-13	1.13E-06	1.13E-06	1.13E-06	2.37E-10	1.14E-06	1.14E-06	1.14E-06	2.17E-14	1.53E-12
39810.72	3.25E-08	3.25E-08	3.25E-08	6.49E-12	6.49E-15	3.25E-08	3.25E-08	3.25E-08	6.82E-12	3.29E-08	3.29E-08	3.29E-08	6.26E-16	4.41E-14
50118.72	3.74E-10	3.74E-10	3.74E-10	7.47E-14	7.47E-17	3.74E-10	3.74E-10	3.74E-10	7.85E-14	3.79E-10	3.79E-10	3.79E-10	7.2E-18	5.07E-16
63095.73	1.35E-12	1.35E-12	1.35E-12	2.71E-16	2.71E-19	1.35E-12	1.35E-12	1.35E-12	2.84E-16	1.37E-12	1.37E-12	1.37E-12	2.61E-20	1.84E-18
79432.82	1.14E-15	1.14E-15	1.14E-15	2.29E-19	2.29E-22	1.14E-15	1.14E-15	1.14E-15	2.4E-19	1.16E-15	1.16E-15	1.16E-15	2.2E-23	1.55E-21
100000	1.55E-19	1.55E-19	1.55E-19	3.09E-23	3.09E-26	1.55E-19	1.55E-19	1.55E-19	3.25E-23	1.57E-19	1.57E-19	1.57E-19	2.98E-27	2.1E-25
125892.5	2.09E-24	2.09E-24	2.09E-24	4.17E-28	4.17E-31	2.08E-24	2.09E-24	2.08E-24	4.38E-28	2.11E-24	2.11E-24	2.12E-24	4.02E-32	2.83E-30
158489.3	1.54E-30	1.54E-30	1.54E-30	3.08E-34	3.08E-37	1.54E-30	1.54E-30	1.54E-30	3.23E-34	1.56E-30	1.56E-30	1.56E-30	2.97E-38	2.09E-36
199526.2	2.94E-38	2.94E-38	2.94E-38	5.88E-42	5.88E-45	2.94E-38	2.94E-38	2.94E-38	6.17E-42	2.98E-38	2.98E-38	2.98E-38	5.66E-46	3.99E-44
251188.6	5.63E-48	5.63E-48	5.63E-48	1.13E-51	1.13E-54	5.63E-48	5.63E-48	5.63E-48	1.18E-51	5.71E-48	5.71E-48	5.71E-48	1.08E-55	7.64E-54
316227.8	3.28E-60	3.28E-60	3.28E-60	6.57E-64	6.57E-67	3.28E-60	3.28E-60	3.28E-60	6.9E-64	3.33E-60	3.33E-60	3.33E-60	6.33E-68	4.46E-66
398107.2	1.3E-75	1.3E-75	1.3E-75	2.6E-79	2.6E-82	1.3E-75	1.3E-75	1.3E-75	2.73E-79	1.32E-75	1.32E-75	1.32E-75	2.51E-83	1.77E-81
501187.2	5.31E-95	5.31E-95	5.31E-95	1.06E-98	1.1E-101	5.31E-95	5.31E-95	5.31E-95	1.11E-98	5.38E-95	5.38E-95	5.38E-95	1E-102	7.2E-101
630957.3	2.1E-119	2.1E-119	2.1E-119	4.1E-123	4.1E-126	2.1E-119	2.1E-119	2.1E-119	4.3E-123	2.1E-119	2.1E-119	2.1E-119	4E-127	2.8E-125
794328.2	3.8E-150	3.8E-150	3.8E-150	7.7E-154	7.7E-157	3.8E-150	3.8E-150	3.8E-150	8.1E-154	3.9E-150	3.9E-150	3.9E-150	7.4E-158	5.2E-156
1000000	7.9E-189	7.9E-189	7.9E-189	1.6E-192	7.2E-193	7.9E-189	7.9E-189	7.9E-189	1.7E-192	8E-189	8E-189	8E-189	1.5E-196	1.1E-194
1258925	1.3E-235	1.4E-235	1.2E-235	2.7E-239	4.2E-236	1.3E-235	1.2E-235	9.9E-236	2.6E-239	1.2E-235	1.1E-235	1.2E-235	1.3E-243	1E-241
1584893	2.8E-282	3E-282	2.7E-282	5.8E-286	9.6E-283	2.7E-282	2.6E-282	2.1E-282	5.6E-286	2.9E-282	2.8E-282	2.9E-282	3.4E-290	2.6E-288

Activities for Ra-226 and progeny where initial activity = 1 pCi

Timestamp: 2023-03-23 13:19:54

ARTHUR S. ROOD

4835 West Foxtrail Lane, Idaho Falls ID 83402 (208) 528-0670, asr@kspar.net

EDUCATION

M.S. - Health Physics, Radioecology, Colorado State University, 1987
B.S. - Geology, Mesa State College, 1982
AA - Mathematics, Santa Monica College, 1978

SUMMARY

Over thirty years of experience in multimedia contaminant fate and transport modeling, dose and risk assessment. Developed and implemented mathematical models for contaminant fate and transport in environment systems, conducted numerical uncertainty analysis, and designed and implemented environmental sampling and monitoring programs.

EMPLOYMENT HISTORY

PRINCIPAL SCIENTIST (7/1994 - PRESENT)
K-Spar Inc. Idaho Falls, Idaho
Develop and implement mathematical and computer models for assessment of multimedia transport of contaminants (radionuclides and other) in the environment. Quantify uncertainty and sensitivity of model predictions using Monte Carlo sampling techniques. Validate models using environmental monitoring data and compute health risk associated with predicted environmental media concentrations. Specific projects that addressed reconstruction of radionuclide concentrations and doses include the former Rocky Flats Plant in Golden CO, former Uravan uranium mill in western CO, former UMETCO uranium fabrication facility in Apollo PA, Mallinckrodt Chemical Works, St. Louis MO, radionuclide releases to the Columbia River from Hanford Reservation, Fukushima nuclear reactor accident, and Cero Grande fire at Los Alamos NM. Mr. Rood also performed modeling for low-level radioactive waste performance assessments at U.S. Ecology site in Richland Washington, Remote Handled Low-Level Radioactive Waste facility at the Idaho National Laboratory, Waste Control Specialists in Andrews TX, and the Calcine Solid Storage Facility at the Idaho National Laboratory. Other projects include evaluation of ambient air monitoring networks at the Idaho National laboratory and Hanford Reservation, development of contaminant transport models for contaminated soils at Los Alamos National Laboratory, and development radionuclide limits in wastewater and sediments for the Waste Control Specialists low-level waste site.

Reviewer for the U.S. Department of Energy Low-Level Federal Review Group (LFRG) for low-level radioactive waste performance assessments and composite analysis. Sites reviewed include the Savanna River Site Saltstone facility, Hanford Integrated Disposal Facility, the Hanford A/AX Tank Farm, and the Hanford Site Composite Analysis.

Instructor for Risk Assessments Corporation courses on radiological risk assessment held in Washington DC (2009, 2012, 2013), Bristol UK (2009), and Nuclear Regulatory Commission (2015, 2017). Member of Task Group 98 of the International Commission on Radiation Protection.

ADVISORY SCIENTIST (RETIRED), 5/1994 – 1/2013
Modeling and Measurements Group, Idaho National Laboratory, Idaho Falls, Idaho
Research, develop, and apply state-of-the-art techniques for assessment of environmental transport and impacts associated with release of radioactive material and hazardous chemicals. Specific modeling expertise includes chronic and accident air dispersion, food-chain transport, groundwater flow and transport, dose and risk assessment, thermodynamic chemical vapor models, shielding and external exposure calculations, and first order kinetic models. Major efforts were directed toward low-level waste performance assessment at the three Idaho National Laboratory low-level waste disposal sites and near-field and long-range atmospheric dispersion calculations for evaluation of toxic pollutants emitted to the air from INL facilities using the AERMOD and CALPUFF dispersion models.

Provide lead technical guidance for INL and Department of Energy-wide programs requiring complex environmental assessments and safety analyses. Provide technical guidance for an international study on uncertainty estimates in reactor consequence code evaluation. Assist the National Low-Level Waste program in providing technical assistance to waste compact states and foreign countries. Instructor for the University of Idaho graduate-level course, **Environmental Modeling** (INTER 504) from 1991 to 1999.

Principal Investigator for a national survey of naturally occurring radioactive material (NORM) in oil and gas production equipment. Member of the Health Physics Society/ANSI working group on NORM.

SENIOR SCIENTIST, 5/1990 - 5/1994

Integrated Earth Science/Geotechnologies, Idaho National Laboratory

Provide lead technical guidance and funding management for Idaho National Engineering Laboratory (INEL) and DOE-wide programs requiring complex environmental assessments and safety analyses. Developed groundwater transport models and computer codes (GWSCREEN) for assessment of CERCLA sites and performance assessment of low-level waste disposal facilities at the INEL. Performed the groundwater modeling and dose assessment section for the Radioactive Waste Management Complex Performance Assessment at the Idaho National Engineering Laboratory. Co-author of the food-chain model (COMIDA) for the MAACS reactor consequence code, an internationally-recognized reactor accident assessment code. Participated in four "AIRDOS/CAP-88" radiological assessment courses for another DOE laboratory, INEL contractor, and state personnel. Conducted Performance Assessment Workshops and provided technical assistance to the low level waste compact states for the National Low-Level Waste Management Program.

STAFF SCIENTIST, 8/1989 - 4/1990

UNC Geotech, Grand Junction, Colorado

Radon Laboratory - Performed indoor radon assessments and developed instrumentation for measurement of radon progeny using alpha and beta spectroscopy. Conducted quality control experiments of radon measuring devices and wrote software for data acquisition systems and computer controlled instrumentation.

ENVIRONMENTAL SCIENTIST, 9/1987 - 7/1989

Environmental Sciences and Engineering Unit, Idaho National Laboratory, Idaho Falls, Idaho

Environmental Sciences and Engineering - Research, develop, and apply state-of-the-art techniques assessing the environmental transport and impacts associated with release of radioactive material and hazardous chemicals. Specific modeling experience includes chronic and accident air dispersion, food-chain transport, groundwater contaminant transport, and dose and risk assessment.

SENIOR HEALTH PHYSICS TECHNICIAN, 11/1984 - 9/1986

Oak Ridge National Laboratory, Grand Junction, Colorado

Coordinated gamma spectroscopy laboratory for gamma spectral analysis of soil samples contaminated with uranium mill tailings. Wrote and implemented spectral analysis algorithms, multichannel analyzer control programs and data base software. Designed, constructed, and calibrated an activated charcoal radon measurement device. Developed and implemented laboratory quality control procedures.

ASSOCIATE MINE GEOLOGIST, 8/1982 - 12/1983

Plateau Resources LTD, Grand Junction, Colorado

Supervised uranium mine longhole-drilling program for ore body fringe development and preparation for full scale production. Evaluated drilling results for ore trend production and ore reserve calculations.

GEOSCIENTIST I, 1/1981 - 7/1982

Bendix Field Engineering, Grand Junction, Colorado

Assisted in researching uranium ore body development and exploration indicators and writing results published in Department of Energy reports. Tasks included interpretation of electric drill hole logs and generation of isopleth maps and cross sections from the data.

PHYSICAL SCIENCE AIDE, 5/1980 - 9/1980

U.S. Department of Energy, Grand Junction, Colorado

Assisted staff geologist in reviewing resource maps and assessment data for the 1980 National Uranium Resource Evaluation Report.

AFFILIATIONS

Chairman of the Health Physics Society Working Group on Naturally Occurring Radioactive Material
Member of the Health Physics Society
Member of the International Commission on Radiation Protection (ICRP) Task Group 98.

HONORS & AWARDS & LEADERSHIP POSITIONS

- Licensed Invention, GWSCREEN Software System, Lockheed Martin 1996
- President and Executive Board Member, Desert Eagles Model Airplane Club, 2008–2010, 2015-2017

COURSES TAUGHT

Environmental Risk Assessment for the Nuclear Regulatory Commission, Bethesda Maryland, May, 2017.

Environmental Risk Assessment for the Nuclear Regulatory Commission, Bethesda Maryland, April 2015.

Radiological Risk Assessment and Environmental Assessment. Crystal City Marriott, Arlington, VA. Risk Assessment Corporation. March 4-8, 2013. 51 Attendees.

Radiological Risk Assessment for Decision Making, Compliance, and Emergency Response. Crystal City Marriott, Arlington, VA. Risk Assessment Corporation. March 5-9, 2012. 37 Attendees.

Radiological Risk Assessment and Environmental Analysis Course. ITC School of Underground Waste Storage and Disposal. University of Bristol Risk Centre, Bristol, United Kingdom. June 22–26, 2009. 17 Attendees.

Environmental Risk Assessment Analysis Training Course H-401. Training Course H-401 prepared and presented by Risk Assessment Corporation for the U.S. Nuclear Regulatory Commission at the NRC's Professional Development Center, Bethesda, Maryland. January 26–30, 2009. 23 Attendees.

EXPERT TESTIMOY

"Reconstruction of Plaintiff Doses Associated with Residues Stored at the St. Louis Airport Storage Site and the Hazelwood Interim Storage Site and Critique of Opinions by Dr. Clark, Dr. Hu, and Dr. Wells." In re: Scott D. McClurg, et al. v. Mallinckrodt, Inc et al. 4:12CV00361 AGF, March 17, 2020.

"Reconstruction of Plaintiff Doses Associated with Residues Stored at the St. Louis Airport Storage Site and the Hazelwood Interim Storage Site and Critique of Opinions by Dr. Cheremisinoff, Ms Sears and Dr Clark." In re: Scott D. McClurg, et al. v. Mallinckrodt, Inc et al. 4:12CV00361 AGF, April 27, 2018.

"Reconstruction of Doses from Atmospheric Releases of Uranium at the Apollo Facility and Critique of Plaintiffs' Expert Opinions." In re: McMunn et al. v Babcock & Wilcox, 2:10-cv-00143-DSC-RCM. February 27, 2013

"Reconstruction of Historical Doses from Radionuclides Released to the Environment by the Uravan Mining and Milling Site." In re: June et al. v. Union Carbide Corporation et al., No.1: 04-CV-00123-MSK-MJW. January 15, 2007.

"Assessment of Thyroid Doses Received by Specified Individuals from Releases of Iodine-131 from Hanford." In re: Hanford Nuclear Reservation Litigation Master File No. CY-91-3015-WFN. August 13, 2004.

"Historical Public Exposures Studies on Rocky Flats." August 6, 2004, In re: Cook et al. v. Rockwell et al., U.S. District Court for the District of Colorado, No. 90-K-181. August 6, 2004.

SELECTED PUBLICATIONS AND REPORTS

TEXT BOOK CHAPTERS

Whicker, F.W. and **A.S. Rood**, 2008. "Terrestrial Food Chain Pathways: Concepts and Models" In: *Radiological Risk Assessment and Environmental Analysis*", J.E. Till and H.A. Grogan Editors. CRC Press, Boca Raton FL.

Grogan, H.A., J.W. Aanenson, P.D. McGavran, K.R. Meyer, H.J. Mohler, S.S. Mohler, J.R. Rocco, **A.S. Rood**, J.E. Till, and L.H. Wilson, 2006. "Modeling of the Cerro Grande Fire at Los Alamos: An Independent Analysis of Exposure, Heath Risk, and Communication with the Public" In: *Applied Modeling and Computations in Nuclear Science*. ACS Symposium Series 945. American Chemical Society, Washington DC.

PEER-REVIEWED PUBLICATIONS (chronological order)

Rood, A.S., H.J. Mohler, H.A. Grogan, C. Mangine, E.A Caffrey, and J.E. Till, 2022. "Potential Airborne Releases and Deposition of Radionuclides from the Santa Susana Field Laboratory during the Woolsey Fire" *Health Physics* [IN PRESS]

Rood, A.S., and R. Whicker, 2022. "Spatial Variability and Behavior of Background Radon Concentrations in Ambient Air in the San Mateo Basin of the Grants Mineral Belt." *Health Physics* DOI: 10.1097/HP.0000000000001513 122(3), pp 409–432.

Caffrey, E.A., **A.S. Rood**, H.A. Grogan, J.E. Till, and K. Herman, 2021. "Dose Assessment for Technologically Enhance Naturally Occurring Radioactive Materials Disposed in Landfills." *Health Physics* 121(3), pp 209–224.

Mohler, H.J., **A.S. Rood**, H.A. Grogan., E.A. Caffrey, and J.E. Till, 2020. "Analysis of Environmental Data to Support Quantification of Historical Releases from a Former Uranium Processing Facility in Apollo, Pennsylvania" *Health Physics* 120(5), pp 495-509.

Caffrey, E.A., P.G. Voillequé, **A.S. Rood**, H.A. Grogan, H.J. Mohler, K.R. Meyer, and J.E. Till, 2020. "Reconstruction of Enriched Uranium Released to Air from the Former Apollo Facility, Apollo Pennsylvania." *Health Physics* 120(4) pp 417-426

Rood, A.S., H.A. Grogan, H.J. Mohler, K.R. Meyer, P.G. Voileque, and J.E. Till, 2019. "Reconstruction of Atmospheric Concentrations of Enriched Uranium from the Former Apollo Facility, Apollo Pennsylvania", USA. *J. of Env Radioactivity*, https://doi.org/10.1016/j.jenvrad.2019.106045

Rood, A.S., H.A. Grogan, H.J. Mohler, J.R. Rocco, E.A. Caffrey, C. Mangini, J. Cartwright, T. Mathews, C. Shaw, M.E. Packard, and J.E. Till, 2019. "Use of Routine Environmental Monitoring Data to Establish A Dose-Based Compliance System for a Low-Level Radioactive Waste Disposal Site." *Health Physics*, DOI: 10.1097/HP.0000000000001116 118(1):1–17; 2020.

R.M Shubbar, D.I. Lee, H.A. Gzar, and **A.S. Rood**, 2019. "Modeling Air Dispersion of Pollutants Emitted from the Daura Oil Refinery, Baghdad-Iraq using the CALPUFF Modeling System." *Journal of Environmental Informatics Letters*, 2(1) pp 28–39 doi: 10.3808.

Rood, A.S., A.J. Sondrup, and P.D. Ritter, 2016. "Quantitative Evaluation of an Air Monitoring Network using Atmospheric Dispersion Modeling and Frequency of Detection Methods" *Health Physics* 110(4).

Till, J.E., **A.S. Rood**, C.D. Garzon, and R.H. Lagdon, 2014. "Comparison of the MACCS2 Atmospheric Transport Model with Lagrangian Puff Models as Applied to Deterministic and Probabilistic Safety Analysis." *Health Physics,* 107(2): 213-230.

Rood, A.S., 2014. "Performance Evaluation of AERMOD, CALPUFF, and Legacy Air Dispersion Models using the Winter Validation Tracer Study Dataset." *Atmospheric Environment,* 89: 707-720.

Till, J.E., H.A. Grogan, J.H. Mohler, J.R. Rocco, **A.S. Rood**, and S.S. Mohler, 2011. "An Integrated Approach to Data Management, Risk Assessment, and Decision Making." *Health Physics,* 102(4): 367-377.

Rood, A.S., P.G. Voillequé, S.K. Rope, H.A. Grogan, and J.E. Till, 2008. "Reconstruction of Atmospheric Concentrations and Deposition of Uranium and Decay Products Released from the Former Uranium Mill at Uravan Colorado USA." *Journal of Environmental Radioactivity*, 99: 1258–1278.

Rood, A.S., 2004. "A Mixing-Cell Model for Assessment of Contaminant Transport in the Unsaturated Zone Under Steady-State and Transient Flow Conditions." *Environmental Engineering Science*, 21(6): 661–677.

Abbott, M.L., D.D. Susong, D.P. Krabbenhoft, **A.S. Rood**, 2002. "Mercury Deposition in Snow near an Industrial Emission Source in Southeastern Idaho and the Teton Range, Wyoming," *Water, Air, and Soil Pollution*, 139: 95–114.

Rood, A.S., H.A. Grogan, J.E. Till, 2002. "A Model for a Comprehensive Evaluation of Plutonium Released to the Air from the Rocky Flats Plant, 1953–1989." *Health Physics,* 82(2).

Till, J.E., **A.S. Rood**, P.G. Voilleque, P.D. McGavran, K.R. Meyer, H.A. Grogan, W.K. Sinclair, J.W. Aanenson, H.R. Meyer, H.J. Mohler, S.K. Rope, and M.J. Case, 2002. "Risks to the Public from Historical Releases of Radionuclides and Chemicals at the Rocky Flats Environmental Technology Site." *Journal of Exposure Analysis and Environmental Epidemiology,* 12 (5): 355-372

White, G.J., and **A.S. Rood**, 2001. "Radon Emanation from NORM-Contaminated Pipe Scale and Soil at Petroleum Industry Sites." *Journal of Environmental Radioactivity,* 54: 401–413.

Rood, A.S., P.D. McGavran, J. Aanennson, 2000. "Stochastic Estimates of Carcinogenic Risk with Uncertainty from Carbon Tetrachloride Released from the Rocky Flats Plant." *Risk Analysis*, 21(4): 675-696.

Rood, A. S., G. G. Killough, J. E. Till, 1999 "Evaluation of Atmospheric Transport Models for use in Phase II of the Historical Public Exposure Studies at the Rocky Flats Plant." *Risk Analysis*, 19(4): 559-576.

McGavran, P. D., **A. S. Rood**, J. E. Till, 1999. "Chronic Beryllium Disease and Cancer Risk Estimates with Uncertainty for Beryllium Released to the Air from the Rocky Flats Plant." *Environmental Health Perspectives,* 107(8): 731-744.

Rood, A. S., G. J. White, and D. T. Kendrick, 1998. "Measurement of ^{222}Rn Flux, ^{222}Rn Emanation, and ^{226}Ra Concentration from Injection Well Pipe Scale" *Health Physics,* 75(2): 187-192.

Rood, A. S., 1994, "GWSCREEN: A Model for Assessment of the Groundwater Pathway from Surface or Buried Contamination", *The Environmental Professional*, 16(3):196-210.

Nguyen, H. D., S. Paik, **A. S. Rood**, 1994, "Effects of Thermally Generated Convection on the Migration of Radionuclides in Saturated Geologic Formations" *International Journal Engineering Science*, 32(10): 1605-1614.

Abbott, M. L. and **A. S. Rood**, 1994 "COMIDA: A Radionuclide Food-Chain Model for Acute Fallout Deposition", *Health Physics*, 66(1):17-29.

Martz, D. E., **A. S. Rood**, J. L. George, M. D. Pearson, G. H. Langner, 1991, "Year-to-Year Variations in Annual Average Indoor ^{222}Rn Concentrations". *Health Physics*, 61(3): 409-413.

Walton, J. C., **A. S. Rood**, R. G. Baca and M. D. Otis, 1989, "Model for Estimation of Chlorinated Solvent Releases from Waste Disposal Sites", *Journal of Hazardous Materials*, 21, 15-34.

COMPANY TECHNICAL PUBLICATIONS (alphabetical order)

Abbott, M. L. and **A. S. Rood**, 1990. *Concentration Factors for Fusion-Related Radionuclides Calculated Using the Food-Chain Model FUSEMOD*, EGG-EST-9223, Idaho National Engineering Laboratory, September.

Abbott M. L. and **A. S. Rood**, 1993. *COMIDA: A Radionuclide Food-Chain Model for Acute Fallout Deposition*, EGG-GEO-10367, Idaho National Engineering Laboratory, November.

Abbott, M. L. S. L. Harms, **A. S. Rood**, 1993. *Dose Calculations for Accidental Airborne Releases of ITER Activation Products*, EGG-EEL-10994, Idaho National Engineering Laboratory, December.

Abbott, M. L. and **A. S. Rood**, 1996. *Source Group Optimization Program (SGOP): A Program the Groups Emission Sources for Input into Air Dispersion Models* INEL-96/0376 Idaho National Engineering Laboratory, Idaho Falls, Idaho.

Brown, J., M. L. H. J. Goossens, B. C. P. Kraan, R. M. Cooke, J. A. Jones, F. T. Harper, F. E. Haskin, M. L. Abbott, M. L. Young, S. C. Hora, **A. S. Rood**, 1997. Probabilistic Accident Consequence Uncertainty Analysis: Food Chain Uncertainty Assessment. NUREG/CR-6523 U.S. Nuclear Regulatory Commission, Washington D.C.

Caffrey, E.A., **A.S. Rood**, H.A. Grogan, and C.D. Mangini, 2020. *Chemical Waste Management Northwest, Inc. Landfill Radiological Dose and Risk Assessment for Bakken Oilfield Disposals in Arlington OR*. Report 06-Arlington Landfill 2020 FINAL. Risk Assessment Corporation, Neeses, SC. September 1, 2020.

Caffrey, E.A., H.A. Grogan, T.E. Johnson. H.J. Mohler, J.R. Rocco, and **A.S. Rood,** 2016. *Dose and Risk Assessment of Technologically Enhanced Naturally Occurring Radioactive Material (TENORM) Disposals at the Blue Ridge Landfill*. Report 1-BRLF TENORM 2016 FINAL. Risk Assessment Corporation, Neeses, SC. October 11, 2016.

Case, M.J., **A.S. Rood**, J.M. McCarthy, S.O. Magnuson, B.H. Becker, T.K. Honeycutt, 2000. *Technical Revision of the Radioactive Waste Management Complex Low-Level Waste Radiological Performance Assessment for Calendar Year 2000*. INEEL/EXT-2000-01089. Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

Electric Power Research Institute (EPRI), 2014. *EPRI Recommendations for the National Academies' Pilot Study of Cancer Risks in Populations around Nuclear Facilities*. Report prepared by H. Grogan and **A. Rood**. Technical Report 3002003163. Electric Power Research Institute, Palo Alto, CA.

EPRI. 2016. *Batch and Continuous Releases to the Atmosphere from Nuclear Power Plants: Comparison of Environmental Concentrations and Doses.* Report prepared by H. Grogan and **A. Rood**. Technical Report 3002008166. Electric Power Research Institute, Palo Alto CA. November.

DOE (U.S. Department of Energy), 2007. *Performance Assessment for the RWMC Active Low-Level Waste Disposal Facility at the Idaho National Laboratory Site*. DOE/NE-ID-11243. Idaho National Laboratory, Idaho Falls, ID.

DOE, 2008. *Composite Analysis for the RWMC Active Low-Level Waste Disposal Facility at the Idaho National Laboratory Site*. DOE/NE-ID-11244. Idaho National Laboratory, Idaho Falls, ID.

DOE, 2011. *Performance Assessment for the Idaho CERCLA Disposal Facility Landfill*. DOE/ID-10978. Idaho National Laboratory, Idaho Falls, ID.

DOE, 2012. *Performance Assessment for the Idaho National Laboratory Remote-Handled Low-Level Waste Disposal Facility*. DOE/ID-11421. Idaho National Laboratory, Idaho Falls, ID.

DOE, 2018. *Performance Assessment for the Idaho National Laboratory Remote-Handled Low-Level Waste Disposal Facility*. DOE/ID-11421, Rev 2. Idaho National Laboratory, Idaho Falls, ID.

DOE, 2018. *Methods, Implementation, and Testing to Support Determination of Performance Assessment Compliance for the RHLLW Disposal Facility WAC*. U.S. Department of Energy Idaho Operations Office

DOE, 2022. *Performance Assessment for the INTEC Calcined Solids Storage Facility at the INL Site*. DOE/ID-12008. Idaho Cleanup Project, U.S. Department of Energy Idaho Operations Office

Grogan, H. A., P. D. McGavran, K. R. Meyer, H. R. Meyer, J. Moler, **A. S. Rood**, W. K. Sinclair, P. G. Voillequé, J. M.

Weber, 1999. *Technical Summary Report of the Historical Public Exposures Studies for Rocky Flats Phase II*. 14-CDPHE-RFP-1999-DRAFT, *Radiological Assessments Corporation*, Neeses, South Carolina. August.

Grogan, H.A., **A.S. Rood**, J.W. Aanenson, and E.B. Liebow, 2002. *A Risk-based Screening Analysis for Radionuclides Released to the Columbia River from Past Activities at the U.S. Department of Energy Nuclear Weapons Site in Hanford, Washington*. RAC Report No. 3-CDC Task Order 7-2000 FINAL. *Risk Assessments Corporation,* Neeses, South Carolina.

Grogan, H.A., B. Jacobs, and **A.S. Rood**, 2010. *Source Term and Transport Modeling for Single-Shell Tanks at the Hanford Site*. RAC Report No. 1-WA-2009-FINAL. *Risk Assessments Corporation,* Neeses, South Carolina.

Maheras, S.J. **A. S. Rood**, S. O. Magnuson, M. E. Sussman, R. N. Bhatt, 1994. *Radioactive Waste Management Complex Low-Level Waste Radiological Performance Assessment*. EGG-WM-8773, Idaho National Engineering Laboratory, May.

McGavran, P. D., **A. S. Rood**, 1999. *Estimated Exposure and Cancer Risk from Beryllium Released to the Air from the Rocky Flats Plant*. 02-CDPHE-RFP-1997 (Rev. 1), *Radiological Assessments Corporation*, Neeses, South Carolina. August.

McGavran, P. D., **A. S. Rood**, 1999. *Estimated Exposure and Cancer Risk from Carbon Tetrachloride Released to the Air from the Rocky Flats Plant*. 04-CDPHE-RFP-1997 (Rev. 1), *Radiological Assessments Corporation*, Neeses, South Carolina. August.

Rood, A. S., 1988. *Environmental Transport Concentration Factors for the FUSECRAC Fusion Reactor Safety Code,* EGG-ESE-8033, Idaho National Engineering Laboratory, May.

Rood, A. S., R. C. Arnett, J. Barraclough, 1989. *Contaminant Transport in the Snake River Plain Aquifer: Phase 1, Part 1: Simple Analytical Model of Individual Plumes,* EGG-ER-8623, Idaho National Engineering Laboratory, May.

Rood, A. S., J. L. George, G. H. Langner, 1990. *Variation in the Annual Average Radon Concentration Measured in Homes in Mesa County, Colorado,* DOE/ID/12584-57 UNC/GJ-50(TMC), U. S. Department of Energy, Grand Junction, Colorado, April.

Rood, A. S. *Assessment of Impacts at the Advanced Test Reactor as a Result of Chemical Releases at the Idaho Chemical Processing Plant*, EGG-EST-9523, Idaho National Engineering Laboratory, February, 1991.

Rood, A. S. and M. L. Abbott, 1991. *Comparison of Dose and Dose-rate Conversion Factors from the Soviet Union, United Kingdom, U.S. Department of Energy and the Idaho National Engineering Laboratory Fusion Safety Program*, EGG-FSP-9865, Idaho National Engineering Laboratory, December.

Rood, A.S., 1994. *GWSCREEN: A Semi-Analytical Model for Assessment of the Groundwater Pathway from Surface or Buried Contamination: Theory and Users Manual Version 2.0*, EGG-GEO-10797, Revision 2, Idaho National Engineering Laboratory, June.

Rood, A. S., H. A. Grogan, 1999. *Estimated Exposure and Lifetime Cancer Incidence Risk from Plutonium Released from the 1969 Fire at the Rocky Flats Plant*. 07-CDPHE-RFP-1999, *Radiological Assessments Corporation,* Neeses, South Carolina. August.

Rood, A. S., H. A. Grogan, 1999. *Comprehensive Assessment of Exposure and Lifetime Cancer Incidence Risk from Plutonium Released from the Rocky Flats Plant*. 13-CDPHE-RFP-1999, *Radiological Assessments Corporation,* Neeses, South Carolina. September.

Rood, A. S., H. A. Grogan, 1999. *Estimated Exposure and Lifetime Cancer Incidence Risk from Plutonium Released from the 1957 Fire at the Rocky Flats Plant*. 02-CDPHE-RFP-1999, *Radiological Assessments Corporation, Neeses*, South Carolina. August.

Rood, A. S., H. A. Grogan, 1999. *Estimated Exposure and Lifetime Cancer Incidence Risk from 903 Area Plutonium Releases at the Rocky Flats Plant*. 01-CDPHE-RFP-1999, *Radiological Assessments Corporation,* Neeses, South Carolina. August.

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Management Complex" John Horan Memorial Symposium on Radioactive Waste Management Issues. Greater Salt Lake Chapter of the Health Physics Society, Salt Lake City, Utah, April 28, 2001.

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Verification Study Conflict of Interest Certification

Verification Study: **Dose Compliance Concentrations (DCC) for Radionuclides at Superfund Sites Electronic Calculator**

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

- Did you contribute to the development of the calculator (and associated webpages) being verified, or were you consulted during its development, or did you offer comments or suggestions to any drafts or versions of the calculator during its development? ☒ No ☐ Yes
- Do you know of any reason that you might be unable to provide impartial advice on the matter under consideration in this verification study, or any reason that your impartiality in the matter might be questioned? ☒ No ☐ Yes
- Have you had any previous involvement with the DCC calculator under consideration? ☒ No ☐ Yes
- Have you served on previous advisory panels, committees, or subcommittees that have addressed the topic under consideration? ☒ No ☐ Yes
- Have you made any public statements (written or oral) on the issue? ☒ No ☐ Yes
- Have you made any public statements that would indicate to an observer that you have taken a position on the issue under consideration? ☒ No ☐ Yes
- Do you, your family, or your employer have any financial interest(s) in the matter or topic under this verification study, 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) Participant 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 Participant has disclosed all such relevant information to EMS or to EPA.
(b) Participant 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 Participant (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. Participant shall continue performance until notified by EMS of any contrary action to be taken.

Arthur S Rood 2-6-2023

Signature Date

☐ Check here if any explanation is attached

Arthur S Rood

Printed Name

K-Spar Inc.

Affiliation/Organization