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TableCalculator: a Transparent Public Tool to Replicate US NRC LLW Classification Table Calculations

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Performance and Risk Assessment
Community of Practice

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Background: US NRC Low-Level Waste (LLW) Classification

- US NRC established concentration limits for Class A, B, and C LLW in Title 10, Code of Federal Regulations (CFR) 61.55 in the early 1980s
- Limits were developed by considering the potential dose to an inadvertent intruder in agricultural and construction scenarios
- Other scenarios (e.g., accident, groundwater contamination) were evaluated but did not directly affect the limits

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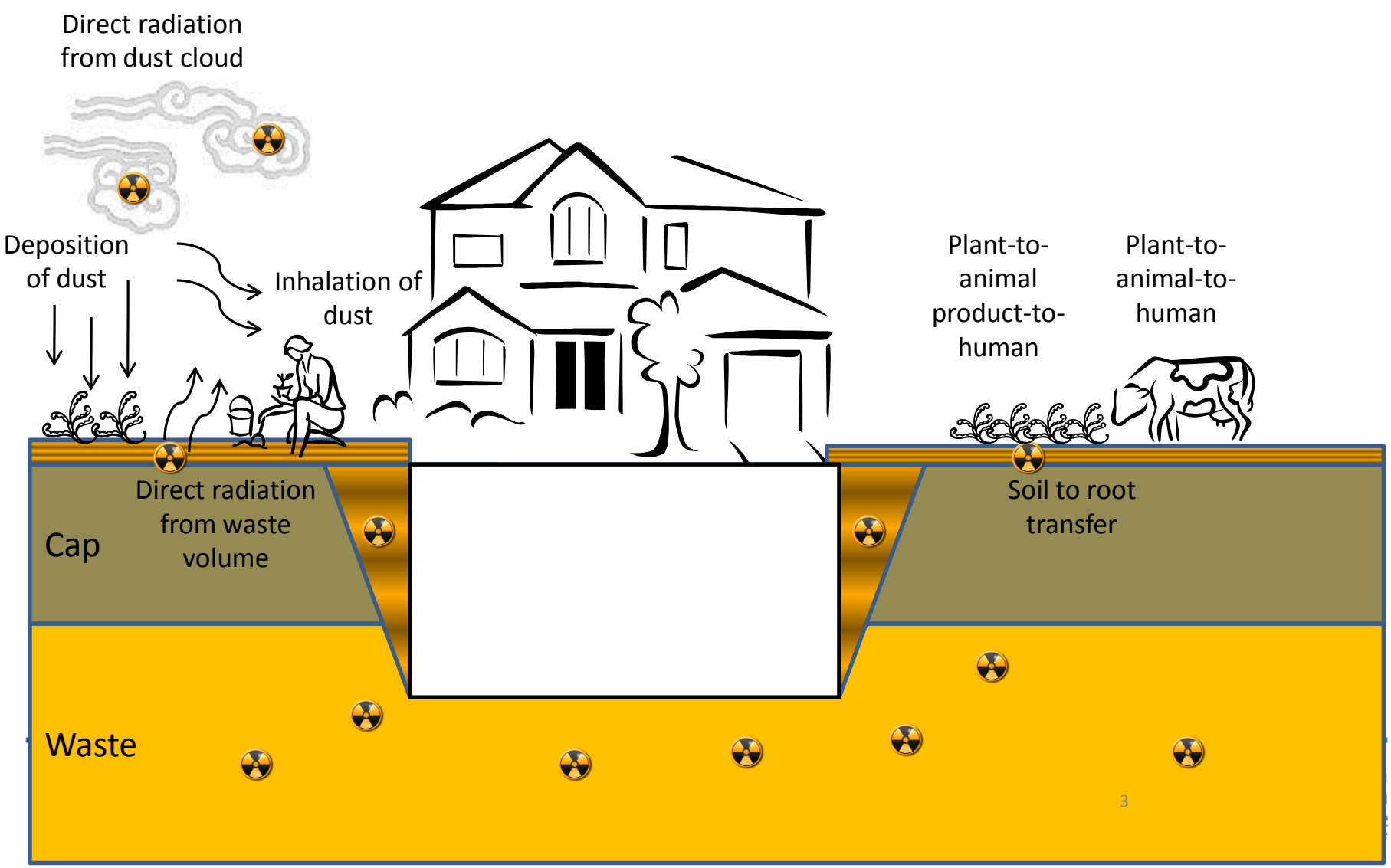
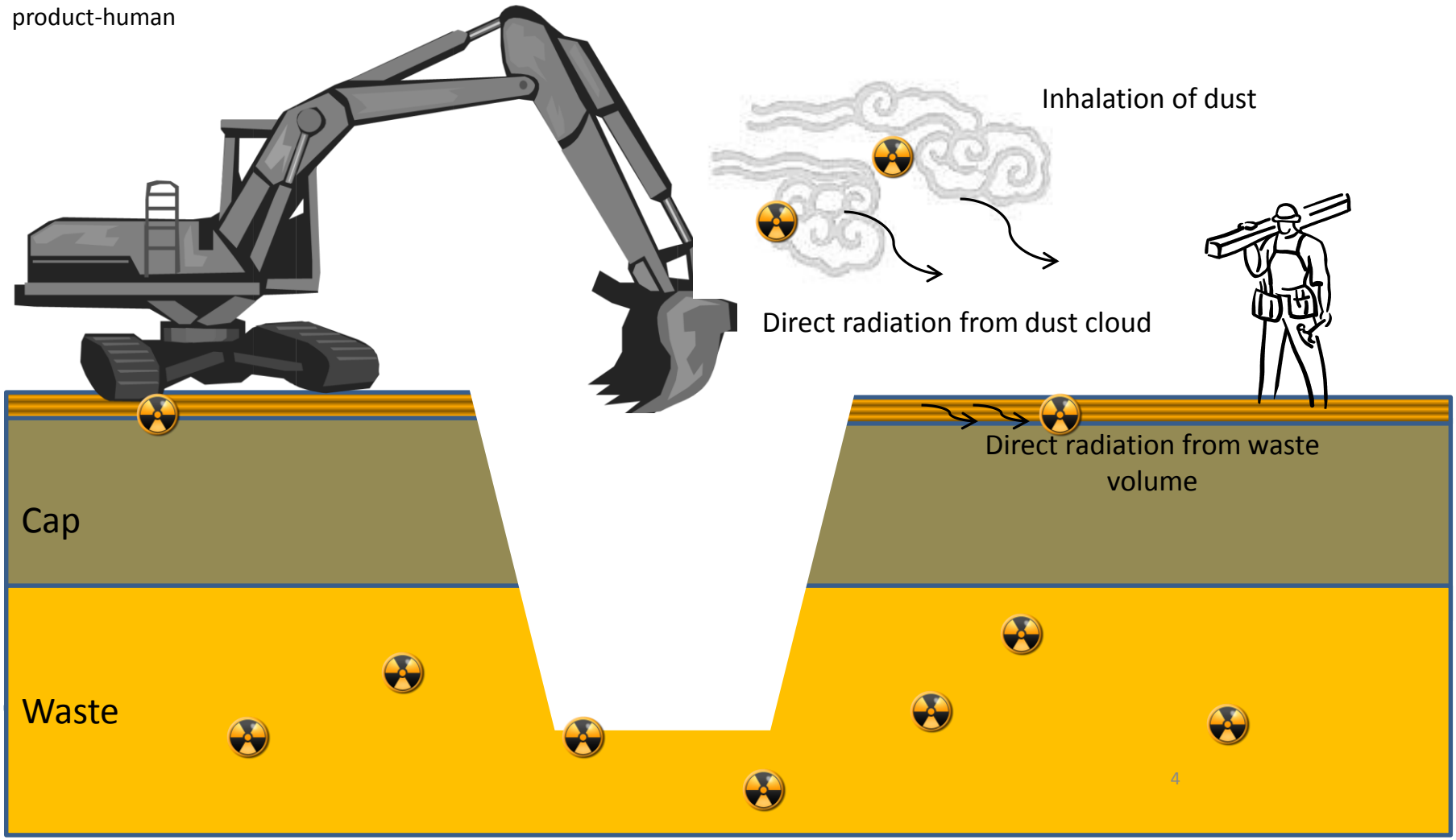
Intruder Agriculture



Intruder Construction

NOTE: Includes modified food pathways to account for non-equilibrium deposition and subsequent root uptake: (i) plant-human; (ii) plant-animal-human; and (iii) plant-animal product-human



Background: US NRC LLW Classification (continued)

- Waste classification limit calculations were a small part of the analyses done to support the Environmental Impact Statement (EIS) for the US NRC LLW regulations
- Class limits were developed from calculations done with two FORTRAN codes, DOSE and INVERSI
- The DOSE code calculated pathway dose conversion factors (PDCFs)
- The INVERSI code used some of the PDCFs calculated by DOSE to calculate radionuclide concentrations in waste corresponding to dose-limiting criteria
  - User inputs were used to specify waste and disposal facility characteristics
  - 20 exposure scenarios were evaluated

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Background: US NRC LLW Classification (continued)

- Calculations were based on a critical organ approach (ICRP-2 recommendations)
  - Initial concentration limits were based on most limiting of the following limits:
    - 5 mSv (500 mrem) to the total body or bone
    - 15 mSv (1.5 rem) to the liver, kidney, lung, or gastrointestinal tract/lower large intestine
    - 30 mSv (3 rem) to the thyroid
  - Certain concentrations were then adjusted based on other factors (e.g., assumptions about waste accessibility or dilution with lower concentration waste)

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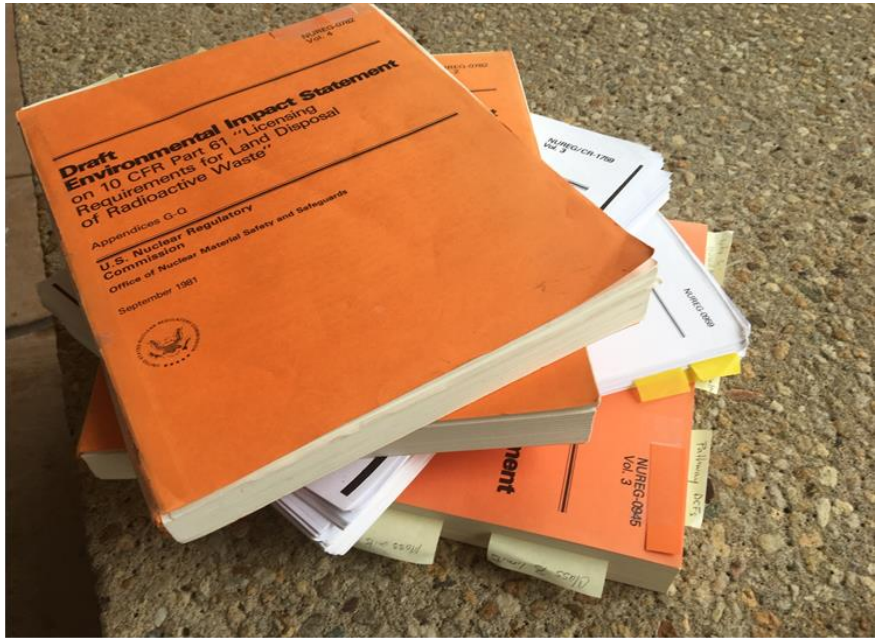
Adjustments to Calculated Concentration Limits

Adjustment	Basis
Class A Cs-137 multiplied by 22	Assumed mixing with lower concentration waste
Class B Cs-137 multiplied by 10	Assumed mixing with lower concentration waste
Class C Cs-137 multiplied by 10	Assumed mixing with lower concentration waste
Class C limits other than Cs-137 multiplied by 10	1) low probability of intrusion, 2) inaccessibility of Class C waste, and 3) assumed mixing with less concentrated waste
All limits for C-14, Ni-59, Ni-63, and Nb-94 in metals multiplied by 10	Inaccessibility of radionuclides in metallic waste
Limits for alpha-emitting transuranic radionuclides with half-lives ≥ 5 yr	Limits for individual radionuclides combined to simplify implementation
Class A and C limits for Pu-241	Adjusted limit based on ingrowth of Am-241 to 10 nCi/g (Class A) and 100 nCi/g (Class C)
Class A and C limits for Cm-242	Limits were not calculated in the Draft EIS. Limits were calculated in the Final EIS based on ingrowth of Pu-238 to 10 nCi/g (Class A) and 100 nCi/g (Class C)

Documentation of LLW Classification Calculations

- DOSE, INVERSI, and the NUCS input file are listed in public guidance documents
- Detailed explanations are provided in the Draft EIS and supporting documents
- All of the scenarios, assumptions, equations, and parameter values underlying the intruder dose calculations and subsequent adjustments are publicly available
- They are not all trivial to trace



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Interpretation of Original Calculations Using Modern Assessments

- Despite critical organ dose approach and subsequent adjustments, US NRC staff and external stakeholders sometimes make the simplifying assumption that the waste classification table values correspond to 5 mSv (500 mrem) Total Effective Dose Equivalent (TEDE)
- “Inverse” or “back” calculations are sometimes used to propose adjusted concentration limits based on comparison to 5 mSv (500 mrem) TEDE in a modern analysis

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Purpose of the Tool

- Enhance transparency of original calculations and adjustments
  - Object-oriented tool shows conceptual connections
  - Internal documentation of parameter values and assumptions includes references to the original documentation

- Eliminate the need for "back calculations" from an assumption of 5 mSv/yr (500 mrem/yr) TEDE by allowing quick forward computations

- Facilitate sensitivity analyses (e.g., how would the limits be different if more modern dosimetry had been used?)

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Inputs

Outputs

Detailed Outputs

About

References

TableCalc

TableCalc Version 0 was developed to enhance understanding of the waste classification calculations used to develop Table 1 and Table 2 of 10 CFR Part 61.55. The waste classification tables were developed from model projections of dose to an inadvertent intruder in agricultural, construction, and discovery scenarios at different times after facility closure. TableCalc replicates the original FORTRAN calculations in modern software that can increase transparency and therefore increase understanding and enhance regulatory efficiency.

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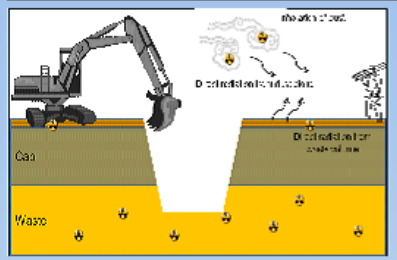

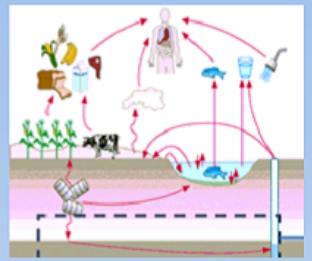

DISCLAIMER:
TableCalc is being released as an initial beta version (Version 0) to allow stakeholders to utilize the tool and provide feedback to the authors. TableCalc should not be used by licensees, applicants, or other members of the public to formulate positions or supply licensing information.

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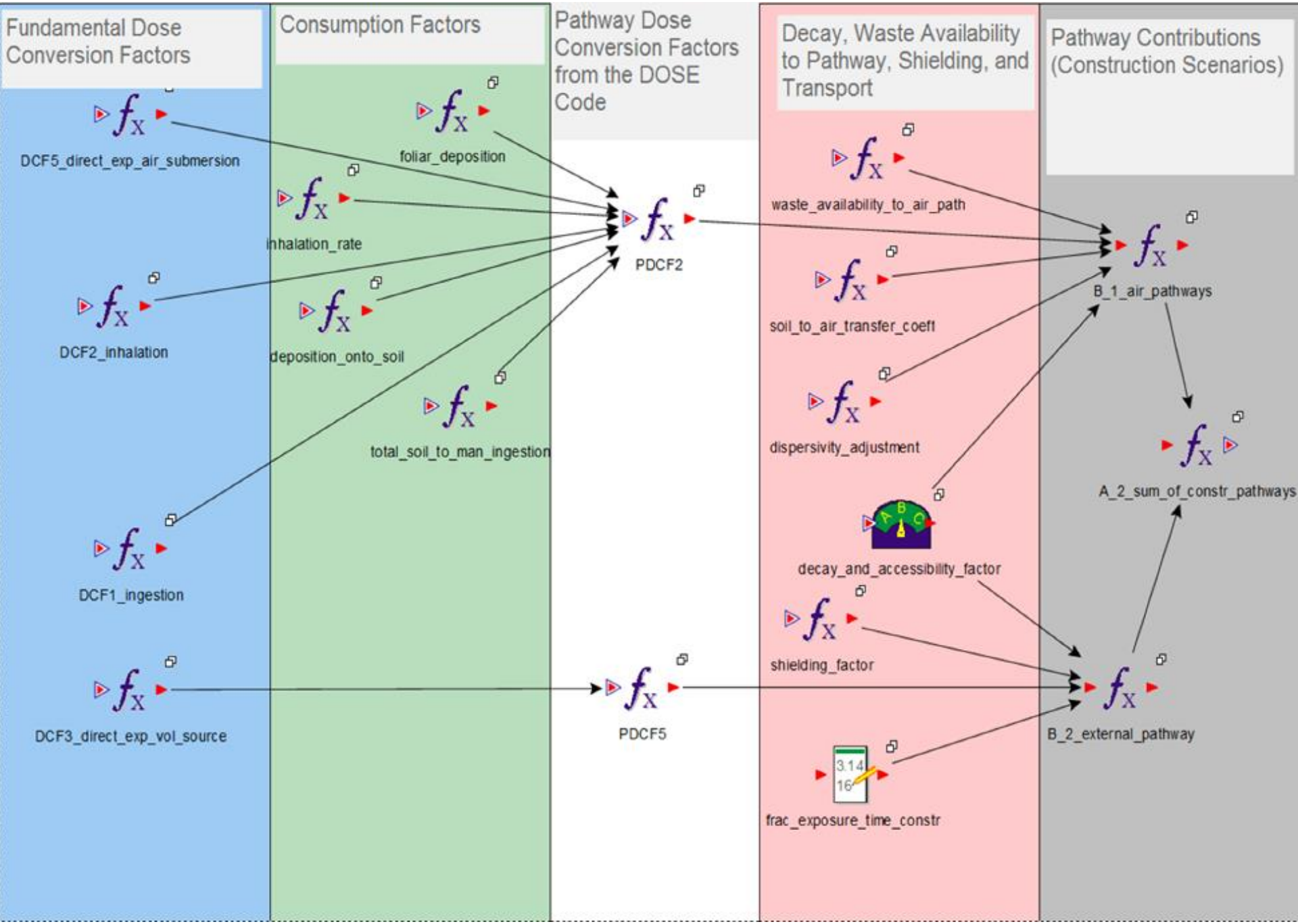
Fundamental Dose Conversion Factors
Consumption Factors
Pathway Dose Conversion Factors from the DOSE Code
Decay, Waste Availability to Pathway, Shielding, and Transport
Pathway Contributions (Construction Scenarios)
DCF5_direct_exp_air_submersion
foliar_deposition
inhalation_rate
PDCF2
waste_availability_to_air_path
B_1_air_pathways
DCF2_inhalation
deposition_onto_soil
soil_to_air_transfer_coeff
total_soil_to_man_ingestion
dispersivity_adjustment
A_2_sum_of_constr_pathways
decay_and_accessibility_factor
DCF1_ingestion
shielding_factor
DCF3_direct_exp_vol_source
PDCF5
B_2_external_pathway
frac_exposure_time_constr

User Inputs in Original Code

User inputs to INVERSI code allowed choice of some site, facility, and waste characteristics. "Base case" values used in development of 10 CFR 61.55 classification limits.

- Region
- Shallow trench or concrete-walled design
- Cover thickness
- Stabilized vs. unstabilized waste
- Type of stabilization
- Waste emplacement
- Segregation
- Layering
- Grouting between packages
- "Normal" or "hot waste" facility
- Post closure level of care
- Length of post-operational period
- Length of institutional control period
- Credit for wasteform
- Flammability
- Dispersibility
- Leachability
- Chemical content (i.e., chelating agents)
- Accessibility

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“Base Case” inputs yield results used in the development of the waste classification limits (prior to adjustments)

DEIS Table 7-1 Comparison

	Model Output	DEIS Table 7.1 Column 1	Model Output	DEIS Table 7.1 Column 2	Model Output	DEIS Table 7.1 Column 3
C-14	0.75	0.75 Ci/m3	12638	12600 Ci/m	0.787	0.787 Ci/m
Ni-59	2.15	2.15 Ci/m3	233	233 Ci/m3	2.16	2.16 Ci/m3
Nb-94	0.0015	0.002 Ci/m	0.152	0.152 Ci/m	0.00157	0.00157 Ci
Tc-99	0.262	0.262 Ci/m	55554	55500 Ci/m	0.263	0.263 Ci/m
I-129	0.0082	0.008 Ci/m	14.8	14.8 Ci/m3	0.00819	0.00819 Ci
Pu-241	0.274	0.274 Ci/m	22.9	11800 Ci/m	0.502	0.501 Ci/m
H-3	36.2	36.2 Ci/m3	1.1e8	1.1e8 Ci/m	2.18e11	0 Ci/m3
Co-60	677	677 Ci/m3	66707	66800 Ci/m	5.77e25	5.77e25 Ci
Ni-63	3.45	3.45 Ci/m3	2837	2840 Ci/m3	70.2	70.2 Ci/m3
Sr-90	0.038	0.038 Ci/m	149	149 Ci/m3	735	735 Ci/m3
Cs-137	0.045	0.045 Ci/m	4.4	4.41 Ci/m3	460	460 Ci/m3

Tool Verification

- Pathway dose conversion factors (i.e., DOSE code output) for 36 radionuclides are given in the Final EIS for 10 CFR Part 61 (NUREG-0945)
- "Base Case" concentration results from the INVERSI code are available in NUREG-0959 for 23 radionuclides and 20 scenarios
- "Base Case" results for the most limiting of three scenarios (agriculture, construction, and construction-discovery) correspond to values in the Draft EIS (NUREG-0782) Table 7-1 and, after documented adjustments, the 10 CFR 61.55 waste classification tables

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Discrepancies & Disagreements

- A few differences were found between the equations or explanations presented in the NRC guidance documents and the equations used in the FORTRAN codes
- One unit conversion error was found (plant ingestion pathway)
- All discrepancies are documented in comments in the tool
- In some cases, staff questioned whether certain assumptions made in the original analysis were applied too broadly. Tool was used to test risk significance of those assumptions

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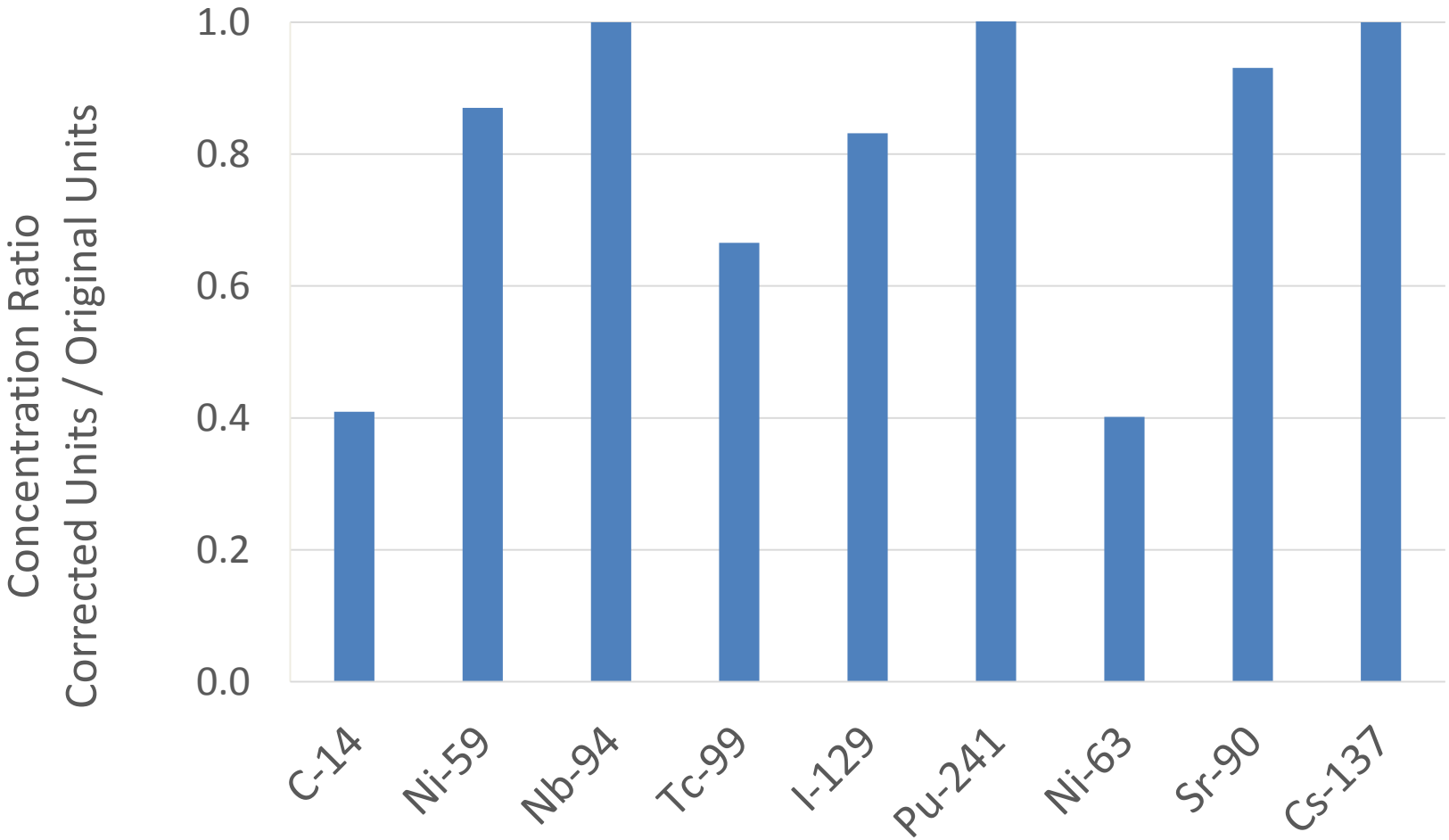
Impact of Plant Pathway Unit Conversion Change (Change from Class C Concentrations)



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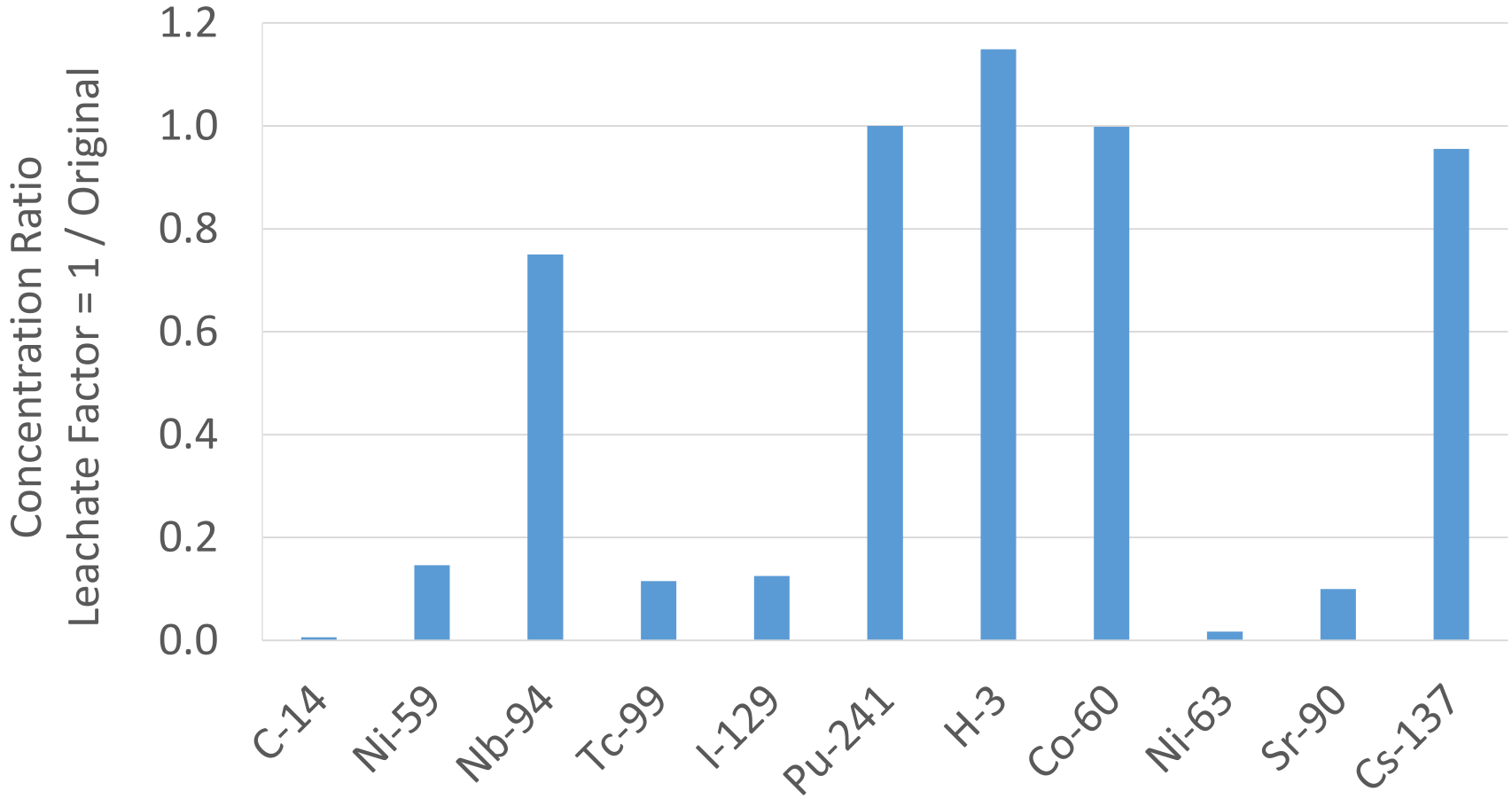
Impact of Waste-to-Leachate Transfer Factor (Change from Class A Concentrations)



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Impact of Updating Dose Methodology

- The NRC 1986 guidance document, Update of Part 61 Impacts Analysis Methodology (NUREG/CR-4370) considered update from ICRP-2 to ICRP-26/30 Methodology, among other changes
  - Proposed different types of limits for a hypothetical "Class D" waste, including volume and mass-based limits as well as areal limits
  - Did not recalculate 10 CFR 61.55 limits
- Work to show effects of changing dosimetry is ongoing
  - Using Federal Guidance Report 11 and 12 instead of original ICRP-2 based DCFs generally results in larger concentration limits
  - Results generally consistent with others (e.g., EPRI report 3002003121)
  - Effects should be considered in the context of multiple assumptions that affect the generic values in 10 CFR 61.55

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Conclusions

- Working, object-oriented tool with internal documentation increases transparency of the original US NRC calculations performed in the early 1980s
- Eliminates the need for “back calculations” from an assumption of 5 mSv/yr (500 mrem/yr) TEDE by facilitating quick forward calculations
- Working implementation facilitates sensitivity analyses
- Allows quick comparisons of modern results with original waste classification results to identify and evaluate effects of different assumptions

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