



A POTENTIAL APPLICATION OF UNCERTAINTY ANALYSIS TO DOE-STD-3009-94 ACCIDENT ANALYSIS

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Introduction

- ↓ Requirement to determine if the 25 rem EG is being challenged let to qualitative discussions of uncertainty in DOE-STD-3009 (STD-3009) accident analysis.
- ↓ Recent and ongoing efforts may allow for a quantitative technical-based uncertainty methodology:
 - Development of DOE-STD-5506 (STD-5506), Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities
 - NRC-sponsored improvements to MACCS2 that include assignment of uncertainty distributions to most input parameters





STD-5506 Guidance on Source Terms

- ↓ STD-5506 provides set guidance on the values to use for each STD-3009 Source Term Factors:

$$D_{MOI} = MAR \cdot [ARF \cdot RF] \cdot DR \cdot LPF \cdot BR \cdot DCF_{ICRP\ 72} \cdot \chi / Q$$

- ↓ MAR is determined using an algorithm of bounding values based on the number of containers anticipated to be impacted (single container, payload, building, etc.), and inventory knowledge.
- ↓ ARF·RF and DR values are set based on the type of accident and the motive force.
- ↓ For the unmitigated analysis, the LPF is always 1.0, i.e., no credit.





STD-5506 Guidance on Consequence Analysis Factors

- ↓ The breathing rate value, as specified in the DOE Toolbox Codes, is $3.3 \times 10^{-4} \text{ m}^3/\text{s}$ and must be used in consequence assessment.
- ↓ Inhalation dose conversion factors for the maximally exposed offsite individual (MOI) evaluation must be consistent with ICRP 72 and optionally may use ICRP 68 for the collocated worker evaluation.
- ↓ The values of χ/Q used for radiological and chemical consequence analysis are generated using MACCS2 Computer Code.





STD-5506 Guidance on Dispersion Modeling

- ↓ Worst case meteorological assumptions (i.e., 95th percentile based on local site data) for onsite radiological and chemical releases.
- ↓ Dry deposition velocity must be used at a value of 1 cm/s for all unfiltered, non tritium, non-noble gas species.
- ↓ Wet deposition must not be modeled.





STD-5506 Guidance on Dispersion Modeling (cont.)

- ↓ A surface roughness value of 3 cm must be assumed for radiological and chemical releases.
- ↓ Building wake effects must not be credited (modeled) unless shown to yield more conservative or bounding results.
- ↓ Plume buoyancy may only be used when modeling fires that are outdoors or venting through a large breach in the facility (use of plume buoyancy should not be credited in a non-conservative manner).





Sources of Uncertainty

- ↓ STD-5506 also outlines the known sources of uncertainty for each source term and consequence analysis factors

Variable	Expected Uncertainty
MAR	<p>For accident analyses, the MAR developed in accordance with Section 4.3.2 of the TRU Waste Standard is expected to be bounding; that is, it represents a conservative accumulation of MAR in the number of containers involved in the accident scenario.</p> <p>Only a limited amount of uncertainty is associated with the generally conservative estimates of MAR for the containers in any accident scenario.</p>
ARF RF	<p>Derivations of ARF/RF values reported in DOE-HDBK-3010 were based on a limited set of experiments, data gathering, and empirical correlations; thus, some uncertainty is expected. The bounding ARF/RF in the Handbook, however, represented in most cases the bounding values for the set of experiments or conditions being represented.</p> <p>Provided that bounding values from DOE-HDBK-3010 are appropriately selected, the calculated doses (for safety analysis purposes) will be sufficiently conservative for derivation of adequate controls.</p>





Sources of Uncertainty (cont.)

Variable	Expected Uncertainty
DR	<p>The determination of the DR for a given accident scenario is heavily dependent on the magnitude of the scenario in question, container configuration during the accident, and number of containers involved. Results of experiments or tests have demonstrated high variability in the DRs.</p> <p>Depending on the particular accident scenario and the number of containers involved, the uncertainty associated with this variable could be as high as one order of magnitude.</p>
LPF	<p>TRU waste facilities are relatively simple facilities (e.g., relatively low number of operational areas, ventilation zones, and fire areas), and in most cases do not rely on active ventilation to maintain confinement during accident scenarios; thus, a LPF of 1 is expected.</p>
BR	<p>The BR of 3.3E-4 m³/s must be used for both hazard and accident analysis. This value is the recommended BR specified in the Radiological Health Handbook.</p>
DCF	<p>The derivation of DCF values are based on a complex combination of metabolic, statistical, historical exposures, experimental, and human characteristics (e.g., age, sensitivity), among others. However, since these values are regulatory driven, they are assumed to be fixed for dose calculation purposes.</p>





Sources of Uncertainty (cont.)



Variable	Expected Uncertainty
χ/Q	<p>Standardized modeling parameters (DOE-EH-4.2.1-MACCS2-Code Guidance, MACCS2 Computer Code Application Guidance for Documented Safety Analysis; from hereon referred as "Tool Box Codes"), ground level release, default terrain (prairie grass), surface roughness, etc.</p> <p>Depending on the site, receptor location, and release characteristics, these variables could result in an uncertainty of about a factor of four.</p>

- ↓ By applying STD-5506 guidance, only two factors have a notable contribution to uncertainty.
- ↓ If the DR value shown to be bounding, then uncertainty only from χ/Q (i.e., MACCS2).





MACCS2 Improvements

- ↓ NRC has been moving toward greater emphasis on probabilistic analysis and risk-informed decision-making:
 - Uncertainty analysis included in RESRAD code
 - Performance-based & risk-informed decision-making, being considered in other parts of NRC
 - Code capability for uncertainty analysis a key part

- ↓ Beta version of WinMACCS supports this NRC trend
 - MACCS2 driver, Windows graphical user interface
 - Latin Hypercube Sampling of uncertainty distributions
 - Selection from approximately 30 uncertainty distributions
 - Correlation of dependent input parameters





Proposed Method

1. Determine which MACCS2 modules are applied for the site-specific accident analysis (ATMOS at a minimum, maybe EARLY).
2. Verify the input parameters for the MACCS2 module(s) of concern,
 - Which ones will MACCS2 allow for uncertainty analysis and/or
 - Which ones can be removed from further assessment based on DOE guidance, the specific scenario assumptions, and/or by site-specific conditions
3. For the selected input parameters, establish their uncertainty distribution type and associated input values (30 distributions available) and enter into WinMACCS input file.
4. Determine if the selected input parameters are dependent and, if so, establish their Correlation Coefficients.
5. Perform necessary MACCS2 runs/simulations and document the results.





LLNL Site-Specific Example

↓ Safety basis fire calculation for a LLNL TRU waste facility selected:

- Largest MOI dose consequence for the selected TRU waste facility; however, below 10 rem guidance in STD-5506 for challenging EG.
- Inventory given for Plutonium Equivalent Curies (PE-Ci).
- Relatively close to fenceline (~150 m).
- All factors either bounding or set (STD-5509 or scenario) except χ/Q
- MACCS2 baseline unit rem/PE-Ci conversion factor of 11.2 rem/PE-Ci in 0.1 to 0.2 km NE sector using FGR-11 library.





Application of Proposed Method

- ↓ Short-term radiological exposure => Principally ATMOS but EARLY could be a factor.
- ↓ Up to 40 input parameters are allowed uncertainty distributions in both modules.
- ↓ Four sub-sections with up to 10 input parameters are not fixed by scenario or STD-5506 guidance.
- ↓ Only 4 input parameters are carried forward into uncertainty analysis
 - 2 input parameters fixed by MACCS2 equations or user guidance
 - Potential code issue with Dispersion Function parameters





Application of Proposed Method (cont.)

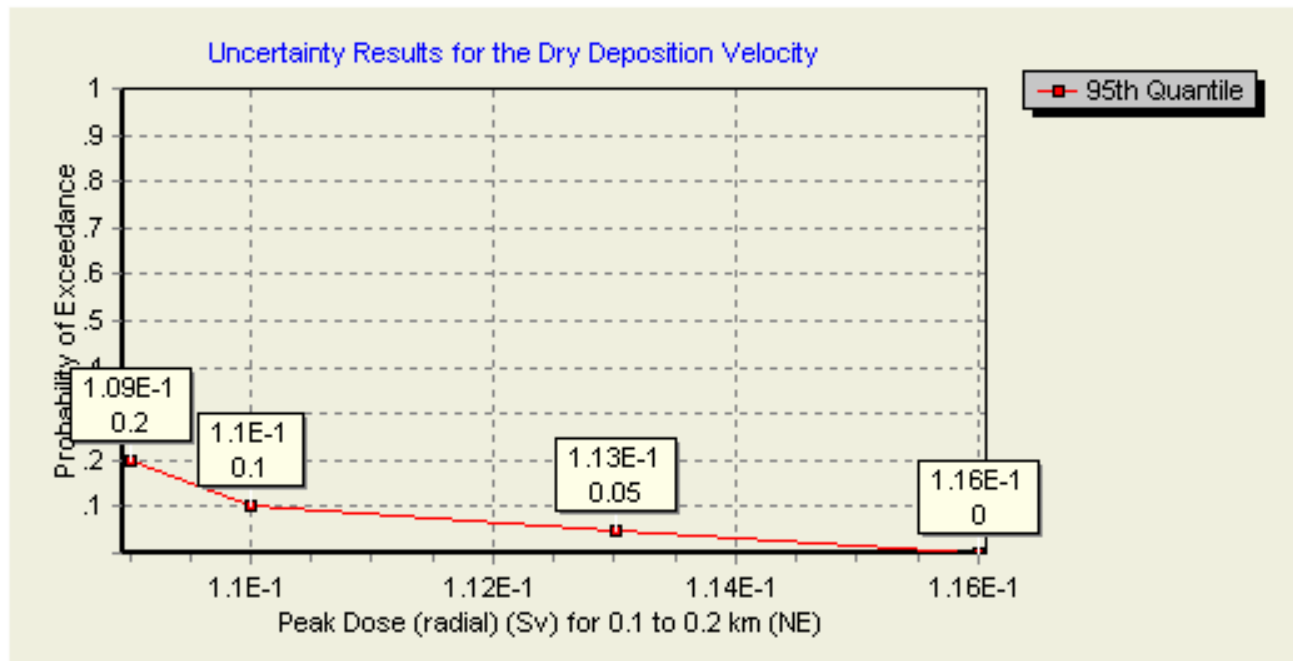
- ↓ Uncertainty distributions and values assigned to selected input parameters.
 - VDEPOS – Orig. value of 0.01 m/s; technical papers show lognormal distribution with range of 2.7E-6 to 0.025 m/s
 - Note on ZSCALE – Orig. value of 2.02; STD-5506 requires setting to a value of 1.0, uniform distribution from 1.0 to 2.51 for range of surface roughness conditions
 - SCLADP & SCLEFP – Orig. value of 1; uniform distribution from 0.1 to 10 (order of magnitude effect)
- ↓ SCLADP & SCLEFP correlated for consistency in sampling.
- ↓ MACCS2 executed for 20 simulations for each input parameter separately and a combined run.





Results

↓ Setting ZSCALE to 1 => 20.6 rem/PE-Ci

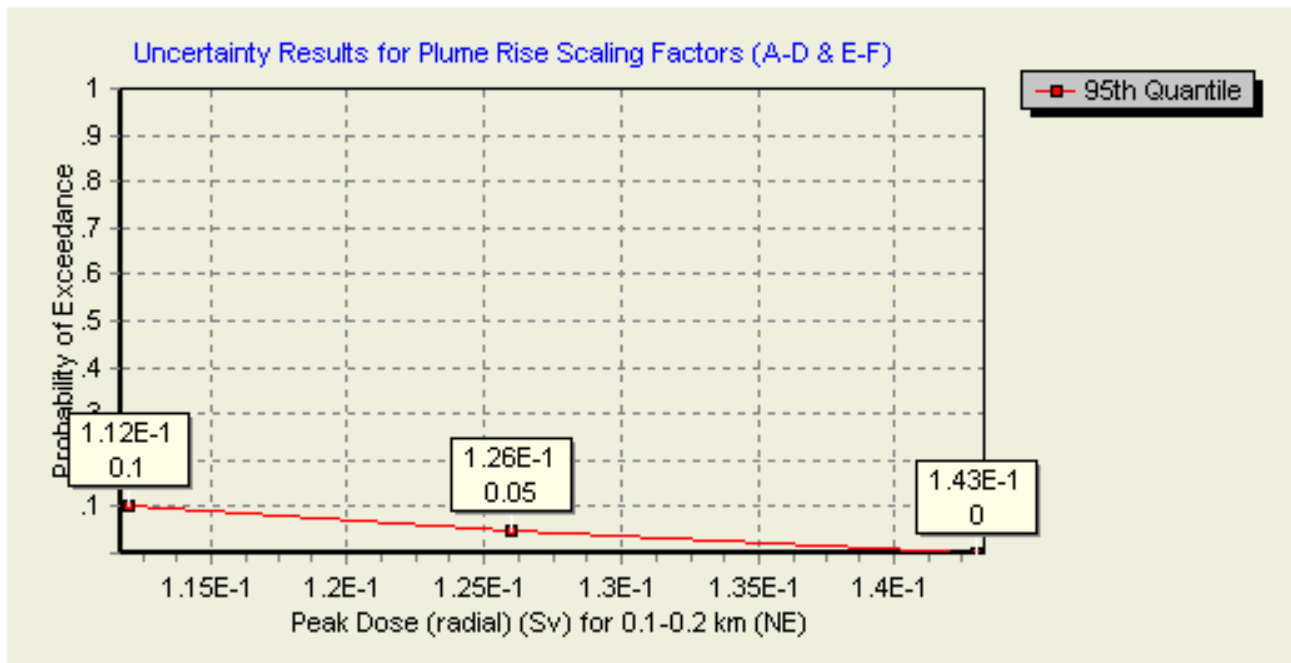


Impact of the Dry Deposition Velocity on Uncertainty





Results (cont.)

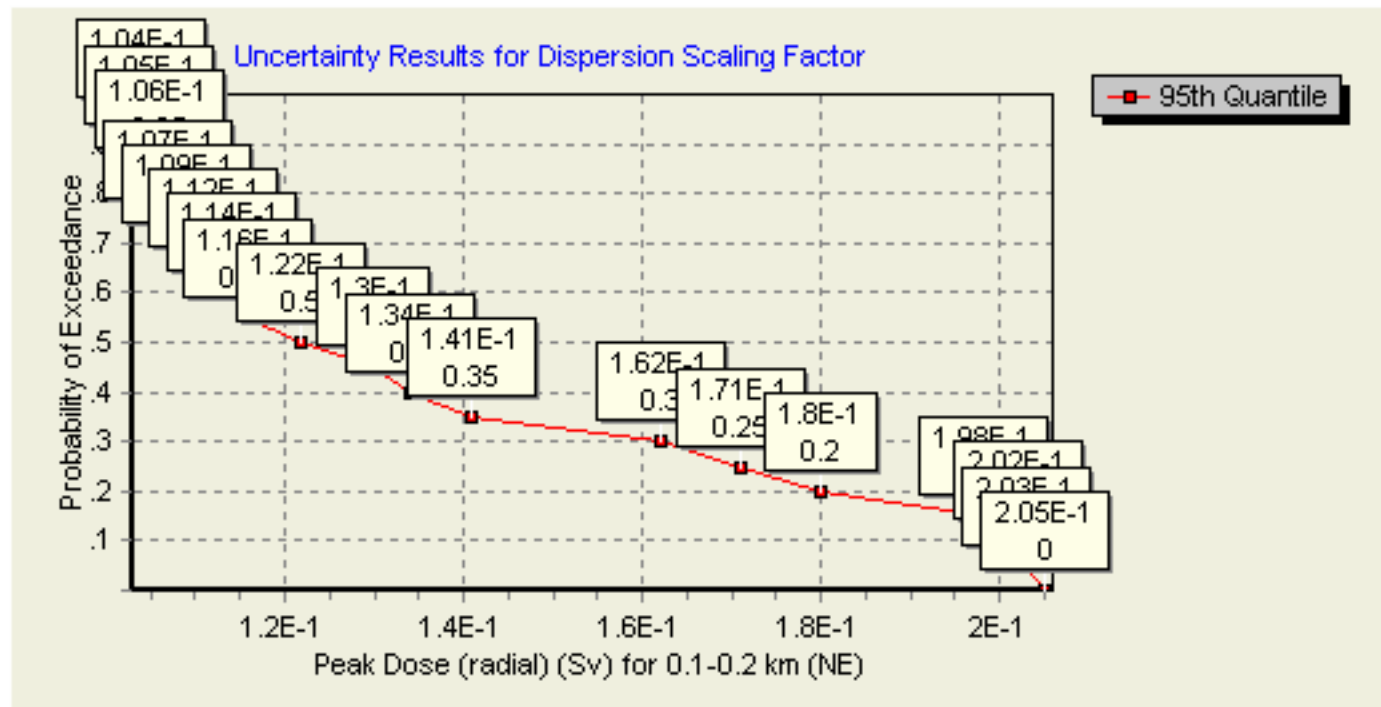


Impact of the Plume Rise Scaling Factors for Stability Classes A-D and E&F on Uncertainty





Results (cont.)

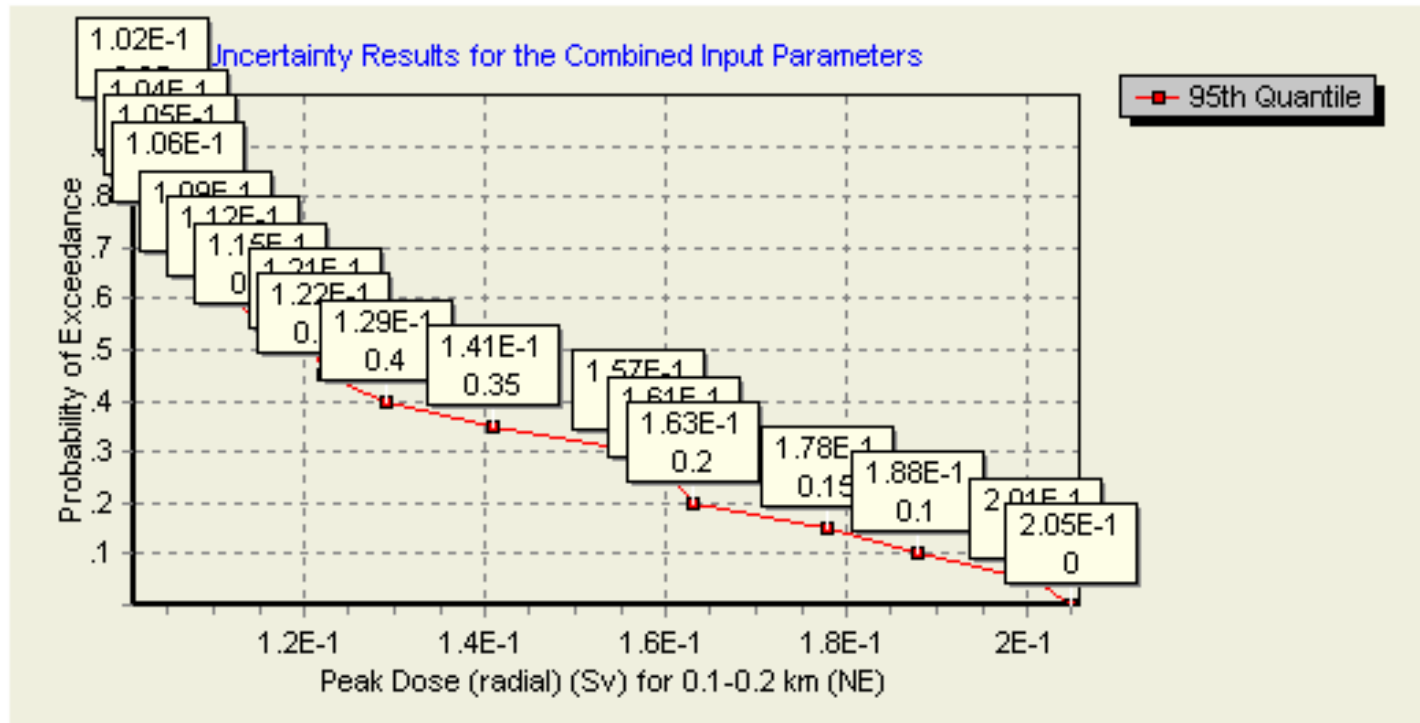


Impact of the Dispersion Scaling Factor on Uncertainty





Results (cont.)



Impact of All Evaluated Input Parameters on Uncertainty





Conclusion

- ↓ Guidance and future code improvements gives opportunity for TRU waste facilities to apply uncertainty analysis for quantitative determination of challenging the EG.
- ↓ Like NRC, benefit to DOE could come from
 - Acceptance of risk in decision-making
 - Focus resources and labor on program segments where greatest reduction in risk can be made or in supporting key controls





Conclusion (cont.)

- ↓ Results only preliminary, further work dependent on or needs to address:
- Final publication of NRC-sponsored MACCS2 improvements:
 - Official released version of WinMACCS
 - Technical justification and recommendations of input parameters' uncertainty distributions
 - DOE position on MACCS2 improvements unknown
 - Contractual implementation of STD-5506 not yet determined
 - Acceptance of uncertainty analysis by DOE Site Office
 - Refine/develop guidance for uncertainty analysis to other DOE nuclear facilities

