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# STANDARDIZED RADIOLOGICAL DOSE EVALUATIONS

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Following the end of the Cold War, the mission of the Rocky Flats Environmental Technology Site (Site) changed from one of production of nuclear weapons components to one of Site clean-up. Authorization basis documents for the facilities at the Site, primarily the Final Safety Analysis Reports (FSARs), have thus become out-of-date. These are being replaced with new authorization basis documents, in which accident scenarios are sorted into coarse bins of consequence and frequency, similar to the approach of DOE-STD-3011-94. Because this binning does not require high precision, a standardized approach for radiological dose evaluations has been taken for all of the facilities at the site. This is done through use of a standard calculation "template" for use by all safety analysts preparing these new authorization basis documents. The use of a standardized approach assures that similar accidents in different facilities are treated in a consistent manner. This report describes this template and its use. The standardized template provides for all of the accident scenarios normally considered when evaluating the safety of operations in a facility. Accidents peculiar to a given facility will still have to be treated individually.

To use this standardized dose calculation template (a Microsoft EXCEL® workbook), the analyst selects from a number of options and provides accident-specific information. For non-criticality accidents these are:

Accident Scenario. There are seven options:

1. Fire (lofted plume) - for unrestricted plumes, as outdoors
2. Fire (non-lofted plume) - for plumes that pass through HEPA filtration
3. External Explosion - for an explosion adjacent to exposed material
4. Internal Explosion - for an explosion within the material
5. Overpressurization - for gas/vapor build-up that breaches container
6. Spill - for both normal spills and earthquakes
7. Loss of Power - for total power loss, including loss of ventilation, throughout release

Form of Material. There are 11 options:

1. Confined Materials - for containerized wastes
2. Unconfined Noncombustible Material - examples are contaminated walls, floors, *etc.*
3. Unconfined Combustible Material - radiologically contaminated paper, cloth, *etc.*
4. HEPA Filters - for HEPA filters in plenums, not in containers
5. Radioactive Metal - bare metal pieces, such as ingots, buttons, and briquettes
6. Powder - finely divided material, primarily oxides
7. Chips - includes turnings, lab samples, coupons, sources
8. Dry Resin Material - contaminated resin beads in ion column that have dried
9. Wet Resin Material - contaminated resin beads in ion column that are still wet
10. Volatile Liquid - radiologically contaminated organic solvents, for example
11. Non-volatile Liquid - radiologically contaminated aqueous solutions, for example

Type of Material. There are six options:

1. Weapons Grade Plutonium - the generic isotopic mix
2. Aged Weapons Grade Plutonium - the generic isotopic mix aged to maximize Am content
3. Enriched Uranium - the generic highly enriched isotopic mix, mostly $^{235}U$
4. 4.5% Enriched Uranium - with 4.5% $^{235}U$
5. Depleted Uranium - the generic isotopic mix, mostly $^{238}U$
6. High-Americium Residues - the residues with the highest americium content

# Disclaimer

Meteorological Conditions. There are two options:

1. Median - approximated by stability class D and a 4.5 m/s wind speed
2. 95th Percentile - approximated by stability class F and a 2 m/s wind speed

Breathing Rate. There are three options:

1. Chronic - for sedentary activities
2. Light Activity - as for walking
3. Heavy Activity - as for running or heavy work

Solubility Class of the Released Material. There are three options:

1. Lung Clearance Class D - for $UF_6$, $UO_2F_2$, and $UO_2(NO_3)_2$
2. Lung Clearance Class W - for $UO_3$, $UF_4$, $UCl_4$, and all Pu compounds except oxides
3. Lung Clearance Class Y - for $UO_2$, $U_3O_8$, and Pu oxides

The accident-specific information is

Effective Material-At-Risk, that is, the total Material-At-Risk times the damage ratio (DR). For cemented materials in a fire, the DR is the fraction of containers involved times the fraction of the cemented material spalled by the fire.
Ambient Leakpath Factor, that is, a leakpath factor other than HEPA filtration. This is used mainly for scenarios in which the ventilation is off and the material leaks out through corridors and doorways.
TNT Explosion Equivalent, grams of TNT. This is needed only for accident scenarios 3 and 4.
Plume Duration, in minutes

The template then finds (through table look-up) the corresponding

Airborne Release Fraction (ARF), which is based on DOE-HDBK-3010-94
Respirable Fraction (RF), also based on DOE-HDBK-3010-94
Dose Conversion Factor (DCF) for the isotopic mix chosen (see Type of Material, above)
Plume Dispersion Parameters ($\chi$/Q and plume expansion factor).

The analyst has the option of rejecting the "default" values of ARF, RF, DCF, and breathing rate and supplying alternative values, if more appropriate for the scenario being evaluated. The template then evaluates the radiological doses (CEDE) to the Collocated Worker (CW), taken to be 100 meter downwind for the Site, and the Maximum Offsite Individual (MOI), for which a generic distance of 1,900 meters is used.

For criticality accidents, the options are:

Material. There are two options:

1. Weapons Grade Plutonium
2. Enriched Uranium

Meteorology. The same two options as for non-criticality accidents
Breathing Rate. The same three options as for non-criticality accidents
Criticality Type. There are four options:

1. single-spike solution - enough solution lost after the first spike to quench criticality
2. multiple-spike solution - criticality continues for eight hours
3. bare metal - single spike from improper geometry
4. water-moderated metal, single spike - enough water lost after first spike to quench criticality

The accident-specific criticality information is

Material-At-Risk, that is, the amount of plutonium or uranium involved in the criticality, in grams
Number of Fissions, typically from $1\times10^{17}$ to $1\times10^{19}$ fissions.

The criticality fission products are from ORIGEN-2 runs. For both non-criticality and criticality accidents, results are given for the MOI and CW for filtration through zero to four stages of HEPA filters.

All user input, as well as the final results, are summarized onto a single page, for ease in archiving results. The template is password-protected, except for the areas of user input, so that the user cannot accidentally or intentionally modify it. Two examples of this single-page summary are shown on the following pages, one for a non-criticality accident and another for a criticality.

# BFO DOSE TEMPLATE

Instructions: Enter selections in the highlighted (yellow) areas, starting in cell C33. Some default parameters can be overridden, starting in cell G35. Only the highlighted areas can be changed, as the remainder of the spreadsheet is protected. For criticalities, enter selections in the highlighted areas starting in cell C45, then click on the "Do Crit" macro button in cell B52 or press CRTL-d to execute the macro. You must execute the macro after entering your criticality selections. Fill in cells I46 and I47 with a "Y" or "N". When finished with user input, click on printer icon to print this input/output page. Other pages are not printed.

| Scenario | For Non-Criticality Accidents |
|---|---|
| 1. Fire (lofted plume) | For unrestricted plume, as outdoors |
| 2. Fire (non-lofted) | For cooled plume, as through HEPAs |
| 3. External Explosion | For explosion adjacent to exposed material |
| 4. Internal Explosion | For explosion within material |
| 5. Overpressurization | Gas/vapor build-up breaches container |
| 6. Spill | For both earthquake and normal spills |
| 7. Loss of Power | Total power loss during release duration |

| Material | 1-6 for Non-Crit, 1 or 3 for Crit Accidents |
|---|---|
| 1. WG Pu | Isotopic mix from RFRAG |
| 2. aged WG Pu | Isotopic mix from RFP-4910 (Am ingrowth) |
| 3. enriched U (eU) | Isotopic mix from RFRAG |
| 4. 4.5% eU | Isotopic mix from assay for Bldg 886 |
| 5. depleted U | Isotopic mix from RFRAG |
| 6. high-Am residues | For IDCs 405-410 and 427 (residues) |

| Meteorology | For Either Accident Type |
|---|---|
| 1. Median | Approximated by Class D and 4.5 m/s |
| 2. 95th Percentile | Approximated by Class F and 2 m/s |

| Breathing Rate | For Either Accident Type |
|---|---|
| 1. Chronic | Corresponds to sedentary activities |
| 2. Light Activity | Corresponds to walking |
| 3. Heavy Activity | Corresponds to running |

| Form of Material | For Non-Criticality Accidents |
|---|---|
| 1. confined materials | Containerized wastes. For noncombustibles in fire, multiply results by fractional involvement. |
| 2. unconfined noncombustible material | Examples are contaminated walls, floors, and glovebox gloves. |
| 3. unconfined combustible wastes | Radiologically contaminated paper, plastics, etc. not in container. |
| 4. HEPA filters | HEPAs in plenums only, not in containers. |
| 5. radioactive metal | Bare metal pieces, such as ingots, castings, and briquettes. |
| 6. powder | Finely divided material, primarily oxides. |
| 7. chips | Chips, turnings, lab samples, coupons, sources. |
| 8. dry resin material | Contaminated resin beads (in ion column) that have dried. |
| 9. wet resin material | Contaminated resin beads (in ion column) that are still wet. |
| 10. volatile liquid | Radiologically contaminated organic liquids, for example. |
| 11. non-volatile liquid | Radiologically contaminated aqueous solutions, for example. |

| Solubility Class | For Non-Criticality Accidents |
|---|---|
| 1. D | For $UF_6$, $UO_2F_2$, and $UO_2(NO_3)_2$. |
| 2. W | For $UO_3$, $UF_4$, $UCl_4$, and all Pu compounds except oxides. |
| 3. Y | For Plutonium oxides, $UO_2$, and $U_3O_8$. |

| Criticality Scenario | These are valid only for WG Pu and eU. |
|---|---|
| 1. Solution, single spike | Enough solution is lost after initial spike to quench criticality, for example. |
| 2. Solution, multiple spikes | Criticality continues for eight hours. |
| 3. Bare Metal | Single spike from improper metal geometry. |
| 4. Water-moderated metal, single spike | Enough solution is lost after initial spike to quench criticality, for example. |

| Input Selections, Non-criticality | Option or Value | Default Calculation Parameters, Non-Criticality** | | | Change Options, Non-Criticality | | |
|---|---|---|---|---|---|---|---|
| | | | | | Accept Default? | New Value | Value Used |
| Scenario (1-7) = | 6 | | | | | | |
| Form of Material (1-11) = | 2 | Material-at-Risk (grams) = | 5,000 | - | NA | - | - |
| Material (1-6) = | 1 | *Airborne Release Fraction = | 1.0E-03 | - | Y | | 1.0E-03 |
| Solubility Class (1-3) = | 3 | Dose Conversion Factor (rem/g) = | 2.77E+07 | - | Y | | 2.77E+07 |
| Meteorology (1-2) = | 2 | Plume Expansion Factor = | 1.00 | - | NA | - | - |
| Breathing Rate (1-3) = | 3 | Collocated Worker X/Q (sec/$m^3$) = | 1.05E-02 | - | NA | - | - |
| MAR (grams) = | 5,000 | Public X/Q (sec/$m^3$) = | 1.08E-04 | - | NA | - | - |
| Ambient Leakpath Factor (not HEPA) = | 1.00 | Ambient Leakpath Factor (not HEPA) = | 1.00 | - | NA | - | - |
| TNT Explosion Equivalent (g) = | 0 | *Respirable Fraction = | 1.0E+00 | - | N | 6.0E-01 | 6.0E-01 |
| Plume/Release Duration, non-crit (min) = | 10 | Breathing Rate ($m^3$/sec) = | 3.6E-04 | - | Y | | 3.6E-04 |

NA above means the parameter is not available for change

| Input Selections, Criticality | Option | Input Selections, Criticality | Option or Value |
|---|---|---|---|
| Material (1 or 3 only) = | 1 | Criticality Scenario (1-4) = | 3 |
| Meteorology (1-2) = | 2 | MAR (grams) = | 50,000 |
| Breathing Rate (1-3) = | 3 | # Fissions = | 1.00E+18 |

| Which Accident Type? | Y/N |
|---|---|
| Evaluate Non-Criticality Accident? | Y |
| Evaluate Criticality Accident? | N |

***RESULTS:

| Number of HEPA Stages | Non-Criticality Building Source Term (grams) | Non-Criticality Accident** | | Criticality Accident** | |
|---|---|---|---|---|---|
| | | CW Dose (rem) | MOI Dose (rem) | CW Dose (rem) | MOI Dose (rem) |
| Zero | 5.0E+00 | 3.1E+02 | 3.2E+00 | - | - |
| One | 5.0E-03 | 3.1E-01 | 3.2E-03 | - | - |
| Two | 1.0E-05 | 6.3E-04 | 6.5E-06 | - | - |
| Three | 2.0E-08 | 1.3E-06 | 1.3E-08 | - | - |
| Four | 4.0E-11 | 2.5E-09 | 2.6E-11 | - | - |

Footnotes:
* "N/A" for Airborne Release Fraction or Respirable Fraction means that the selected "Form of Material" is not applicable for the selected "Scenario".
** "#REF!", "#VALUE!", and "Error" refer to the selection of an invalid input option or value.
*** Collocated Worker (CW) is at 100 meters and Maximum Offsite Individual (MOI) is at 1,900 meters.

Original BIODOSE template prepared by Edwin Stahlnecker. Revision by Vern Peterson, Safety Analysis/Nuclear Safety. December 1995 and February 1996 and renamed to BFODOSE.

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| 3. Y | For Plutonium oxides, $UO_2$, and $U_3O_8$. |

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| 3. Bare Metal | Single spike from improper metal geometry. |
| 4. Water-moderated metal, single spike | Enough solution is lost after initial spike to quench criticality, for example. |

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|---|---|---|---|---|---|---|---|
| | | | | | Accept Default? | New Value | Value Used |
| Scenario (1-7) = | 6 | | | | | | |
| Form of Material (1-11) = | 2 | Material-at-Risk (grams) = | 5,000 | - | NA | - | - |
| Material (1-6) = | 1 | *Airborne Release Fraction = | 1.0E-03 | - | Y | | 1.0E-03 |
| Solubility Class (1-3) = | 3 | Dose Conversion Factor (rem/g) = | 2.77E+07 | - | Y | | 2.77E+07 |
| Meteorology (1-2) = | 2 | Plume Expansion Factor = | 1.00 | - | NA | - | - |
| Breathing Rate (1-3) = | 3 | Collocated Worker X/Q (sec/$m^3$) = | 1.05E-02 | - | NA | - | - |
| MAR (grams) = | 5,000 | Public X/Q (sec/$m^3$) = | 1.08E-04 | - | NA | - | - |
| Ambient Leakpath Factor (not HEPA) = | 1.00 | Ambient Leakpath Factor (not HEPA) = | 1.00 | - | NA | - | - |
| TNT Explosion Equivalent (g) = | 0 | *Respirable Fraction = | 1.0E+00 | - | Y | | 1.0E+00 |
| Plume/Release Duration, non-crit (min) = | 10 | Breathing Rate ($m^3$/sec) = | 3.6E-04 | - | Y | | 3.6E-04 |

NA above means the parameter is not available for change

| Input Selections, Criticality | Option | Input Selections, Criticality | Option or Value |
|---|---|---|---|
| Material (1 or 3 only) = | 1 | Criticality Scenario (1-4) = | 3 |
| Meteorology (1-2) = | 2 | MAR (grams) = | 50,000 |
| Breathing Rate (1-3) = | 3 | # Fissions = | 1.00E+18 |

| Which Accident Type? | Y/N |
|---|---|
| Evaluate Non-Criticality Accident? | N |
| Evaluate Criticality Accident? | Y |

***RESULTS:

| Number of HEPA Stages | Non-Criticality Building Source Term (grams) | Non-Criticality Accident*** | | Criticality Accident*** | |
|---|---|---|---|---|---|
| | | CW Dose (rem) | MOI Dose (rem) | CW Dose (rem) | MOI Dose (rem) |
| Zero | - | - | - | 1.9E+02 | 2.0E+00 |
| One | - | - | - | 3.1E-01 | 2.8E-03 |
| Two | - | - | - | 1.1E-01 | 8.2E-04 |
| Three | - | - | - | 1.1E-01 | 8.2E-04 |
| Four | - | - | - | 1.1E-01 | 8.2E-04 |

Footnotes:
* "N/A" for Airborne Release Fraction or Respirable Fraction means that the selected "Form of Material" is not applicable for the selected "Scenario".
** "#REF!", "#VALUE!", and "Error" refer to the selection of an invalid input option or value.
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