APPENDIX V - Sensitive Parameters Used to Assess DU Exposure for the OSAGWI Level II and Level III Scenarios

V.1 Introduction

The sensitive parameters used in the exposure assessment to estimate exposure, intake, and characterize risk from possible DU exposures in the Gulf have been categorized into three primary groups (1) Source Term Parameters, (2) Physiological Parameters, and (3) General Parameters.

V.1.1 Source Term Parameters

Source term parameters are those that pertain to the initial quantity of DU available for an exposure and the physical and chemical processes involved in DU residues being produced as a result of a fratricide incident. Seven sensitive source term parameters have been identified:

- Type of DU munition (mass)
- Isotopic and elemental composition of DU
- DU armor
- Airborne Release Fraction
- Respirable Fraction

- Chemical form
- Particle size distribution

V.1.2 Physiological Parameters

Physiological parameters are those that pertain to biological factors associated with internalizing DU in an individual. Eleven sensitive parameters have been identified:

- Reference Man
- Breathing rate or ventilation rate (type of exercise or exertion)
- Type (or Route) of breathing (nose or mouth)
- Exposure duration
- Particle size distribution
- Solubility of DU in lung fluid (chemical form)
- ICRP lung model(s)
- ICRP biokinetic model(s)
- Intake
- Weighting Factors (organ and radiation)
- Radiation internal dose (first-year and fifty-year)

V.1.3 General Parameters

- Oily surfaces
- PPE
- Fires to vehicles
- Fire suppression system
- Vehicle integrity

V.2 ASSESSMENT OF PARAMETERS

V.2.1 Source Term Parameters

- **Type of DU Munition**

  - Several DU munitions were fielded at the time of the Gulf War. The DU munitions used in the exposure assessment are 120mm DU penetrators fired from the Abrams Heavy armored-tank platform.
  - The 120mm DU penetrator had a mass of 4.7 kg of DU as compared with the other DU munitions expended in Southwest Asia. In addition, all of the fratricide incidents during the Gulf War involved 120mm DU munitions, OSAGWI, (1998).

- Developer test data from 120mm DU munitions were used in the exposure assessment report. Therefore, it is more accurate to use the 120mm DU munitions to assess exposure and characterize risk to individuals involved in fratricide incidents.

- **<u>Isotopic and Elemental Composition of Uranium and Other Isotopes in DU</u>**

- DU is a by-product of the uranium enrichment process. During the enrichment process, the uranium isotopes in natural uranium, that are useful for energy and fissionable applications, are removed. The result is a by-product referred to as DU.
- The isotopic composition of DOD DU munitions is based on an analysis performed on a DU penetrator by ORNL (99.8 percent U-238, 0.2 percent U-235, 0.0006 percent U-234 and 0.0003 percent U-236).
- There may be other contaminants in DU that are the result of reprocessing nuclear fuel. These contaminants (Pu-238, Pu-239, Am-241, Np-237, and Tc-99) are present in trace quantities based on current data. These contaminants add less than 1 percent to the dose and are inconsequential from a chemical toxicity standpoint. (See Memorandum For Record, 7 August 2000.)
- The elemental composition of aerosols from hard-target DU perforations frequently contained iron, aluminum, silicon, Ca, magnesium, potassium, titanium and tungsten. The contaminants are inconsequential from a dose or chemical toxicity standpoint, but they may influence the solubility of the DU compounds.

- **Armor Package**

  - Fratricide incidents during the Gulf War involved the Abrams tank and the BFV.
  - The BFV is less armored than the Abrams. Interviews of individuals and battle damage assessments regarding fratricide incidents with these armored vehicles vary in their accounts.
  - The Abrams tank offers more resistance to anti-tank munitions than the BFV. This aspect leads researchers to believe that a greater amount of aerosolized DU particles are generated when 120mm DU munitions penetrate Abrams tanks. As a result, removable DU contamination available for resuspension upon entry into damaged vehicles would be expected to be greater in an Abrams tank than in a BFV. There have been no hard-perforation tests involving the BFV and DU munitions. There has been one hard-perforation test involving DU munitions against an M1A1 Abrams Heavy (with DU armor) tank.
  - The exposure assessment utilizes data from a test involving a DU munition, which penetrated the DU armor of an Abrams Heavy M1A1 tank. This represents the most appropriate set of data to model a fratricide incident involving DU munitions.
  - The exposure assessment also utilizes data from a fire in a DU munitions-uploaded Abrams Heavy tank.

- **Airborne Release Fraction**

- The ARF refers to the portion of the DU penetrator that becomes aerosolized.
- Researchers have also determined that fires involving uploaded DU munitions produce a different ARF than hard target perforations involving DU munitions.
- Although ARF is a key parameter in determining the intake of aerosolized DU, its reported range of values leads to a tremendous amount of uncertainty. However, if airborne concentrations of DU are measured and if estimated intake values are based on air sampling, then the dose modeling should focus on using the airborne concentration and exposure duration.
- The exposure assessment considered the ARF but utilized airborne concentrations measured by breathing zone samplers that were worn by individuals as they climbed on, in and out of vehicles potentially contaminated by DU munitions and fires. Inhalation intake data were generated by hard-target testing with DU munitions. The data from the Jette et al., (1990) test involving DU munitions and a hard target (rolled homogeneous armor) estimated that approximately 18 percent of the penetrator aerosolized.
- The exposure assessment considered the ARF but utilized airborne DU concentrations measured downwind with air samplers. These measurements were made at the time of a hard-target perforation and during a fire involving uploaded DU munitions.

- **Respirable Fraction**

  - The RF is used in estimating an inhalation intake. For conservatism, the USACHPPM assessment considers an RF of 96 percent for hard-target perforations.
  - Researchers have also determined that fires involving uploaded DU munitions produce different RFs than hard-target perforations involving DU munitions. In pallet fires involving DU munitions, the RF of the aerosolized DU is less than 1 percent.

- **Particle Size Distribution**

  - The aerosolized fraction that is produced when a DU penetrator perforates a hard target or when DU munitions are on fire will produce particles of various sizes. Generally, particles less than 100 μm AED can be inhaled. Respirable particles are those that are less than 10 μm AED.
  - Particle size will affect the initial suspendability of the oxidized material, aerosol deposition, and the fraction deposited in the different regions of the respiratory tract.
  - Immediately following a perforation, the DU aerosol puff will be a mixture of dusts and vapors. As the puff cools, the DU will agglomerate into particles with varying sizes. Because of this evolution, particle sizes are difficult to predict. However, most of the data accumulated in field tests show that a portion of the oxide produced falls within the respirable size range.

- Immediately following a fire that involved DU munitions, the DU aerosol plume will be a mixture of dusts and vapors. As the plume cools and migrates, the DU will agglomerate into particles with sizes ranging from very small to very large. Because of this action, particle sizes are difficult to predict. However, most of the data accumulated in field tests show that a portion of the oxide produced falls outside the respirable size range.
- The exposure assessment utilizes 1 μm AMAD and 5 μm AMAD aerosols, standard choices in HRA methodology. A more thorough explanation will be provided in the physiological parameters section of this summary.

- **Chemical Form**

- Research from the testing and evaluation of DU munitions indicate that hard-target perforations and fires and explosions involving DU munitions produce DUO_2 and DU_3O_8. As DU oxides weather in the environment, DUO_3 may be formed. Therefore, the chemical forms most likely to be encountered in battlefield situations are DU_3O_8, DUO_2 and DUO_3.
- Based on the various and different fratricide incidents and the complexity of uranium chemistry, the exact composition of the oxide may be uncertain. Oxides of DU will change their chemical form over time as weathering takes place.
- Finely divided uranium metal is reactive (sometimes called pyrophoric) and oxidizes to DU_3O_8 in air. The chemical form of the pure uranium oxide is DUO_3

when formed at 1 atmosphere O_2 pressure and below 500°C; DU_3O_8 is the stable phase when formed above 500°C. In limited oxygen environments or as an intermediate form, DUO_2 is formed.

- Fires involving DU munitions tend primarily to produce DU_3O_8 and a trace of DUO_2. Hard-target perforations involving DU munitions tend to produce two uranium compounds: DUO_2 and DU_3O_8.

- Data that have been reviewed indicate that uranium oxides produced as a result of testing, as part of the life cycle of DU munitions and of hard-target perforations span a considerable range. Because the test data indicate that a range of DU oxides are produced in hard-target perforations, this assessment utilized the most conservative chemical forms in addressing chemical and radiological toxicity.

V.2.2 Physiological Parameters

- **Reference Man**

  - Reference Man is a shortened term for "Reference Man for Purposes of Radiation Protection". The current version is a classic 1975 publication, published in ICRP-23. This publication addresses human characteristics that relate directly or indirectly to the intake, metabolism, distribution, and retention of selected radionuclides in the human body.

- ICRP-23 contains a wealth of information useful for radiation dosimetry, including anatomical and physiological data and the gross and elemental composition of the human body, its organs and its tissues. The anatomical data provide specific reference values for an adult male and an adult female. Other reference values primarily pertain to the adult male. ICRP-23 has been updated in ICRP-66 and ICRP-70. Currently, there is an ICRP task group working on revising selected parts of the Reference Man publication.
- The models used to assess exposure and characterize risk from potential DU exposures in the Gulf War incorporate Reference Man values. Also, standard parameters outlined in the Reference Man document are consistent with values utilized in risk assessments.

- **<u>Breathing Rate (or Ventilation Rate) and Type of Exercise or Exertion</u>**

  - Breathing rate (or ventilation rate) pertains to the amount of air breathed in by an individual per unit time. The type of exercise an individual exerts dictates the BR (or ventilation rate). The types of exercise are sleeping, sitting, light work and heavy work.
  - The models that were used have default BRs or ventilation rates based on the type of activity (or exercise) an individual is performing.
  - The BR (or ventilation rate) of both Level II and Level III individuals was assumed to be conservative as a result of the type of work they may have been tasked

to do. The BR (or ventilation rate) is factored into the lung model used in this exposure assessment.

- Breathing rate (or ventilation rate) also dictates deposition in the respiratory tract (that is, the greater the BR, the greater the deposition). This exposure assessment assumes a BR of 3 m^3/hr, while performing heavy exercise, for the OSAGWI Level II and Level III scenarios.

- **<u>Type (or Route) of Breathing</u>**

- The type (or route) of breathing is another parameter that also affects deposition of respirable particles in the respiratory tract. There are two basic types of breathing, nose and mouth. Breathing through the mouth results in a different deposition profile in the respiratory tract when compared to that of nose breathing.

- This exposure assessment utilizes a nose breather and a BR (or ventilation rate) of 3 m^3/hr for OSAGWI Level II and Level III Exposure scenarios, a conservative parameter. One exception to this scenario involves individuals that may or may not have patch-welded armor plate. This scenario utilized a mouth breather, with a BR or ventilation rate of 3 m^3/hr.

- **Exposure Duration**

  - The exposure duration pertains to the time in which an individual is exposed to DU. It is assumed the primary routes of exposure, excluding embedded fragment casualties, is via inhalation and ingestion.
  - Exposure duration is also linked to the airborne concentration and particle size. This is because after penetration of a DU munition occurs, the airborne concentration is diminished due to gravitational settling over time. At later times, individuals entering a DU-contaminated area may resuspend some of the settled DU particles and increase the DU airborne concentration once again. However, physicists believe that some of the aerosolized particles of DU agglomerate to form larger particles that become unavailable for exposed individuals to breath into their respiratory tract. The exposure duration is a key parameter, which requires assessment in conjunction with the DU-airborne concentration, particle size, resuspension of DU particles, and how these parameters change over an integrated time period.

- **Particle Size Distribution**

  - Particle size distribution refers to the size of an aerosolized particle, in this case DU, which is available for intake into the human body via inhalation or ingestion. (See Appendix D.)

- Particles that are less than 100 µm AED are considered available for inhalation. In dealing with oxides of DU, the particle size ranges that are of most concern are those less than 10 µm AED. Such particles are considered respirable, (that is, they are retained in the lower regions of the respiratory tract and are not cleared by physical processes).
- Particles that range from 10 to 100 µm AED in size enter the upper regions of the respiratory tract but are cleared via the mucocilliary escalator (mucus and cilia) and are either coughed out and/or consequently swallowed.
- Particles of DU oxide(s) swallowed and ingested enter the GI tract. The fraction of ingested DU, in the form of the identified oxides that is absorbed into the bloodstream is minimal. The ingestion (direct and secondary) pathway contributes very little from either a chemical toxicity or an internal radiation dose standpoint.
- Specifically, this exposure assessment characterized exposure using 1 µm AMAD and 5 µm AMAD aerosols. The ICRP recommends that 1 µm AMAD particles be used for environmental (public) exposures and that 5 µm AMAD particles be utilized for occupational exposures. Because of different DU exposure scenarios a 5 µm AMAD aerosol was used in these exposure assessments. Some DU munitions test reports include a range of respirable particle sizes.

- **<u>Solubility of DU in Simulated Lung Fluid (Chemical Form)</u>**

  - Solubility pertains to the chemical reactivity and absorption rate of particles that are internalized into the human body.
  - The chemical form of the DU particles internalized dictate the reactivity and absorption rate from the lung into the bloodstream. The three DU oxides that have been identified in the exposure assessment report exhibit different rates of absorption into the bloodstream as indicated by the ICRP. The manner in which DU oxides are formed may influence solubility.
  - The absorption process involves particles that are dissociated into material that can be absorbed into the body fluids. However, absorption into the bloodstream is time dependent, and the ICRP has identified three different absorption rates that can be applied to the DU oxides. See Appendix J for a discussion of the respiratory tract and transport of DU through the kidney. The rate at which a compound is absorbed into the bloodstream determines the region in the body most likely to be affected by the transfer.
  - The ICRP has recently published a new lung model somewhat different to the previous lung model, but the absorption rates are essentially the same. (See Appendix J.)
  - ICRP has identified DUO_2 as being Class Y (exhibiting slow absorption into the bloodstream), DU_3O_8 as Class Y (exhibiting slow absorption into the bloodstream), and DUO_3 as Class W (exhibiting moderate absorption into the bloodstream).

Various lung solubility studies conducted as a result of Army tests indicate that a range of DU solubility exists. Because only DUO_2 and DU_3O_8 have only been observed from either hard-target tests or fires, the Class D compound chosen to model the soluble fraction in DU oxides is DUO_3.

- DU oxides that exhibit fast or Class D characteristics tend to concentrate in the kidney at a much faster rate than DU oxides exhibiting Class Y or slow absorption characteristics.

- DU oxides exhibiting fast absorption rates would pose more of a chemical toxicity concern, and DU oxides exhibiting slow absorption rates would pose more of an internal radiation dose concern.

- In reviewing the DU test reports, a wide range of absorption characteristics were identified for hard-target perforations. This exposure assessment focuses on bounding this parameter from a standpoint of both chemical toxicity and internal radiation dose. For OSAGWI Level II and Level III scenarios, the upper-bound value for considering chemical toxicity assumed 17 percent of the aerosolized fraction that is internalized as being Class D material (exhibiting fast absorption). In addition, the upper-bound value for considering internal radiation dose assumed 83 percent of the aerosolized fraction that is internalized as Class Y material (exhibiting slow absorption).

- For fires involving uploaded DU munitions, the upper-bound value for consideration of chemical toxicity assumed 7 percent of the aerosolized fraction that is internalized as being Class D material (exhibiting fast absorption). The upper-bound value for considering internal radiation dose assumed 93 percent of the aerosolized fraction that is internalized as Class Y (exhibiting slow absorption).

- **The ICRP Respiratory Tract Model(s)**

  - The ICRP recently adopted a new lung-dosimetry model of the human respiratory tract. This model is discussed in ICRP-66 and ICRP-71. The ICRP-66 updates the previous lung model described in ICRP-30.
  - The new lung model is broader in scope. It has been designed not only to evaluate secondary limits on intake of radionuclides by inhalation for Reference Man but also to provide a more realistic framework for modeling lung retention and excretion characteristics in individual cases.
  - The new lung model also calculates biologically meaningful doses in a manner that is consistent with the morphological, physiological, and radiobiological characteristics of the various tissues of the respiratory tract.
  - This dose assessment and exposure used the computer software LUDEP, which incorporates the newer ICRP lung model.

- **<u>ICRP Biokinetic Model(s)</u>**

  - The ICRP has also recently revised the biokinetic model described in ICRP-30. The new biokinetic model (ICRP-69, ICRP-71 and ICRP-78) considers additional and modified transport mechanisms of radioactive material in the human body.
  - The version of the LUDEP software used in these calculations incorporates the ICRP-30 biokinetic model with the ICRP-66 new lung model.
  - There is a version of LUDEP, not yet available for distribution at this time that incorporates the new DU biokinetic model in ICRP-69 and ICRP-78. One of the authors of the LUDEP software has calculated internal radiation doses using USACHPPM data. the unreleased, newer version of the LUDEP software that incorporates ICRP-66, ICRP-69, ICRP-78, and biokinetic model transfer rates. Results of that exercise indicated close agreement (increase of 1 percent) in using either the ICRP-30 or the ICRP-69 and ICRP-78 biokinetic models with the ICRP-66 lung model and the ICRP-26 or ICRP-60 weighting factors.
  - For DU oxides that enter the GI tract, the fraction that goes to blood is termed the GI transfer coefficient. This depends on the solubility of the oxide. For Class D and W uranium compounds, the value is 0.02. For Class Y uranium compounds, the value is 0.002. For example, for an intake of 10 mg of a Class Y oxide, the transfer from the GI tract to blood would be 0.02 mg. Therefore, only 0.02 mg would enter

the bloodstream and pass through the kidney. The remainder, 9.98 mg would then be excreted in the feces.

- **Intake**

  - Intake is defined as the amount of material that is internalized into the human body.
  - The amount of material that is absorbed into the bloodstream is referred to as an uptake. The ICRP models utilized the exposure assessment into consideration the uptake of the material internalized or the intake into the body:

    - Intake is a function of the BR (or ventilation rate), airborne concentration, particle size, exposure duration, and exposure frequency.
    - The uptake of material is a function of the chemical form and the solubility (either in the GI or respiratory tract).
    - Intake values used were calculated from DU test reports involving hard-target perforations of DU munitions or from fires involving uploaded DU munitions, Fliszar et al., (1989).

  - Measured airborne concentrations of DU from fires involving uploaded DU munitions and from resuspension due to reentry were entered into the LUDEP software, along with parameter values for BR, particle size, and density of the DU oxide, to calculate an internal dose. In addition, USACHPPM calculated doses for all of the uranium isotopes that comprise DU (using the weight percentage of the uranium isotopes in DU). The appropriate progeny in equilibrium with parent uranium isotopes were also included in the dose calculations.

- Airborne concentrations and hand contamination were used to determine intake values used by USACHPPM, which include upper-bound values of intakes reported in the DU test reports reviewed.

- Removable DU-surface contamination available for exposure by secondary ingestion (hand-to-mouth) depends on the following. (See Appendix F.) DU intakes and internal dose rate estimates are calculated in Section 5.2:

  - Removable DU contamination may possibly be found on all interior and exterior surfaces of vehicles and equipment damaged by DU perforation or from DU smoke.

  - The limited space within an armored vehicle when occupied by individuals can result in body contact with the interior surfaces of the vehicles. Entry into and access to areas inside the armored vehicles can also result in body contact with exterior surface as well.

  - This body contact with interior and exterior surfaces can increase the possibility of ingestion of DU particles by way of hand-to-mouth transfer.

- Any activity causing movement within the armored vehicle by re-entry increases the airborne concentration of DU by resuspension, therefore, increasing possible DU intake by inhalation.

The following assumptions have been made to estimate the dose from hand-to-mouth transfer of DU contamination:

- A secondary ingestion effective transfer rate of $1 \times 10^{-4}\ m^2/hr$ for loose/transferable surface contamination associated with a contaminating event (transfer from contaminated surface to palm of hand 100 percent).
- The hands were uniformly contaminated.
- The effect of personal hygiene (washing hands and face) was not factored into the secondary ingestion equation.
- All the contaminant on the surface was transferred to the palm of the hand(s) (100 percent transfer).
- Only the contamination on the palm(s) of the hand(s) was transferred from hand-to-mouth.
- To estimate the lower-bound secondary ingestion intake, approximately 50 percent of the contamination on the surface was transferred to the hand.
- See Appendix F for calculation of intake via secondary ingestion.

- **<u>Weighting Factors (Organ and Radiation)</u>**

  - The organ or tissue weighting factor is the proportion of the risk of stochastic effects resulting from irradiation of that organ or tissue to the total risk of stochastic effects when the whole body is uniformly irradiated:

    - A stochastic effect is a health effect that occurs randomly and for which the probability of the effect occurring, rather than its severity, is assumed to be a linear function of dose without threshold. Hereditary effects and cancer incidence are examples of stochastic effects.
    - Organ and tissue weighting factors are applied, because the radiation-absorbed dose is insufficient by itself to predict either the severity or the probability of the deleterious effects on health resulting from irradiation under unspecified conditions.
    - The radiation Q or W_R allows for radiation effects upon the detriment of the microscopic distribution of the absorbed energy:

      - When the distribution of radiation is not known at all points in the volume of interest, the ICRP recommends that the same values of Q or W_R be used for both external and internal radiation.
      - The ICRP has established the radiation Q in ICRP-26 and the W_R in ICRP-60.

- The exposure assessment utilized the organ or tissue weighting factors and the radiation Q described in ICRP-26.

- **Radiation Internal Dose**

The 50-year dose (CEDE) was calculated for the OSAGWI Level II and Level III exposure groups.

Q.2.3 General Parameters

- **Oily Surfaces**

  - The surfaces of damaged vehicles may have been coated with oily residue from engine oil or hydraulic fluid.
  - Oily surfaces would tend to trap DU particles that would otherwise be available for resuspension; therefore, there would be less material resuspended.
  - Oily surfaces on damaged U.S. and Iraqi vehicles were considered, but due to the variability in the condition of these surfaces, were not factored into the exposure assessment report. Instead, the exposure assessment report utilized data from breathing zone air samplers, which inherently considered resuspension of the DU particles and the condition of the surface.

- **<u>Personal Protective Equipment</u>**

  - The use of respiratory protection and gloves by the OSAGWI Level II and III exposure group could have significantly reduced the mechanism by which DU particles were available for intake.
  - This would especially apply to individuals that make up the OSAGWI Level II exposure groups.
  - It has been reported that some of the individuals in the OSAGWI Level II exposure group wore respiratory protection, OSAGWI, (1998).
  - The PPE was considered but following a conservative approach, protection factors associated with properly fitted respirators were not applied.

- **<u>Fires to Vehicles Containing DU</u>**

Fires may add to oxide generation; however, other fire-ash combustion products may reduce DU-resuspension ability (coagulation, agglomeration, and trapping of DU oxides under the fire ash).

- **<u>Fire Suppression System</u>**

  - It is unknown whether or not the fire suppression system on board an Abrams Tank activated after a “friendly fire” incident.

- Without adequate test data, it is not possible to properly evaluate impact of the fire suppression system on DU particle concentration and characteristics within the DU-perforated vehicles.

- **Vehicle Integrity**

The integrity of the vehicle may have been compromised through open hatches, leaking seals, blown turrets, and/or operation of the NBC System. Any or all of these could affect the levels of DU oxides available for resuspension. The effects of vehicle integrity were considered in the exposure assessment, but no data were available.

V.3 Summary Of Sensitive Parameters

A listing of the sensitive parameters used in the this exposure and dose assessment report for the OSAGWI Levels II and III exposure group is provided in Table V-1.

Table V-1. Sensitive Parameters used in the OSAGWI Level II and Level III DU Assessment

PARAMETER	RANGE	SELECTED VALUE	COMMENT
Source Term			
Type of DU Munition	200 grams – 4.7 kg	4.7 kg	All fratricide incidents involved 120mm DU penetrators
Isotopic Composition of DU	99.8% U-238 0.2% U-235 0.0006% U-234 0.0003% U-236	99.8% U-238 0.2% U-235 0.0006% U-234 0.0003% U-236	Based on analysis by ORNL
DU Armor	BFV & Abrams Tank	Heavy Abrams Tank	No available test data for BFV
Airborne Release Fraction	10%–35%	18%	Jette et al., 1990 and Parkhurst et al., 1995b
Respirable Fraction	60%-96%	96%	Conservative parameter for hard-target perforation
Chemical Form	DUO_2, DU_3O_8, DUO_3	DUO_2, DU_3O_8, DUO_3	DUO_2 and DU_3O_8 considered for fires and hard-target perforation; DUO_3 considered for environmental evaluation
Physiological			
Reference Man	70 kg man	70 kg man	Standard weight used in HRAs
Breathing Rate or Ventilation Rate	1.2 m^3/hr – 3.0 m^3/hr	3.0 m^3/hr	Conservative
Type of Breathing	Nose or Mouth	Mouth Nose	Welders and armor removers (mouth) All other individuals (nose)
Type of Exercise	Sleep, sitting, light, heavy	100% heavy exercise	Conservative
Exposure Duration	1 min–1 hr	1 hr	Most practical
Particle Size	1 µm–10 µm	1 µm & 5 µm	1 µm used for public 5 µm used for soldiers
Solubility in Lung Fluid	1%–93% Class Y 1%-7% Class D	93% Class Y 7% Class D	Fires
Solubility in Lung Fluid	1%–83% Class Y 1%-17% Class D	83% Class Y 17% Class D	Hard-target perforation
ICRP Respiratory Tract Model	ICRP-30 ICRP-66	ICRP-66	Better flexibility and used in LUDEP
ICRP Biokinetic Model	ICRP-30 ICRP-78	ICRP-30	ICRP-78 not incorporated into LUDEP as of yet
Inhalation Intake	0.0000039 mg .025 mg	0.0000039 mg 0.025 mg	Lower-bound value Upper-bound value
Secondary Ingestion Intake	0.057 mg	0.047 mg 0.01 mg	Insoluble Soluble
Weighting Factors	ICRP-26 ICRP-60	ICRP-26	Consistent with NRC
Dose (CEDE)	50 yr	50 yr	Consistent with ICRP & NRC