APPENDIX S - Intake and Internal Radiation Dose Estimates Representative Examples of OSAGWI Level II Exposure Scenarios from the Gulf War

S.1 Introduction

The examples in this Appendix describe a method on how to use the information presented in Tables 47 and 48 and Part V of this report. Adjustments to these examples can be made by altering the exposure duration or number of vehicles or entries made. These examples only use the upper-bound values reported in Tables 47 and 48. The following examples include all of the vehicles that were involved in the "friendly fire" incidents as well as those that were involved in the Doha fire (the three Abrams tanks uploaded with DU munitions that partially burned during the Doha fire). These examples assume that all 31 vehicles were involved and that the DU surface contamination was the same for both Abrams and BFVs. Although considered, personal hygiene (for example, washing hands at the end of a work shift or prior to eating) was not factored for conservative purposes. See Appendix J for the DCFs for inhalation and ingestion and the method used for calculating kidney burdens.

S.2 Explosive Ordnance Disposal Team Member

As an example for discussion, the OSAGWI scenario of the EOD and other unit personnel who downloaded equipment and munitions from DU-contaminated vehicles/systems, a maximum estimation of DU intake and internal dose can be estimated. These examples present a method on how to use the information in Table 47. Adjustments to these examples can be made by altering the exposure duration or number of vehicles or entries made.

- If an EOD individual entered 31 DU-damaged armored vehicles and spent 1 hour in each, a maximum estimation of his total soluble DU intake via inhalation and indirect ingestion would be 0.062 mg. The maximum total insoluble DU intake via inhalation and indirect ingestion would be 0.713 mg. His internal radiation dose (CEDE) would be 0.016 rem.

  - From Table 47, take the maximum estimate for soluble DU that an EOD individual could have received (0.002 mg/hr in a vehicle) and multiply by the duration of exposure and number of vehicles entered.

$$\text{soluble:} \quad \frac{0.002\,\text{mg}}{\text{hr}} * (1\,\text{hr}) * (31\,\text{vehicles}) = 0.062\,\text{mg}$$

  - From Table 47, take the maximum estimate for insoluble DU that an EOD individual could have received (0.023 mg/hr in a vehicle) and multiply by the duration of exposure and number of vehicles entered.

$$\text{insoluble:} \quad \frac{0.023\,\text{mg}}{\text{hr}} * (\text{hr}) * (31\,\text{vehicles}) = 0.713\,\text{mg}$$

- The total amount of DU (soluble and insoluble) that reaches the kidney from an intake of 0.775 mg (0.062 mg soluble and 0.713 mg insoluble) is 0.006 mg. Using the fraction of 5 μm AMAD DU particles that are transferred from the respiratory tract to blood, the calculation to determine the total amount of DU that passes through the kidney is as follows. (See Appendix J for a more detailed discussion of DU biokinetics.)

$$(0.062\,\text{mg})*(0.0642)+(0.713\,\text{mg})*(0.0034)=0.006\,\text{mg}$$

- To determine the concentration of DU in the kidney, this value is multiplied by 1000 then divided by the default kidney weight of 310 grams:

μg DU/g of kidney	=	(0.006 mg) * (1000 μg/mg)/310 grams
	=	0.02 μg DU/g of kidney

- From Table 47, take the CEDE radiation dose for a 1-hour exposure duration (0.0004 rem) and multiply by 31 vehicles.

$$\text{internal radiation (CEDE) dose: } (0.0005\,\text{rem})*(31\,\text{vehicles})=0.016\,\text{rem}$$

- If the individual was not wearing gloves (PPE), he may have had hand-to-mouth transfer (secondary ingestion) of DU surface contamination. His maximum total soluble DU intake (after entering 31 vehicles) by secondary ingestion per event would be 0.31 mg. The maximum total insoluble DU intake by secondary ingestion per event would be 1.46 mg. His internal radiation dose from this secondary ingestion (CEDE) would be 0.00006 rem per contaminating event.

- From Section 5.3, take the upper-bound estimate of soluble DU intake for secondary ingestion (0.01 mg) and multiply by exposure duration and number of vehicles entered.

$$\text{soluble intake: } \frac{0.01\text{mg}}{\text{hr}} * (1\text{hr}) * (31\text{vehicles}) = 0.31\text{mg}$$

- Mass of soluble DU that enters the bloodstream and passes through the kidney (multiply the total soluble DU intake by GI absorption coefficient for soluble DU):

$$(0.31\text{mg}) * (0.02) = 0.006\text{ mg}$$

$$\mu\text{g DU/g of kidney} = (0.006\text{ mg}) * (1000\ \mu\text{g/mg})/310\text{ grams}$$

$$= 0.019\ \mu\text{g DU/g of kidney}$$

- The remaining mass of soluble DU (0.304 mg) is excreted via the GI tract.

- From Section 5.3 take the upper-bound estimate of insoluble DU intake for secondary ingestion (0.047 mg) and multiply by the exposure duration and number of vehicles entered.

$$\text{insoluble intake:} \quad \frac{0.047\,\text{mg}}{\text{hr}} * (1\,\text{hr}) * (31\,\text{vehicles}) = 1.46\,\text{mg}$$

- Mass of insoluble DU that enters the bloodstream and passes through the kidney (multiply the total soluble DU intake by GI absorption coefficient for insoluble DU):

$$(1.46\text{mg}) * (0.002) \quad 0.003\,\text{mg}$$

μg DU/g of kidney = (0.003 mg)*(1000 μg/mg)/310 grams

= 0.01 μg DU/g of kidney

- The remaining mass of insoluble DU (1.457 mg) is excreted via the GI tract. The total amount of DU (soluble and insoluble) from secondary ingestion that passes through the kidney is 0.009 mg. This is equal to a kidney concentration of 0.03 μg DU/g of kidney.

- From Section 5.3, take the CEDE radiation dose for a 1-hour exposure duration (0.000002 rem) and multiply by 31 vehicles.

internal radiation (CEDE) dose:

$$(0.057\,\text{mg}) * (1\,\text{hr}) * \frac{0.000002\,\text{rem}}{0.057\,\text{mg in } 1\,\text{hr}} * (31\,\text{vehicles}) = 0.00006\text{rem}$$

- If he used his bare hands to handle an intact penetrator, his hands may have been exposed externally to beta radiation when downloading the DU munition. The contact dose rate from an intact DU penetrator is about 0.2 rad/hr.

S.3 Radiation Control Team Member

As an OSAGWI discussion example, for RADCON Team members who entered DU-perforated vehicles, a maximum estimation of DU intake and internal dose can be suggested.

- If a RADCON team member entered 31 DU-damaged armored vehicles and spent 1.5 hours in each one, a maximum estimation of his total soluble DU intake via inhalation and indirect ingestion would be 0.093 mg. The maximum total insoluble DU intake via inhalation and indirect ingestion would be 1.07 mg. His internal radiation dose (CEDE) would be 0.023 rem.

    - From Table 47, take the maximum estimate for soluble DU that a RADCON individual could have received (0.002 mg/hr in a vehicle) and multiply by duration of exposure and number of vehicles entered.

$$\text{soluble:} \quad \frac{0.002\,\text{mg}}{\text{hr}} * (1.5\,\text{hr}) * (31\,\text{vehicles}) = 0.093\,\text{mg}$$

- From Table 47, take the maximum estimate for insoluble DU that a RADCON individual could have received (0.023 mg/hr in a vehicle) and multiply by duration of exposure and number of vehicles entered.

$$\text{insoluble:} \quad \frac{0.023\,\text{mg}}{\text{hr}} * (1.5\,\text{hr}) * (31\,\text{vehicles}) = 1.07\,\text{mg}$$

- The total amount of DU (soluble and insoluble) that reaches the kidney from an intake of 0.093 mg (soluble) and 1.07 mg (insoluble) is 0.0096 mg. Using the fraction of 5 μm AMAD DU particles that are transferred from the respiratory tract to blood, the calculation to determine the total amount of DU that passes through the kidney is as follows. (See Appendix J for a more detailed discussion of DU biokinetics.)

$$(0.093\,\text{mg}) * (0.0642) + (1.07\,\text{mg}) * (0.0034) = 0.0096\,\text{mg}$$

- To determine the concentration of DU in the kidney, this value is multiplied by 1000 and then divided by the default kidney weight of 310 grams:

μg DU/g of kidney = (0.0096 mg)*(1000 μg/mg)/310 grams

= 0.031 μg DU/g of kidney

- From Table 47, take the CEDE radiation dose for a 1-hour exposure duration (0.0005 rem) and multiply by 31 vehicles.

internal radiation (CEDE) dose:

$$(1.5\,\text{hr})*(0.0005\,\text{rem})*(31\,\text{vehicles}) = 0.023\,\text{rem}$$

- If the individual was not wearing gloves (PPE), he may have had hand-to-mouth transfer (secondary ingestion) of DU surface contamination. His maximum total soluble DU intake by secondary ingestion per event would be 0.465 mg. The maximum total insoluble DU intake by secondary ingestion per event would be 2.66 mg. His internal radiation dose from this secondary ingestion (CEDE) would be 0.0001 rem per contaminating event.

- From Section 5.3, take the upper-bound estimate of soluble DU intake for secondary ingestion (0.01 mg) and multiply by exposure duration and number of vehicles entered.

$$\text{soluble intake: } \frac{0.01\text{mg}}{\text{hr}} * (1.5\text{ hr}) * (31\text{ vehicles}) \cong 0.465\text{ mg}$$

- Mass of soluble DU that enters the bloodstream and passes through the kidney is (multiply the total soluble DU intake by GI absorption coefficient for soluble DU):

$$(0.465\text{ mg}) * (0.02) \cong 0.0093\text{ mg}$$

$$\mu\text{g DU/g of kidney} = (0.0093\text{ mg})*(1000\ \mu\text{g/mg})/310\text{ grams}$$
$$= 0.03\ \mu\text{g DU/g of kidney}$$

- The remaining mass of soluble DU (0.455 mg) is excreted via the GI tract.

- From Section 5.3, take the upper-bound estimate of insoluble DU intake for secondary ingestion (0.047 mg) and multiply by exposure duration and number of vehicles entered.

$$\text{insoluble intake:}\quad \frac{0.047\text{mg}}{\text{hr}} * (1.5\text{ hr}) * (31\text{ vehicles}) \cong 2.19\text{ mg}$$

- Mass of insoluble DU that enters the bloodstream and passes through the kidney is (multiply the total soluble DU intake by GI absorption coefficient for insoluble DU):

$$(2.19\text{ mg}) * (0.002) \cong 0.0044\text{ mg}$$

$$\mu\text{g DU/g of kidney} = (0.0044\text{ mg})*(1000\ \mu\text{g/mg})/310\text{ grams}$$
$$= 0.014\ \mu\text{g DU/g of kidney}$$

- The remaining mass of insoluble DU (2.186 mg) is excreted via the GI tract. The total amount of DU (soluble and insoluble) from secondary ingestion that passes through the kidney is 0.014 mg. This is equivalent to a kidney concentration of 0.044 µg DU/g of kidney.

- From Section 5.3, take the CEDE radiation dose for a 1-hour exposure duration (0.000002 rem) and multiply by 31 vehicles.

internal radiation (CEDE) dose:

$$(0.057\text{ mg}) * (1.5\text{ hr}) * \frac{0.000002\text{ rem}}{0.057\text{ mg for a 1hr exposure}} *(31\text{ vehicles}) = 0.0001\text{ rem}$$

- If he used his bare hands to handle an intact penetrator, his hands may have been exposed externally to beta radiation when downloading the DU munition. The contact dose rate from an intact DU penetrator is about 0.2 rad/hr.

S.4 Battle Damage Assessment Team Member

As an OSAGWI discussion example, for BDAT members who examined U.S. combat vehicles damaged and destroyed by DU, a maximum estimation of DU intake and internal dose can be suggested.

- If a BDAT member entered 31 DU-damaged armored vehicles and spent 3 hours in each vehicle, a maximum estimation of his total soluble DU intake via inhalation and indirect ingestion would be 0.186 mg. The maximum total insoluble DU intake via inhalation and indirect ingestion would be 2.14 mg. His internal radiation dose (CEDE) would be 0.047 rem.

  - From Table 47, take the maximum estimate for soluble DU that a BDAT individual could have received (0.002 mg/hr in a vehicle) and multiply by duration of exposure and number of vehicles entered.

$$\text{soluble: } \frac{0.002\,\text{mg}}{\text{hr}} * (3\,\text{hr}) * (31\,\text{vehicles}) = 0.186\,\text{mg}$$

  - From Table 47, take the maximum estimate for insoluble DU that a BDAT individual could have received (0.023 mg/hr in a vehicle) and multiply by duration of exposure and number of vehicles entered.

$$\text{insoluble: } \frac{0.023\,\text{mg}}{\text{hr}} * (3\,\text{hr}) * (31\,\text{vehicles}) = 2.14\,\text{mg}$$

  - The total amount of DU (soluble and insoluble) that reaches the kidney from an intake of 0.186 mg (soluble) and 2.14 mg (insoluble) is 0.0192 mg. Using the fraction of 5 µm AMAD DU particles that are transferred from the respiratory tract to blood the calculation to determine the total amount of DU that passes through the kidney is as follows. (See Appendix J for a more detailed discussion of DU biokinetics.):

$$\lfloor(0.186\,\text{mg})*(0.0642)\rfloor + \lfloor(2.14\,\text{mg})*(0.0034)\rfloor = 0.0192\,\text{mg}$$

- To determine the concentration of DU in the kidney, this value is multiplied by 1000 then divided by the default kidney weight of 310 grams:

μg DU/g of kidney = (0.0192 mg) * (1000 μg/mg)/310 grams

= 0.062 μg DU/g of kidney

- From Table 47, take the CEDE radiation dose for a 1-hour exposure duration (0.0005 rem) and multiply by 31 vehicles.

internal radiation dose:

$$(3\,\text{hr})* \frac{0.0005\,\text{rem}}{\text{for a 1 hr exposure}} *(31\,\text{vehicles}) = 0.047\,\text{rem}$$

- If the individual was not wearing gloves (PPE), he may have had hand-to-mouth transfer (secondary ingestion) of DU surface contamination. His maximum total soluble DU intake by secondary ingestion per event would be 0.93 mg. The maximum total insoluble DU intake by secondary ingestion per event would be 4.37 mg. His internal radiation dose from this secondary ingestion (CEDE) would be 0.0002 rem per contaminating event.

- From Section 5.3, take the upper-bound estimate of soluble DU intake for secondary ingestion (0.01 mg) and multiply by exposure duration and number of vehicles entered.

$$\text{soluble intake:} \frac{0.01\text{mg}}{\text{hr}} * (3 \text{ hr}) * (31 \text{ vehicles}) \cong 0.93 \text{ mg}$$

- Mass of soluble DU that enters the bloodstream and passes through the kidney (multiply the total soluble DU intake by GI absorption coefficient for soluble DU):

$$(0.93 \text{ mg}) * (0.02) \cong 0.019 \text{ mg}$$

$$\mu\text{g DU/g of kidney} = (0.019 \text{ mg}) * (1000\ \mu\text{g/mg})/310 \text{ grams}$$

$$= 0.06\ \mu\text{g DU/g of kidney}$$

- The remaining mass of soluble DU (0.911 mg) is excreted via the GI tract.

- From Section 5.3, take the upper-bound estimate of insoluble DU intake for secondary ingestion (0.047 mg) and multiply by exposure duration and number of vehicles entered.

$$\text{insoluble intake: } \frac{0.047\text{mg}}{\text{hr}} * (3\text{ hr}) * (31\text{ vehicles}) \cong 4.37\text{ mg}$$

- Mass of insoluble DU that enters the bloodstream and passes through the kidney is (multiply the total soluble DU intake by GI absorption coefficient for insoluble DU):

$$(4.37\text{ mg}) * (0.002) \cong 0.009\text{ mg}$$

$$\mu\text{g DU/g of kidney} = (0.009\text{ mg}) * (1000\ \mu\text{g/mg})/310\text{ grams}$$

$$= 0.03\ \mu\text{g DU/g of kidney}$$

- The remaining mass of insoluble DU (4.36 mg) is excreted via the GI tract. The total amount of DU (soluble and insoluble) that passes through the kidney is 1.11 mg. This is equivalent to a kidney concentration of 0.09 μg DU/g of kidney.

- From Section 5.3, take the CEDE radiation dose for a 1-hour exposure duration (0.000002 rem) and multiply by 31 vehicles.

internal radiation (CEDE) dose:

$$(0.057\text{ mg}) * (3\text{ hr}) * \frac{0.000002\text{ rem}}{0.057\text{ mg for a 1 hr exposure}} * (31\text{ vehicles}) = 0.0002\text{ rem}$$

- If he used his bare hands to handle an intact penetrator, his hands may have been exposed externally to beta radiation when downloading the DU munition. The contact dose rate from an intact DU penetrator is about 0.2 rad/hr.

S.5 Logistics Assistance Representative Individual

As an OSAGWI discussion example, for LARs who inspected DU-contaminated vehicles/systems to determine reparability, a maximum estimation of DU intake and internal dose can be suggested.

- If a LAR entered 31 DU-damaged armored vehicles and spent 1 hour in each, a maximum estimation of his total soluble DU intake via inhalation and indirect ingestion would be 0.062 mg. The total insoluble intake via inhalation and indirect ingestion will be 0.713 mg. His internal radiation dose (CEDE) would be 0.016 rem.

    - From Table 47, take the maximum estimate for soluble DU that a LAR individual could have received (0.002 mg/hr in a vehicle) and multiply by duration of exposure and number of vehicles entered.

$$\text{soluble:} \quad \frac{0.002\,\text{mg}}{\text{hr}} * (1\,\text{hr}) * (31\,\text{vehicles}) = 0.062\,\text{mg}$$

- From Table 47, take the maximum estimate for insoluble DU that a LAR individual could have received (0.023 mg/hr in a vehicle) and multiply by duration of exposure and number of vehicles entered.

$$\text{insoluble:} \quad \frac{0.023\,\text{mg}}{\text{hr}} * (\text{hr}) * (31\,\text{vehicles}) = 0.713\,\text{mg}$$

- From Table 47, take the CEDE radiation dose for a 1-hour exposure duration (0.0005 rem) and multiply by 31 vehicles.

$$\text{internal radiation (CEDE) dose:} \quad (0.0005\,\text{rem}) * (31\,\text{vehicles}) = 0.016\,\text{rem}$$

- The total amount of DU (soluble and insoluble) that reaches the kidney from an intake of 0.062 mg (soluble) and 0.713 mg (insoluble) is 0.0064 mg. Using the fraction of 5 μm AMAD DU particles that are transferred from the respiratory tract to blood, the calculation to determine the total amount of DU that passes through the kidney is as follows. (See Appendix J for a more detailed discussion of DU biokinetics.)

$$(0.062\,\text{mg}) * (0.0642) + (0.713\,\text{mg}) * (0.0034) = 0.0064\,\text{mg}$$

- To determine the concentration of DU in the kidney, this value is multiplied by 1000 then divided by the default kidney weight of 310 grams:

$$\mu g \text{ DU/g of kidney} = (0.0064 \text{ mg})*(1000\ \mu g/mg)/310 \text{ grams}$$
$$= 0.021\ \mu g \text{ DU/g of kidney}$$

- If the individual was not wearing gloves (PPE), he may have had hand-to-mouth transfer (secondary ingestion) of DU surface contamination. His maximum total soluble DU intake by secondary ingestion per event would be 0.31 mg. The maximum total insoluble DU intake by secondary ingestion per event would be 1.46 mg. His internal radiation dose from this secondary ingestion (CEDE) would be 0.00006 rem per contaminating event.

  - From Section 5.3, take the upper-bound estimate of soluble DU intake for secondary ingestion (0.01 mg) and multiply by exposure duration and number of vehicles entered.

$$\text{soluble intake: } \frac{0.01\text{mg}}{\text{hr}} * (1 \text{ hr}) * (31 \text{ vehicles}) \cong 0.31 \text{ mg}$$

  - Mass of soluble DU that enters the bloodstream and passes through the kidney is (multiply the total soluble DU intake by GI absorption coefficient for soluble DU):

$$(0.31 \text{ mg}) * (0.02) \cong 0.006 \text{ mg}$$

$$\mu g \text{ DU/g of kidney} = (0.006 \text{ mg}) * (1000\ \mu g/mg)/310 \text{ grams}$$
$$= 0.019\ \mu g \text{ DU/g of kidney}$$

- The remaining mass of soluble DU (0.304 mg) is excreted via the GI tract.

- From Section 5.3, take the upper-bound estimate of insoluble DU intake for secondary ingestion (0.047 mg) and mulitply by exposure duration and number of vehicles entered.

$$\text{insoluble intake: } \frac{0.047\text{mg}}{\text{hr}} * (1\text{ hr}) * (31\text{ vehicles}) \cong 1.46\text{ mg}$$

- Mass of insoluble DU that enters the bloodstream and passes through the kidney is (multiply the total soluble DU intake by GI absorption coefficient for insoluble DU):

$$(1.46\text{ mg}) * (0.002) \cong 0.003\text{ mg}$$

$$\mu\text{g DU/g of kidney} = (0.003\text{ mg}) * (1000\ \mu\text{g/mg})/310\text{ grams}$$

$$= 0.01\ \mu\text{g DU/g of kidney}$$

- The remaining mass of insoluble DU (1.457 mg) is excreted via the GI tract. The total amount of DU (soluble and insoluble) that passes through the kidney is 0.009 mg. This is equivalent to a kidney concentration of 0.03 µg DU/g of kidney.

- From Section 5.3, take the CEDE radiation dose for a 1-hour exposure duration (0.000002 rem) and multiply by 31 vehicles.

internal radiation (CEDE) dose:

$$(0.057\,\text{mg}) * (1\,\text{hr}) * \frac{0.000002\,\text{rem}}{0.057\,\text{mg for a 1 hr exposure}} * (31\,\text{vehicles}) = 0.00006\,\text{rem}$$

S.6 Unit Maintenance Personnel

As an OSAGWI discussion example, a maximum estimation of DU intake and internal dose can be suggested for unit maintenance personnel who performed maintenance on or in DU-contaminated vehicles/systems.

- If a unit maintenance individual entered 31 DU-damaged armored vehicles and spent 3 hours in each, a maximum estimation of his total soluble DU intake via inhalation and indirect ingestion would be 0.186 mg. The total insoluble DU intake via inhalation and indirect ingestion would be 2.14 mg. His internal radiation dose (CEDE) would be 0.047 rem.

  - From Table 47, take the maximum estimate for soluble DU that a unit maintenance individual could have received (0.002 mg/hr in a vehicle) and multiply by duration of exposure and number of vehicles entered.

$$\text{soluble:} \quad \frac{0.002\,\text{mg}}{\text{hr}} * (3\,\text{hr}) * (31\,\text{vehicles}) = 0.186\,\text{mg}$$

- From Table 47, take the maximum estimate for insoluble DU that a unit maintenance individual could have received (0.023 mg/hr in a vehicle) and multiply by duration of exposure and number of vehicles entered.

$$\text{insoluble:} \quad \frac{0.023\,\text{mg}}{\text{hr}} * (3\,\text{hr}) * (31\,\text{vehicles}) = 2.14\,\text{mg}$$

- The total amount of DU (soluble and insoluble) that reaches the kidney from an intake of 0.186 mg (soluble) and 2.14 mg (insoluble) is 0.0192 mg. Using the fraction of 5 μm AMAD DU particles that are transferred from the respiratory tract to blood, the calculation to determine the total amount of DU that passes through the kidney is as follows. (See Appendix J for a more detailed discussion of DU biokinetics.)

$$(0.186\,\text{mg}) * (0.0642) + (2.14\,\text{mg}) * (0.0034) = 0.0192\,\text{mg}$$

- To determine the concentration of DU in the kidney, this value is multiplied by 1000 then divided by the default kidney weight of 310 grams:

$$\begin{aligned} \mu\text{g DU/g of kidney} &= (0.0192\text{ mg}) * (1000\ \mu\text{g/mg})/310\text{ grams} \\ &= 0.0619\ \mu\text{g DU/g of kidney} \end{aligned}$$

- From Table 47, take the CEDE radiation dose for a 1-hour exposure duration (0.0005 rem) and multiply by 31 vehicles.

internal radiation (CEDE) dose:

$$(3\,\text{hr}) * \frac{0.0005\,\text{rem}}{\text{for a 1 hr exposure}} * (31\,\text{vehicles}) = 0.047\,\text{rem}$$

- If the individual was not wearing gloves (PPE), he may have had hand-to-mouth transfer (secondary ingestion) of DU-surface contamination. His maximum total soluble DU intake by secondary ingestion per event would be 0.93 mg. The maximum total insoluble DU intake by secondary ingestion per event would be 4.37 mg. His internal radiation dose from this secondary ingestion (CEDE) would be 0.0002 rem per contaminating event.

- From Section 5.3, take the upper-bound estimate of soluble DU intake for secondary ingestion (0.01 mg) and multiply by exposure duration and number of vehicles entered.

$$\text{soluble intake: } \frac{0.01\text{mg}}{\text{hr}} * (3\text{ hr}) * (31\text{ vehicles}) \cong 0.93\text{ mg}$$

- Mass of soluble DU that enters the bloodstream and passes through the kidney is (multiply the total soluble DU intake by GI absorption coefficient for soluble DU):

$$(0.93 \text{ mg}) * (0.02) \cong 0.019 \text{ mg}$$

$$\mu\text{g DU/g of kidney} = (0.019 \text{ mg}) * (1000\ \mu\text{g/mg})/310 \text{ grams}$$

$$= 0.06\ \mu\text{g DU/g of kidney}$$

- The remaining mass of soluble DU (0.911 mg) is excreted via the GI tract.

- From Section 5.3, take the upper-bound estimate of insoluble DU intake for secondary ingestion (0.047 mg) and multiply by exposure duration and number of vehicles entered.

$$\text{insoluble intake: } \frac{0.047\text{mg}}{\text{hr}} * (3 \text{ hr}) * (31 \text{ vehicles}) \cong 4.37 \text{ mg}$$

- Mass of insoluble DU that enters the bloodstream and passes through the kidney is (multiply the total insoluble DU intake by GI absorption coefficient for insoluble DU):

$$(4.37 \text{ mg}) * (0.002) \cong 0.009 \text{ mg}$$

$$\mu\text{g DU/g of kidney} = (0.009 \text{ mg})*(1000\ \mu\text{g/mg})/310 \text{ grams}$$

$$= 0.03\ \mu\text{g DU/g of kidney}$$

- The remaining mass of insoluble DU (4.36 mg) is excreted via the GI tract. The total amount of DU (soluble and insoluble) that passes through the kidney is 0.03 mg. This is equivalent to a kidney concentration of 0.09 μg DU/g of kidney.

- From Section 5.3, take the CEDE radiation dose for a 1-hour exposure duration (0.000002 rem) and multiply by 31 vehicles.

internal radiation (CEDE) dose:

$$(0.057\,\text{mg})*(3\,\text{hr})*\frac{0.000002\text{rem}}{0.057\,\text{mg for a 1 hr exposure}}*(31\,\text{vehicles}) = 0.0002\,\text{rem}$$

- If he used his bare hands to handle an intact penetrator, his hands may have been exposed externally to beta radiation when downloading the DU munition. The contact dose rate from an intact DU penetrator is about 0.2 rad/hr. Discussion can also be followed for the special cases of welding and removal of the DU armor, which may or may not have happened in Southwest Asia region.

The 144th Service and Supply Company was divided into 4 platoons. Only one of the platoons actually worked in the storage yard. The platoon was further divided into an Operations Center Team that initially checked the vehicles into the storage yard and a separate team that actually worked in the storage yard. Operations Center personnel estimated they averaged 15 minutes inside each Abrams tank and 10 minutes inside each BFV. The second team that worked in the storage yard periodically had to reenter the damaged vehicles to remove equipment. That team estimated they averaged 1 hour per reentry. In addition, the 556th Maintenance Company worked in the storage yard; they reportedly also had responsibility for removing automotive components. While a precise record of the number of times individuals actually reentered the vehicles once they were in the storage yard is not available, a range of 10 to 20 incidents (1 hour each) should be used for equipment removal and 10 entries (15 minutes) for the Operations Center personnel.

- As an example for discussion, the OSAGWI scenario of the 144th Service and Supply Company. and other unit personnel who performed maintenance on damaged equipment, a maximum estimation of DU intake and internal dose can be estimated.
- Although a couple of different work scenarios are described, differentiating between operations and armor removal individuals, the exposure duration was assumed to be 1 hour for each vehicle entered and 31 vehicles entered. If a 144th individual entered 31 DU-damaged armored vehicles and spent 1 hour in each one, a maximum estimation of his total soluble DU intake via inhalation and indirect ingestion would be 0.062 mg. The maximum total insoluble DU intake via inhalation and indirect ingestion would be 0.713 mg. His internal radiation dose (CEDE) would be 0.016 rem.

- From Table 47, take the maximum estimate for soluble DU that a 144th individual could have received (0.002 mg/hr in a vehicle) and multiply by duration of exposure and number of vehicles entered.

$$\text{soluble:} \quad \frac{0.002\,\text{mg}}{\text{hr}} * (1\,\text{hr}) * (31\,\text{vehicles}) = 0.062\,\text{mg}$$

- From Table 47, take the maximum estimate for insoluble DU that an EOD individual could have received (0.023 mg/hr in a vehicle) and multiply by duration of exposure and number of vehicles entered.

$$\text{insoluble:} \quad \frac{0.023\,\text{mg}}{\text{hr}} * (1\,\text{hr}) * (31\,\text{vehicles}) = 0.713\,\text{mg}$$

- The total amount of DU (soluble and insoluble) that reaches the kidney from an intake of 0.062 mg (soluble) and 0.713 mg (insoluble) is 0.006 mg. Using the fraction of 5 μm AMAD DU particles that are transferred from the respiratory tract to blood, the calculation to determine the total amount of DU that passes through the kidney is as follows (see Appendix J for a more detailed discussion of DU biokinetics):

$$(0.062\,\text{mg}) * (0.0642) + (0.713\,\text{mg}) * (0.0034) = 0.006\,\text{mg}$$

- To determine the concentration of DU in the kidney, this value is multiplied by 1000 and then divided by the default kidney weight of 310 grams:

$$\mu g\ DU/g\ of\ kidney = (0.006\ mg) * (1000\ \mu g/mg)/310\ grams$$

$$= 0.02\ \mu g\ DU/g\ of\ kidney$$

- From Table 47, take the CEDE radiation dose for a 1-hour exposure duration to (0.0004 rem) and multiply by 31 vehicles.

internal radiation dose: (0.0005 rem) * (31 vehicles) = 0.016 rem

- If the individual is not wearing gloves (PPE), he may have had hand-to-mouth transfer (secondary ingestion) of DU-surface contamination. His maximum total soluble DU intake (after entering 31 vehicles) by secondary ingestion per event would be 0.31 mg. The maximum total insoluble DU intake by secondary ingestion per event would be 1.46 mg. His internal radiation dose from this secondary ingestion (CEDE) would be 0.00006 rem per contaminating event.

- From Section 5.3, take the upper-bound estimate of soluble DU intake for secondary ingestion (0.10 mg) and multiply by exposure duration and number of vehicles entered.

$$\text{soluble intake: } \frac{0.10\text{mg}}{\text{hr}} * (1\text{ hr}) * (31\text{ vehicles}) \cong 0.31\text{ mg}$$

- Mass of soluble DU that enters the bloodstream and passes through the kidney is (multiply the total soluble DU intake by GI absorption coefficient for soluble DU):

$$(0.31\text{ mg}) * (0.02) \cong 0.006\text{ mg}$$

$$\mu\text{g DU/g of kidney} = (0.006\text{ mg}) * (1000\ \mu\text{g/mg})/310\text{ grams}$$

$$= 0.019\ \mu\text{g DU/g of kidney}$$

- The remaining mass of soluble DU (0.304 mg) is excreted via the GI tract.

- From Section 5.3, take the upper-bound estimate of insoluble DU intake for secondary ingestion (0.047 mg) and multiply by exposure duration and number of vehicles entered.

$$\text{insoluble intake: } \frac{0.047\text{mg}}{\text{hr}} * (1\text{ hr}) * (31\text{ vehicles}) \cong 1.46\text{ mg}$$

- Mass of insoluble DU that enters the bloodstream and passes through the kidney is (multiply the total soluble DU intake by GI absorption coefficient for insoluble DU):

$$(1.46 \text{ mg}) * (0.002) \cong 0.003 \text{ mg}$$

$$\mu\text{g DU/g of kidney} = (0.003 \text{ mg}) * (1000 \ \mu\text{g/mg})/310 \text{ grams}$$

$$= 0.01 \ \mu\text{g DU/g of kidney}$$

- The remaining mass of insoluble DU (1.457 mg) is excreted via the GI tract. The total amount of DU (soluble and insoluble) from secondary ingestion that passes through the kidney is 0.009 mg. This is equal to a kidney concentration of 0.03 μg DU/g of kidney.

- From Section 5.3, take the CEDE radiation dose for a 1-hour exposure duration (0.000002 rem) and multiply by 31 vehicles.

internal radiation (CEDE) dose:

$$(0.057 \text{ mg}) * (1 \text{ hr}) * \frac{0.000002 \text{ rem}}{0.057 \text{ mg in } 1 \text{ hr}} * (31 \text{ vehicles}) = 0.00006 \text{ rem}$$

- If he used his bare hands to handle an intact penetrator, his hands may have been exposed externally to beta radiation when downloading the DU munition. The contact dose rate from an intact DU penetrator is about 0.2 rad/hr.

Table S-1 summarizes the intake, kidney concentration, and radiation dose estimates for representative examples of OSAGWI Level II Exposure Scenarios.

Table S-1. Summary Table of Intake, Kidney Concentration, and Radiation Dose Estimates for Representative Examples of OSAGWI Level II Exposure Scenarios

Exposure Classification: Levels and Scenarios	Duration of Exposure	Type of Intake	DU Intake (mg)	Soluble DU Intake (mg)	DU in Kidney µg-DU/g of kidney tissue	Radiation Dose (rem)
Explosive Ordinance Disposal	1 hour per vehicle	Inhalation and direct ingestion	0.775	0.062	0.02	0.016
		Secondary ingestion	1.77	0.31	0.03	0.00006
		Total	**2.5**	**0.37**	**0.05**	**0.016**
Radiation Control Team Member	1.5 hours per vehicle	Inhalation and direct ingestion	1.16	0.093	0.031	0.023
		Secondary ingestion	2.66	0.47	0.044	0.0001
		Total	**3.8**	**0.56**	**0.075**	**0.023**
Battle Damage Assessment Team Member	3 hours per vehicle	Inhalation and direct ingestion	2.33	0.186	0.062	0.047
		Secondary ingestion	5.3	0.93	0.09	0.0002
		Total	**7.6**	**1.12**	**0.15**	**0.047**
Logistics Assistance Representative Individual	1 hour per vehicle	Inhalation and direct ingestion	0.775	0.062	0.02	0.016
		Secondary ingestion	1.77	0.31	0.03	0.00006
		Total	**2.5**	**0.37**	**0.05**	**0.016**
Unit Maintenance Personnel	3 hours per vehicle	Inhalation and direct ingestion	2.33	0.186	0.062	0.047
		Secondary ingestion	5.3	0.93	0.09	0.0002
		Total	**7.6**	**1.12**	**0.15**	**0.047**
144th Service and Supply Co.	Various minutes to hours (chose) 1 hour per vehicle	Inhalation and direct ingestion	0.775	0.062	0.02	0.016
		Secondary ingestion	1.77	0.31	0.03	0.00006
		Total	**2.5**	**0.37**	**0.05**	**0.016**